Technical report for the EU Biofuel Baseline project

Producing Feedstock for Biofuels: Land-Use and Local Environmental Impacts

Oskar Englund [1, 2]
Göran Berndes [2]
Lina Lundgren [2]
Matilda Palm [2]
Linda Engström [3]
Carol Bäckman [3]
Kristina Marquardt [3]
Eva Stephansson [3]

2 Department of Energy and Environment
Division of Physical Resource Theory
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2011

3 Swedish EIA Centre
Department of Urban and Rural Development
Swedish University of Agricultural Sciences
Uppsala, Sweden

Report no: FRT 2011:06

[1] Corresponding author: oskar.englund@chalmers.se

Table of Contents

List of figures

List of tables

INTRODUCTION

This report covers Chalmers responsibilities for *subtask 1.3 - land-use patterns* as well as parts of *subtask 3.4 – data for other environmental impacts*.

For subtask 1.3, we were asked to:

i. Identify and quantify land use patterns for biofuels feedstock production for the study region as indicated in discussions between Ecofys and the European Commission.
ii. Analyse land use change linked to expanded biofuels feedstock production (comprehensiveness and precision depending on data availability).
iii. Analyse how agriculture land use is influenced by national land use plans and other relevant policies.

For subtask 3.4, we were asked to:

iv. Describe possible local/regional environmental impacts of biofuel production. The results will be presented at the country level for the selected target countries, where the biofuel production is described as a distinct component of the total biomass production systems and where attempts will be made to assess and quantify the environmental impacts attributable to EU demand for biofuels or biofuels feedstock from each target country. Assessed environmental impacts include those affecting air and water quality, and biodiversity. Depending on whether information is available, also aspects such as soil degradation due to excessive extraction of biomass from croplands, water and wind erosion, and drainage can be included.

Since most of the information was either explicitly requested, or natural to present, on a country level, country profiles constitute the biggest part of this report. All profiles share the same structure and may therefore be read individually. As indicated already in the contract (see ii above) the amount of available information varies between countries. This is reflected in a varying comprehensiveness between country profiles.

In addition to the country profiles, other chapters are also possible to read individually. Therefore, references are presented at the end of each chapter.

SUMMARY: LOCAL ENVIRONMENTAL IMPACTS

Feedstock production and conversion to biofuels can affect the local environment in many different ways. Given that biofuels presently mostly are produced from conventional food crops, impacts resemble those characterising the present day agriculture. These depend on the crops produced, the production systems employed, governance conditions, and local environmental conditions. In the main report, production system characteristics and current documented environmental impacts (Table 1) – related to e.g. air and water quality and biodiversity – associated with the production of relevant biofuel crops are presented in each country land-use profile.

Table 1: Assessed local environmental impacts

Assessed local environmental impacts
Deforestation
Loss of agro-biodiversity
Loss of biodiversity
Air pollution
Water pollution
GMO contamination
Eutrophication
Soil fertility decline
Erosion

Environmental Impact Assessments (EIAs) provide information about specific local environmental impacts for a given biofuel feedstock and/or biofuel conversion option (see separate chapter for an overview of impacts that are typically covered by EIAs). Reports, scientific articles and other documentation provide complementary information about environmental impacts associated with biofuel crop production and agriculture in general in a country. In this project local environmental impacts has been assessed particularly for (a) domestic biofuel production in 2008, and (b) EU biofuel demands in 2008.

In the assessment, the cultivation of crops as feedstock for production of biofuels was assumed to have the same characteristics – including environmental impacts – as cultivation of the same crop for other purposes. The contribution to environmental impacts of biofuel feedstock production for (a) domestic use and (b) export to EU was assumed to be proportional to the share of the total cropland that is used for these purposes. When the biofuel production generates co-products that displace other cultivation, the net land requirement associated with the specific biofuel is calculated using RED allocation principles. Calculations were made using FAOSTAT data concerning land-use and yields, and data developed in this project concerning biofuel production and international trade (see main report for methodology). Potential indirect effects were not assessed.

Since the biofuel crops are mainly produced for non-biofuel purposes, biofuel demands have a small role in causing local environmental impacts (Table 2 and 3). Exceptions include sugarcane in Brazil and jatropha in Guatemala where the biofuel production – primarily for domestic markets – uses a large part of the total crop harvest (although the jatropha acreage in Guatemala in 2008 was only 200 ha). EU biofuel import demands in 2008 had a significant role only for the case of biodiesel production from Ukrainian rapeseed. A small role was also seen in Bolivia (sugarcane), Peru (sugarcane), Indonesia (oil palm), and Malaysia (oil palm).

Thus, EU biofuel demand accounts for a rather small share of local environmental impacts from biofuel crop cultivation in most exporting countries. As described in more detail in the respective countries' land use profile, environmental impacts differ significantly between the assessed biofuel crops.

Table 2: Local environmental impacts allocated to domestic biofuel production and EU biofuel demands: Ethanol feedstock crops

Country	Crop	Impacts allocated to domestic biofuel production in 2008	Impacts allocated to EU biofuel demands in 2008
Bolivia	Sugarcane	18%	7%
Peru	Sugarcane	5%	4%
Pakistan	Sugarcane	8%	1%
Guatemala	Sugarcane	9%	1%
Brazil	Sugarcane	52%	1%
Ethiopia	Sugarcane	0%	1%
Ukraine	Sugarbeet	3%	0.1%
USA	Maize	15%	0%
India	Sugarcane	7%	0%
Indonesia	Sugarcane	10%	0%
Malawi	Sugarcane	10%	0%
Mozambique (sugarcane), **Nigeria** (cassava), **Sudan** (sorghum, millet, sugarcane), **Tanzania** (sugarcane), **Uganda** (sugarcane, sorghum), **Pakistan** (maize)		0%	0%

Table 3: Local environmental impacts allocated to domestic biofuel production and EU biofuel demands: Biodiesel feedstock crops

Country	Crop	Impacts allocated to domestic biofuel production in 2008	Impacts allocated to EU biofuel demands in 2008
Ukraine	Rapeseed	0%	16%
Indonesia	Oil palm	3%	3%
Malaysia	Oil palm	1%	2%
USA	Soybean	4%	1%
Brazil	Soybean	3%	1%
Argentina	Soybean	3%	1%
Brazil	Oil palm	0%	0.3%
Bolivia	Soybean	0%	0.1%
Guatemala	Jatropha	100%	0%
Peru (oil palm), **Ethiopia** (castor, jatropha), **Malawi** (jatropha), **Mozambique** (jatropha), **Nigeria** (oil palm, soybean), **Tanzania** (oil palm, jatropha), **Uganda** (jatropha), **India** (jatropha, neem), **Pakistan** (rapeseed)		0%	0%

SUMMARY: LAND-USE PATTERNS

Land use change– especially conversion of natural vegetation to cropland – can result in a range of environmental impacts, and the land use consequences of biofuel development is a topic that attracts much attention. The quantification of GHG savings from biofuel initiatives also requires resulting land use changes to be assessed. At project level it should be possible to monitor and analyse the direct land use change consequences with acceptable levels of confidence. But assessments of indirect land use change require modelling of complex interactions between countries/regions as well as between different sectors in societies, which introduces large uncertainties.

Assessing the land use change consequences of EU biofuel policies is more complicated than project level assessments since it is not known exactly where the biofuels supplying the EU market will be produced; the location for the biofuel crop production is unknown, which means that modelling is required for assessing both the direct consequences of land use change to produce biofuels for the EU market and the indirect consequences of this biofuels production.

Illustrative of this, a study by the EC-Joint Research Centre[2], comparing models and results for marginal biofuels production from different feedstocks, found diverging model results. While some of the disagreements between the models could be explained – and some general features could be identified (e.g., that increased ethanol/biodiesel demand in EU has larger land use change effects outside EU) – it remains a challenge to quantify land use change effects with sufficient level of confidence.

In Table 4, data is shown that provides some indication about the extent to which production of EU biofuels may have caused expansion of biofuel crops in selected countries. Since the EU biofuel import demand was small before 2004 it can be assumed that the area used for producing biofuel crops for the EU market was negligible before 2004. Thus, comparing the required area for a given biofuel crop in 2008 with the total expansion of the same crop between 2004-2008, gives an indication of the role of EU biofuel demands in driving cropland expansion. As mentioned above, the mechanisms for EU biofuel demands driving land-use change can be both direct (i.e. new land is converted to cropland for biofuels exported to EU) and indirect (i.e. already existing cropland is used, which requires cropland for other purposes to be expanded elsewhere). Even so, the comparison made in Table 4 makes it possible to identify the countries where EU biofuel import demand has been significant in comparison to the total crop production in a country.

---

[2] Edwards R., Mulligan, D. And Marelli, L., 2010. *Indirect Land Use Change from increased biofuels demand. Comparison of models and results for marginal biofuels production from different feedstocks*. JRC Scientific and Technical Reports

Table 4: Cropland used for production of feedstock for EU biofuels in 2008 compared to total crop expansion. Note that both total cropland and net cropland requirements are given, where net is calculated using RED allocation principles.

Country	Crop	Total harvested area in 2008	Crop expansion 2004-2008	Cropland used for production of EU biofuels in 2008 – total and net after allocation		Cropland needed for EU biofuels in 2008 compared to total crop expansion 2004-2008	
		kha	(kha)	total (kha)	net (kha)	total	net
Argentina	Soybean	16,387	2,083	542	178	26%	9%
Bolivia	Sugarcane	160	53	11	11	21%	21%
	Soybean	786	-18	1.2	0.4	-	
Brazil	Sugarcane	8,140	2,508	91	91	4%	4%
	Soybean	21,057	-482	782	257	-	
	Oil Palm	66	11	0.2	0.2	2%	2%
Ethiopia	Sugarcane	21	-2	0.1	0.1	-	
Guatemala	Sugarcane	287	61	2	2	5%	5%
USA	Maize	31,796	1,999	0.3	0.2	0%	0%
	Soybean	30,223	293	1,270	418	434%	434%
Indonesia	Oil Palm	5,000	1,680	190	173	11%	10%
Malaysia	Oil Palm	3,900	498	98	90	20%	18%
Pakistan	Sugarcane	1,241	167	16	16	10%	10%
Peru	Sugarcane	69	-2	2	2	-	
Ukraine	Rapeseed	1,380	1,272	366	214	29%	17%
Ukraine	Sugarbeet	377	-319	0.3	0.2	-	

In 2008, particularly large areas were used for cultivation of feedstock for EU biofuels in USA (soybean), Brazil (soybean), Argentina (soybean) and Ukraine (rapeseed). Large amounts of land were also used in Indonesia (oil palm), Malaysia (oil palm) and Brazil (sugarcane). As can be seen in Table 1, the net cropland demand is substantially smaller for maize ethanol and soybean biodiesel due to the co-production of animal feedstuff replacing other feed. However, it should be noted that the land savings associated with this co-production could take place elsewhere than in the country where the soybean is cultivated.

Cropland expansion pressure can be reduced by improving yields. Table 5 shows how much the national average yields would have to increase to avoid crop expansion in case of a doubled EU demand for biofuels, compared to 2008. In most countries, cropland used for production of feedstock for EU biofuels constitutes a small share of the total cropland (e.g. Figure 1). Therefore, small yield increases may help to avoid crop expansion that otherwise would occur as the EU demand for biofuels increases.

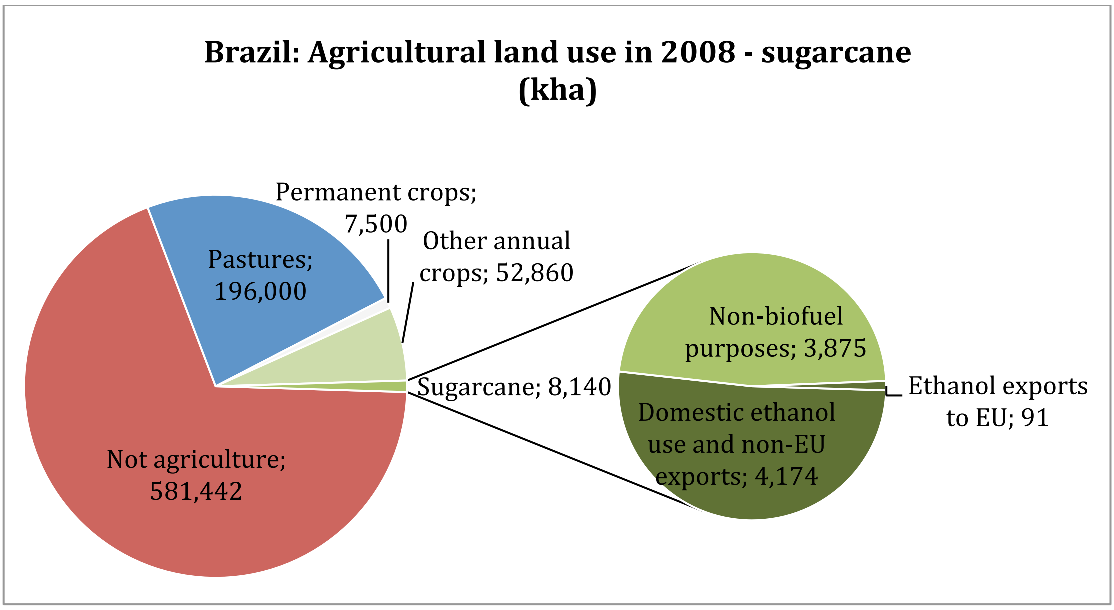


Figure 1: Agricultural land use in Brazil in 2008, focused on sugarcane production

However, in some countries, cropland used for production of feedstock for EU biofuels constitutes a large share of the total cropland. This implies that large yield increases would be necessary to avoid crop expansion as the EU demand for biofuels increases. This is particularly the case for sugarcane in Bolivia, Soybean in USA and, most significantly, rapeseed in Ukraine (Figure 2)

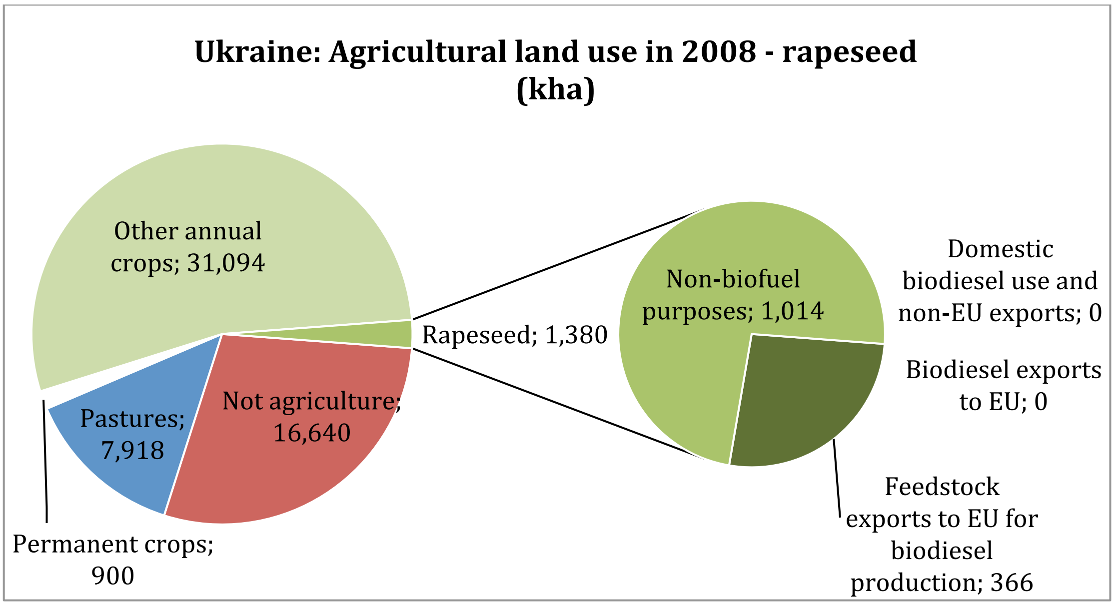


Figure 2: Agricultural land use in Ukraine in 2008, focused on rapeseed production

To conclude, the countries that appear to have been mostly influenced in their land use by EU biofuel import demands are Argentina (soybean), Brazil (soybean and sugarcane), USA (soybean) and Ukraine (rapeseed) Malaysia and Indonesia (both oil palm) are also likely to have experienced significant land use changes, although to a smaller extent. Bolivia has a relatively small area dedicated to sugarcane production, but a significant part of this production was for the purpose of producing ethanol for export to EU.

Table 5: Yield increases needed to avoid crop expansion in case of doubled EU demands for biofuels compared to 2008

Country	Crop	Total production in 2008	Production for EU biofuels in 2008	Average yields in 2008	Yield increases needed to avoid crop expansion if production for EU demands would double
		kt	kt	(t/ha)	%
Argentina	Soybean	46,238	1,528	2.8	3.3%
Bolivia	Sugarcane	7,009	480	43.8	6.8%
	Soybean	1,260	2	1.6	0.2%
Brazil	Sugarcane	645,300	7,226	79.3	1.1%
	Soybean	59,242	2,201	2.8	3.7%
	Oil Palm	660	2	10.0	0.3%
Ethiopia	Sugarcane	2,300	12	107	0.5%
Guatemala	Sugarcane	25,437	12	88.6	0.9%
USA	Maize	307,142	218	9.7	0.001%
	Soybean	80,749	3	2.7	4.2%
Indonesia	Oil Palm	85,000	3,394	17.0	3.8%
Malaysia	Oil Palm	83,000	3,236	21.3	2.5%
Pakistan	Sugarcane	63,920	2,096	51.5	1.3%
Peru	Sugarcane	9,396	334	136	3.6%
Ukraine	Rapeseed	2,873	831	2.1	26.5%
	Sugarbeet	13,438	334	35.6	0.1%

Land use dynamics

The means of increasing production determines the environmental effects. Crop expansion may cause deforestation and loss of biodiversity, while intensification may result in, e.g., eutrophication, water pollution and damage on neighbouring ecosystems from an increased use of fertilizers and pesticides. Assessing past-to-present land use dynamics associated with the cultivation of biofuel crops helps to understand which environmental effects that might arise due to increasing crop production in the different countries. Table 6 shows the extent to which crop production increases were obtained based on cropland expansion during 1990-2008 and 2004-2008, for crops that were used as feedstock for EU biofuels in 2008. The country profiles include more detailed information about land use dynamics.

Table 6: Means of increasing crop production during the last two decades. Orange: mainly expansion; Yellow: more even contribution from expansion and intensification; Green: mainly intensification; Black: production decreased during the period. Each country-crop combination consists of two cells. The first cell shows the result for 1990-2008 and the second for 2004-2008.

Country	Biodiesel feedstock						Ethanol feedstock			
	Soybean		Oil palm		Rapeseed		Sugarcane		Maize	
Argentina	Orange	Yellow								
Bolivia	Orange	Black					Orange	Orange		
Brazil	Yellow	Green	Orange	Orange			Yellow	Orange		
Guatemala							Orange	Orange		
USA	Yellow	Black							Yellow	Orange
Indonesia			Orange	Orange						
Malaysia			Orange	Orange						
Pakistan							Yellow	Orange		
Ukraine					Orange	Orange				

Source: FAOSTAT data

Interpretation: Orange: ≥80% of the production increase was obtained from crop expansion; Yellow: 21-79%; Green: ≤20%.

Seen over the last two decades, increased soybean production in Argentina and Brazil was mainly obtained from expanding the area used for soybean cultivation, while the contribution from yield increases has been relatively larger during the most recent years. Yield increases is indicated in Table 3 to have become less important contributors to increased sugarcane production the most recent years in Brazil and also in Pakistan. This may be explained by the significant increase in ethanol production capacity in these countries recent years, given the character of sugarcane ethanol expansion - new ethanol plants are built with simultaneous establishment of surrounding sugarcane plantations.

The dynamics for soybean and maize in USA (these crops are commonly cultivated in rotations) is described in some detail in the country profile section. It can be noted here that maize yields have grown steadily over practically the whole period 1990-2008, while soybean yields have varied more over time. Both crops have expanded over the last two decades. Oil palm production in the assessed countries seems to continue to be increasing almost entirely due to expansion and the same trend can be seen for rapeseed production in Ukraine.

It should be noted that expansion of cropland is likely to have different effects in different countries. Some countries may be able to expand their cropland for specific crops by changing the crop rotation patterns, including reducing the amount of land in fallow, while others may have to expand onto pastures or natural vegetation. The effects of the latter are also likely to vary between different countries, depending on the types of land that become converted to cropland. For example, conversion of tropical peat forests would result in more adverse impacts on e.g. biodiversity and GHG balances than conversion of degraded grasslands. Country specific treatments of these issues are included in the country profiles in the full report.

This summary has mainly focused on land use patterns over the last decades and paid particular attention to land use dynamics in relation to EU biofuel demands in 2008. Undesired consequences of increasing production for food and biofuels can be expected to trigger governments to implement mitigating measures. The character and implementation patterns for such measures will influence the future land use patterns, which may well deviate significantly from the historic patterns. A separate section contributes three illustrative case studies intended to show how different types of measures can alter the way land use for biofuels evolves into the future.

MEASURES THAT MAY INFLUENCE FUTURE LAND-USE PATTERNS[3]

In this report, several trends in land-use change have been identified and discussed (see previous chapters and country profiles), as well as the likelihood that these trends will continue or change due to e.g. biophysical constraints. However, such trends might also change due to countries taking active measures in changing them. Understanding such measures is necessary in order to be prepared for (a) unexpected shifts in land-use trends and (b) further developments of policy instruments on an EU-level with the intention to influence land-use trends in exporting countries.

Three different cases in three different regions have been selected to illustrate the range of such measures:

The *Indonesia* case study shows how targeting of degraded land for oil palm expansion can reduce the deforestation pressure. In the Indonesian context, the term degraded land refers to areas that are already clear of their natural forest cover, currently contain low levels of biodiversity and low stocks of carbon, and are not presently used for productive agriculture or human habitation. Alang-alang grasslands (Imperata cylindrica) are an example of such degraded lands in Indonesia. The case study describes the challenges involved and how these are addressed in a project managed by World Resources Institute.

The *Tanzania* case study describes a situation where international land investment interests may cause unwanted land-use changes due to limited overview of existing land-use and insufficient understanding of the suitability of different land-uses in different areas. The development of a land-use inventory and -plan is presented as a necessity for ensuring the international investments results in a positive outcome for environment as well as the local populations affected by foreign land investments.

The *Brazil* case study discusses the Forest Act, which is the most important legal framework for regulating conservation and restoration on private land. The Forest Act is presently subject to revision and the outcome will have much influence on Brazilian land use, including the cultivation of crops such as sugar cane and soybean for biofuel production. It is proposed that the revision process can go in two contrasting directions - either towards finding an adequate balance between conservation and agriculture development, or towards promoting spatial agriculture expansion while disregarding nature conservation needs. Much of the outcome will be determined by the parliaments' perception of the relative importance of different objectives and to what extent these objectives are compatible.

---

[3] In this project, national land-use plans were intended to be analysed for understanding how they are influencing agricultural land use. It soon became apparent, however, that this was not feasible, since few such land-use plans were found for the selected countries. In addition, significant variations in structure and legislative status existed between the land-use plans that were found. Therefore, a similar approach was decided in discussions between Ecofys and the authors.

The Indonesia case

Palm oil on degraded land - the Potico project (World Resources Institute, WRI)

Palm oil is an increasingly popular natural ingredient for food, cosmetics, consumer goods, and fuel. Part of its attractiveness is that the oil palm tree has the highest oil yield of any cultivated plant in the world—yielding 10 times more oil per hectare than soybeans.

However, increasing demand for palm oil is contributing to tropical deforestation. Indonesia, with 44%of global palm oil supply and most of the planned expansion, is currently at the epicentre of this issue. Oil palm plantations now cover nearly 7 million hectares of the Indonesian archipelago, and are projected to cover an additional 5 million hectares by 2020. More than 50% of the country's existing oil palm plantations were established by clearing natural forests.[4]

The oil palm/forest frontier in Indonesia.

This loss of forests to oil palm plantations has numerous negative impacts including greenhouse gas emissions, biodiversity loss, and social disruption and conflict for forest-dependent communities. Furthermore, because palm oil is linked to tropical deforestation, companies involved in the oil's supply chain may be at brand, and ultimately financial, risk.

But palm oil is likely here to stay. It is a productive and versatile crop. Plantations are labour intensive, with 1 person per 5-10 hectares, and therefore create local jobs. Palm oil is a significant export for Indonesia and thus contributes to national GDP. Moreover, the Indonesian government is committed to doubling its current palm oil production by 2020.

Therefore, for the sake of sustainability it is imperative to find ways to break the link between palm oil and tropical deforestation. To accomplish this, both demand and supply need to be addressed. On the demand side, the Roundtable on Sustainable Palm Oil (RSPO) and buyer commitments to purchase RSPO-certified palm oil are playing an important role. On the supply side, yields need to increase so that it takes fewer hectares to grow more palm oil. Furthermore, new plantations—as well as those already permitted but not yet started—should be diverted to non-forested areas, sometimes called "degraded land."

The opportunity

Indonesia has at least 6 million hectares of degraded land.[5] In this context, "degraded land" does not necessarily refer to poor soil quality. Rather, the term refers to areas that are already clear of their natural forest cover, currently contain low levels of

[4] Koh, L.P. and D.S. Wilcove, "Is oil palm agriculture really destroying tropical biodiversity?" *Conservation Letters* 1 (2008): 60-64.
[5] See http://www.wri.org/stories/2010/11/faq-indonesia-degraded-land-and-sustainable-palm-oil

biodiversity and low stocks of carbon, and are not presently used for productive agriculture or human habitation. Alang-alang grasslands (*Imperata cylindrica*) are an example of such degraded lands in Indonesia.

If planned oil palm plantations were to be diverted to some of these degraded lands, then oil palm could expand to meet growing world demand while avoiding deforestation and the associated greenhouse gas emissions, biodiversity loss, and social conflict for indigenous peoples. Agro-economic analyses[6] and WRI interviews with oil palm companies confirm that growing oil palm productively on degraded areas such as alang-alang grasslands is possible and can be profitable. Furthermore, WRI research and engagement with oil palm firms indicate that there is interest among them to divert future plantations toward degraded areas.[7]

An alang-alang grassland in West Kalimantan, Indonesia. *Photo: WRI/Sekala*

The challenge

However, there are four primary obstacles to Indonesia realizing widespread diversion of oil palm plantations toward degraded lands:

- *Technical.* There is a dearth of data—particularly maps—showing exactly where degraded lands that are physically suitable and economically viable for oil palm are located in Indonesia.
- *Social.* For an oil palm plantation to be sustainable, it needs to be on degraded lands that are not only physically suitable and economically viable but also socially acceptable to local communities. This is an important consideration because degraded lands, especially in a populous country like Indonesia, are often not devoid of people who have claims on them. However, there are few documented examples of oil palm permitting and establishment that have utilized best practice social procedures such as free, prior and informed consent (FPIC)—a criterion of RSPO. In addition, developers claim that they often lack skills for the FPIC process.[8]
- *Legal.* Some degraded tracts of land that are physically suitable, economically viable, and socially acceptable for sustainable oil palm may not be currently legally available for oil palm development because they are zoned as "Forest Estate"—despite being devoid of trees. According to Indonesian law, Forest Estate lands cannot be utilized for agricultural uses.
- *Enforcement.* In order for a degraded lands utilization strategy to be effective, stakeholders such as palm oil buyers, governments, non-governmental

---

[6] Fairhurst, T. and D. McLaughlin, "Sustainable Oil Palm Development on Degraded Land in Kalimantan." WWF, 2009.
[7] Fairhurst, T., M. McLeish (WRI), and R. Prasodjo (WRI). 2010. *Conditions Required by the Private Sector for Oil Palm Expansion on Degraded Land in Indonesia.* Working paper for the Prince's Rainforests Project.
[8] Fairhurst, T., M. McLeish (WRI), and R. Prasodjo (WRI). 2010. *Conditions Required by the Private Sector for Oil Palm Expansion on Degraded Land in Indonesia.* Working paper for the Prince's Rainforests Project.

organizations, and international investors need to be able to identify implementation shortfalls (e.g., a tract of degraded land is not converted to oil palm as planned, a natural forest is cleared) and take corrective action. Likewise, oil palm companies need to know that on-the-ground activities are being monitored, creating a deterrent to clearing new forests. A monitoring system that provides such information in a timely manner does not yet exist.

WRI's response

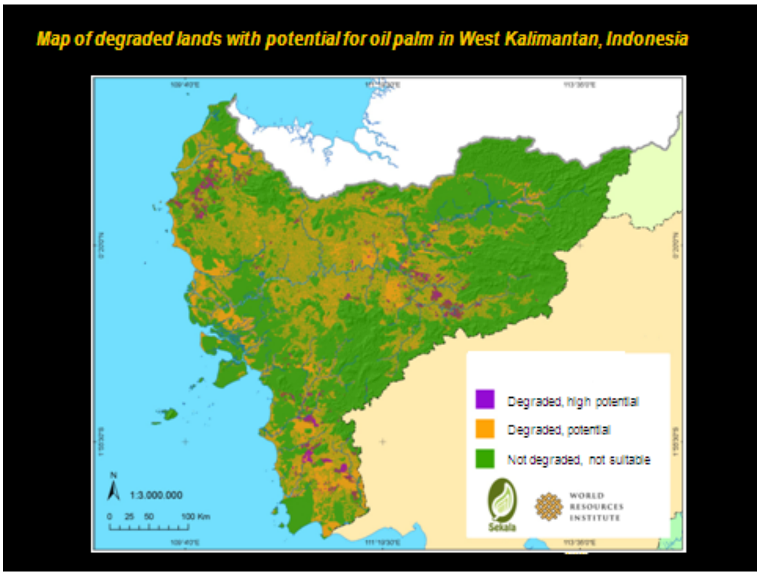
WRI's Project POTICO is designed to address these challenges. POTICO seeks to prevent deforestation in Indonesia—and enable sustainable supply of palm oil—by diverting planned oil palm plantations away from natural forests and onto degraded land instead, and by enabling the sustainable management of natural forests previously slated for conversion. The project is pursuing a simultaneous two-prong strategy:

- *Pilot.* Pilot projects are pursued in the field to demonstrate the viability of diverting oil palm to degraded land, identify solutions to the primary obstacles, and ultimately blaze a trail for others to follow.

- *Scale up.* Policymakers are engaged to generate political and financial support for the degraded lands utilization strategy and systems are built to scale up adoption of the approach. Insights and experiences from the pilot work are informing the scale up strategy.

The Project POTICO team consists of WRI staff in Jakarta and Washington, DC, as well as staff from the Indonesian field partner, Sekala.[9]

Progress to date



In the "pilot" portion of the strategy, WRI and Sekala have been constructively engaging oil palm companies and district and provincial officials to pioneer the diversion of oil palm to degraded lands. Among other advances, an economic business case has been developed for degraded land utilization. A systematic methodology was created for identifying degraded lands that are physically suitable, economically viable, socially acceptable, and legally available for sustainable oil palm development. Furthermore, the first ever detailed map of degraded lands that are physically suitable and economically viable for sustainable oil palm was created.

[9] Sekala is an Indonesian organization with expertise in spatial analysis, spatial planning, community mapping, multi-stakeholder engagement, and capacity building. WRI has worked with Sekala in Indonesia for nearly a decade.

This map covers the province of West Kalimantan on Borneo and was corroborated by field surveys.

Based on this work, the first ever "land swap" of natural forest for degraded land for the purposes of oil palm development has been started. An oil palm company that has been engaged has received a permit to convert a natural forest in West Kalimantan into an oil palm plantation but now will not exercise the permit. Instead, it has applied for a permit to convert a similar sized tract of degraded land—identified by the WRI/Sekala map—into a plantation. As part of this pilot, Sekala has led a community mapping process with local villages as input into the FPIC procedure. Likewise, government officials and legal experts have been engaged while going through the process of rezoning to allow for a degraded area zoned "Forest Estate" to be converted to agriculture. Therefore, throughout the pilot the project has been pioneering approaches for addressing the technical, social, and legal obstacles to diverting oil palm to degraded lands.

In the "scale up" portion of the strategy, WRI and Sekala have been engaging national government officials and international development agencies to build political and financial support for the degraded land utilization strategy. When Project POTICO was launched in 2009, utilizing degraded lands for oil palm neither was on the political agenda nor had international financial support. Now it has both.

Next steps

Because of these developments, momentum is building for scaling up the degraded lands utilization strategy. But to achieve the vision, more work needs to be done to address the four challenges facing widespread diversion of oil palm to degraded lands. To do this, three systems are to be developed:

1. ***An online degraded land identification system.*** WRI will design, develop, and promote a free, online system that enables users to identify tracts of degraded land throughout Indonesia. The system will apply pre-determined screening criteria and user-defined parameters to generate maps of degraded land with high potential for sustainable oil palm expansion and prioritize areas for site-specific field assessments. Essentially, the system will standardize, make user-friendly, and mainstream the methodology we developed for the Indonesian province of West Kalimantan.

   The system has multiple target users. For instance, governments and spatial planners could use it when redoing their land use plans and zoning. Oil palm companies could use it to find tracts of degraded land for their future oil palm plantations. Investors could use it to guide their investments in sustainable palm oil. Buyers can use it when negotiating with suppliers to ensure or encourage suppliers to site only on degraded lands.
   This system is designed to address the "technical" challenge to widespread diversion of oil palm to degraded lands.

2. ***A "how to" guide.*** Based on field experience in West Kalimantan, a "how to" guide for utilizing degraded lands for oil palm expansion will be published and promoted. The guide will offer practical, step-by-step guidance to oil palm companies and government officials. It will provide technical advice on spatial decision-making for degraded land and detail how to permit and

develop plantations on degraded lands in accordance with best practice social and environmental processes—including community mapping and FPIC. Furthermore, the guide will recommend changes to Indonesian law to facilitate degraded land utilization and land swaps.

The guide is designed to address the "social" and "legal" challenges to widespread diversion of oil palm to degraded lands.

3. ***A forest monitoring system.*** WRI will develop a publicly available, web-based Indonesian forest cover monitoring system that allows investors, palm oil buyers, government agencies (e.g., the REDD+ Task Force), and nongovernmental organizations to monitor and verify adherence of oil palm growers to the degraded land utilization strategy. The system will use historic (back to year 2000) and current satellite imagery to identify changes in forest cover on an annual basis. Combined with data on concession boundaries, this system could be used to determine whether or not oil palm companies are using degraded lands, are following through on commitments to not develop natural forests, and other features. In addition, the monitoring system can "look back in time" to detect where deforestation occurred between 2000 and today, enabling investors, buyers, and others to screen out oil palm plantations or companies that have violated the law or RSPO criteria (e.g., converted forest after 2005).

   This system is designed to address the "enforcement" challenge to widespread diversion of oil palm to degraded lands.

WRI and project partner Sekala are developing these tools over the course of 2011 and 2012. Once these systems are in place, Project POTICO will have taken a significant step towards mainstreaming degraded land utilization for sustainable palm oil.

The Tanzania case

The National Land-use Framework Plan

Tanzania, as well as several other East-African countries, is experiencing a vast foreign interest for investments in farmland. Allowing international companies to lease unused land may have several benefits; economically (both national and local) as well as technically (introduction of better agricultural practices) and socially (investor commitments). This provides that the company is paying reasonable land fees, that little relocation of local communities is needed, that investor commitments are included in the contract and that the produced crops are not entirely exported without any refinements or payment of reasonable customs fees. However, even though the above measures are taken into consideration, allowing for Tanzania to benefit from international agricultural investments, it is important that only suitable land is leased for such projects. Tanzania needs to preserve both a potential to increase food-production as well as ecologically valuable areas to allow for conservation of biodiversity (global interest) and profitable eco-tourism (national interest). Therefore, it is important that Tanzania develops a land-use inventory and -plan before allocating too large land areas to foreign agricultural projects.

National land-use policy developments

The National Land Use Policy of Tanzania was adopted in 1995 and was later revised in 1997 (Ministry of land and human settlement development, 1997). The main objective with the policy is to secure a land tenure system, encourage optimal land use and to promote development without disturbing the ecological balance of the environment. The policy was adopted since there has been a need to guide land use since achieving political independence in 1961. Some of the main reasons for why a land use policy is needed are increased population and urbanization, increased cultivation and land use conflicts, among other things.

In 2000, the Human Settlement Development Policy was adopted (Ministry of land and human settlement development, 2000). The policy considers issues such as increased population, urban and rural development, housing, village planning and gender equality. The main goals with the policy are to promote human settlement development in a sustainable manner and to facilitate the provision of affordable and adequate shelter to all income groups on Tanzania. The objectives are focused on employment generation, infrastructure development and capacity building, among other things.

The land use planning act of Tanzania (United Republic of Tanzania 2007) was adopted in June 2007 and rest upon the guiding principles of the National Land Policy and the Human Settlement Development policy. These policies should be used as basis for interpreting and applying the Land Use Planning Act, hereafter referred to as the Act.

The Land Use Planning Act and the National Land use Framework Plan

The Act should help prepare and implement land use plans in Tanzania (United republic of Tanzania, 2007). According to the Act, the objectives of land use planning is to:

a) Facilitate efficient and orderly management of land use;
b) Empower landholders and users to make better and more productive use of their land;
c) Promote sustainable land use practices;
d) Ensure security and equity in access to land resources,
e) Facilitate the establishment of a framework for the prevention of land use conflicts;
f) Facilitate overall macro-level planning while taking into account regional and sectorial considerations;
g) Provide for inter-sectorial co-ordination at all levels;
h) Ensure the use of political and administrative structures and resources available at national, regional, district and village levels; and
i) Provide a framework for the incorporation of such relevant principles contained in national and structural development policies as may be defined by the Government

The National Land use Planning Commission (NLUCP) was established under the Act and should, among other things, prepare the National land use framework plan (NLUFP) (United republic of Tanzania, 2007). A district and a village council was also established as planning authorities under the Act, responsible for formulating the district respective village land use plans, scaling down the national land use framework plan. The NLUFP should be finished within five years after the adoption of the Act (United Republic of Tanzania, 2007), meaning at latest in June of 2012. Unfortunately, few documents have been found regarding the NLUFP.

Implications on the production of biofuels

Biofuels are relatively new in many developing countries, with very few research initiatives to prove or support the process. The main priority, in many developing countries, on land use is food security and environment. The land use policy does not necessarily indicate the type of crops to be grown but is a platform to enhance sustainable utilization of the resources while maximising productivity. Productivity is a relative term and could take different forms and trajectories (Kongo 2011).

Several of the objectives described for land use planning can have an effect on the biofuel production in the future, especially objective b-e as seen above. The second objective (b): "*empower landholders and users to make better and more productive use of their land*" could have an effect on the potential for producing biofuels, depending on the priorities. Implementation of more productive farming could allow for food crop production to occur at the same time as biofuel crop production. The objective to promote sustainable land use practice (c) can be relevant to how and where biofuel crops can be produced. Both goal (d) and (e) are important in regard to access to land for production of biofuel crops. Although Tanzania has large uncultivated land areas, an increased population increases the demand for land, in turn affecting the availability of land. The land tenure system implemented will affect the accessibility of land for foreign or large-scale investment in biofuel production. An increase in population is likely to increase the risk of land use conflict between, for example, biofuel production and small-scale household agriculture. Kongo (2011) supports this, reporting that the biggest challenge is the land tenure system, which has led to painful experiences especially to the local people. Thus, biofuel production, as an enterprising venture, is not seen as a problem, but the land issue associated with the venture is. Land issues in the region are a bit sensitive and biofuel production is a victim of this insecurity. On the

Since development is a clear focus of all documents, the potential conflict between land used for food crops and biofuel crop can affect the potential of Tanzania to contribute with biofuels. Still, biofuel crops could be relevant in relation to the discussion of income and employment generation in the human settlement development plan. It also depends on how *better* and *productive* use of land is defined in the Act (objective b).

In May of 2009 a workshop on the NLUFP 2008-2028 was held (Ministry of land and human settlement development/NLUCP, 2009). The land use plan presented at the workshop in 2009 has not been found. A document or an outline for the land use plan for 2008-2028 was found in Swahili and was translated into English (NLUPC, 2008). As for the other documents, biofuels are not explicitly considered. The document describes that the purpose with the land use plan is to guide land-use and improve community life and development.

At a NLUFP workshop, participants were allowed to express their opinions regarding the land use plan (Ministry of land and human settlement development/NLUCP, 2009). Some of the participant expressed that promotion of large scale farm can cause conflicts with small- or medium-scale farms. Although it is not mentioned what type of large scale farming they refer to, it seem likely that biofuel production, such as large sugarcane plantations, would be seen as problematic when formulating land use plans and will need careful consideration.

In the report from the workshop, the NLUPC reports that Tanzania has enough land for agriculture and other purposes, but that this requires the implementation of more modern farming techniques with higher yields and smaller land demands (Ministry of land and human settlement development/NLUCP, 2009). It is not defined what type of agriculture they refer to, or what “other purposes” are, but it seems to indicate an openness to use of land for other purposes than food production.

According to the Ministry of land and human settlement development and NLUCP (2009) preparing land use plans is further so costly that many authorities on a local level have difficulties carrying out the task. Regardless, Tanzania’s land-use policy development is an important and necessary step towards a sustainable use of land in a longer perspective.

References

Kongo, V., 2011. *Personal communication: Victor Kongo, PhD, Stockholm Environment Institute - Africa Centre, Dar es Salaam, Tanzania.*

Institute of Resource Assessment (IRA)

University of Dar es Salaam

Ministry of land and human settlement development, 1997. *National Land Policy*. Dar Es Salaam: the United Republic of Tanzania.

Ministry of land and human settlement development, 2000. *National Human Settlement Development Policy.* Dar Es Salaam, the United Republic of Tanzania.

Ministry of land and human settlement development/NLUCP, 2009. *National Land Use Framework Plan 2008 – 2028, Workshop report*. Adem-Bagamoyo, 22nd May, 2009

NLUPC, 2008. *Pango Wa Taifa wa Matumizi Yaardhi 2008 hadi 2028*. (in English: National Land use plan 2008 - 2028) Available at: http://www.nlupc.org/images/uploads/utekelezaji_wa_mpango_wa_taifa_wa_matumizi_ya_ardhi_2028.pdf Accessed on April 11, 2010.

United Republic of Tanzania, 2007. *The Land use Planning Act*. Act Suppliment No. 10. ISSN: 0856 – 033IX. Dar Es Salaam, the United Republic of Tanzania.

The Brazil case

Implications of the revision of the Brazilian forest act and non-deforestation expansion potential for agriculture

The Forest Act

In July 2010, the Brazilian parliament began the analysis of a substitutive legislation on natural vegetation protection on private land (Forest Act - FA). The FA is the most important legal framework for regulating conservation and restoration on private land, covering all natural vegetation; i.e., not only forests, as the name of the law may suggest, but also the non-forest biomes. The revision of the FA is partly driven by the ineffectiveness of the current legislation. Assessments of the compliance of Brazilian agriculture with the legislation report a large deficit in protection of natural vegetation on private farmland (Sparovek et al. 2010).

The FA includes two types of conservation concepts: Permanent Preservation Areas (PPAs) and Legal Reserve Areas (LRAs). PPAs aim at protecting water resources and are defined in a geographically explicit way. They consist of riparian areas along water bodies, steep slopes, high altitude areas, and hilltops. PPAs are established exclusively for the purpose of conservation and must be covered by natural vegetation. LRAs are not geographically defined and aim at biodiversity conservation in more general terms. LRAs correspond to the proportion of each private farmland, with location determined by the landowner, where natural vegetation should not be removed to make place for conventional agriculture. Some productive uses are possible, but only if they can be combined with natural vegetation preservation, i.e., no clear cutting is allowed. In the Legal Amazon Region, the proportion of LRAs varies from 80% to 35% of private farmland and outside the Legal Amazon Region the proportion is 20%.

According to the FA, each farm has to keep the PAAs covered with natural vegetation and follow the land use restrictions imposed for LRAs. The current FA includes a compensation mechanism that leaves some room for reducing the protection on the farm, but this mechanism has proven to be difficult to apply and is not frequently used by the farmers. Legal enforcement of compliance with the FA requirements is usually carried out by compelling landowners to stop agricultural production and reforest at their own costs.

Natural ecosystems and their protection

From Brazilian continental territory (850 Mha) an area of 537 Mha still has prevalence of natural vegetation covering biomes such as the Amazon rainforests, savannas (Cerrado); the typical sparse, thorny woods with drought-resistant trees in northeastern Brazil (Caatinga); the tropical wetland (Pantanal); the world biosphere reserve complex along the Atlantic coast (Atlantic Forest); and the grassland of South Brazil (Pampa). These areas are not all pristine. Some may be used for grazing, low impact extraction, undergo regeneration, or be occupied by less intensive agriculture; all productive activities that does not require the complete removal of the natural vegetation. Although not all being pristine, much of these areas have high conservation value, as shown by their reflectance pattern in satellite images being similar to those of the corresponding natural sites.

About 170 Mha out of the 537 Mha of natural vegetation is located within publicly owned Conservation Parks and Indian Reservations (CP/IR), where legislation and its enforcement is reported to be highly efficient (95%) in keeping the natural vegetation (Sparovek *et al.* 2010). The remaining 367 Mha is mainly on private lands used for agriculture, upon which the FA applies. Another part of this natural vegetation, mainly located in the Amazon Region and difficult to define in terms of precise location and area, is public land that has not yet been converted to CP/IR, or assigned for private ownership. The unclear ownership situation is an additional threat to natural land in these cases since legal measures cannot be effectively applied until the land status has been defined.

Effectiveness of the current FA

The land use restrictions that apply on PPAs and LRAs result in significant opportunity costs, especially on lands with high agricultural suitability. There can consequently arise tensions between farmers and authorities, both in areas where agriculture is well established, and in naturally preserved regions with high suitability for agriculture. These tensions between farmers and authorities have resulted in a low level of law enforcement and a widespread accumulation of legal deficits regarding PPAs and LRAs. The agriculture producers look at the FA – and especially the more diffuse conservation concept of LRAs – as a barrier against development. The concept of PAA, which is more directly related to water conservation, reduction of soil erosion and sediment flows in rivers, is perceived by the farmers as a more justifiable restriction on their land use.

From a total PPAs area of 103 Mha, 44 Mha is used for crop production or as pastures, i.e., land uses that do not conform to the FA requirements and that do not effectively protect water resources in riparian systems. The area needed to meet the LRAs requirements is approximately 254 Mha in total. This is about 43 Mha more than the existing natural vegetation area on farmlands that is outside PPAs and CP/IR areas, i.e., that could be reserved by farmers as LRAs areas (Sparovek *et al.*, 2011, Sparovek *et al.* 2010). The non-compliance what regards PPAs and LRAs occurs in all regions having significant agricultural land use (Figure 1).

As noted above, even in the event of full compliance with the present FA, there would still be large areas (103 Mha) of unprotected natural vegetation on private farms that have larger share natural lands than required, i.e., lands that could be legally converted to agriculture. Part of these 103 Mha is located on land that is not suitable for crop production (approximately 73 Mha has severe soil or climate restrictions for intensive cropping), but extensive pasture based beef cattle production is viable on much of this land (Sparovek *et al.*, 2011). In a hypothetic situation of full compliance with the current FA, where 87 Mha (44+43 Mha) of agriculture land has been re-converted to natural land, the conversion process would likely have induced substantial leakage where some of the 103 Mha of unprotected natural vegetation become converted to agriculture land, significantly reducing the conservation benefits of full compliance. Furthermore, while the impacts of natural land conversion is immediate and may be difficult to revert, re-establishment of natural vegetation by planting may require a long time to attain the ecological values of comparable preserved sites. Thus, preservation of lands that currently host natural vegetation, combined with restoration where the benefits are highest (PPAs), may result in higher ecological benefits.

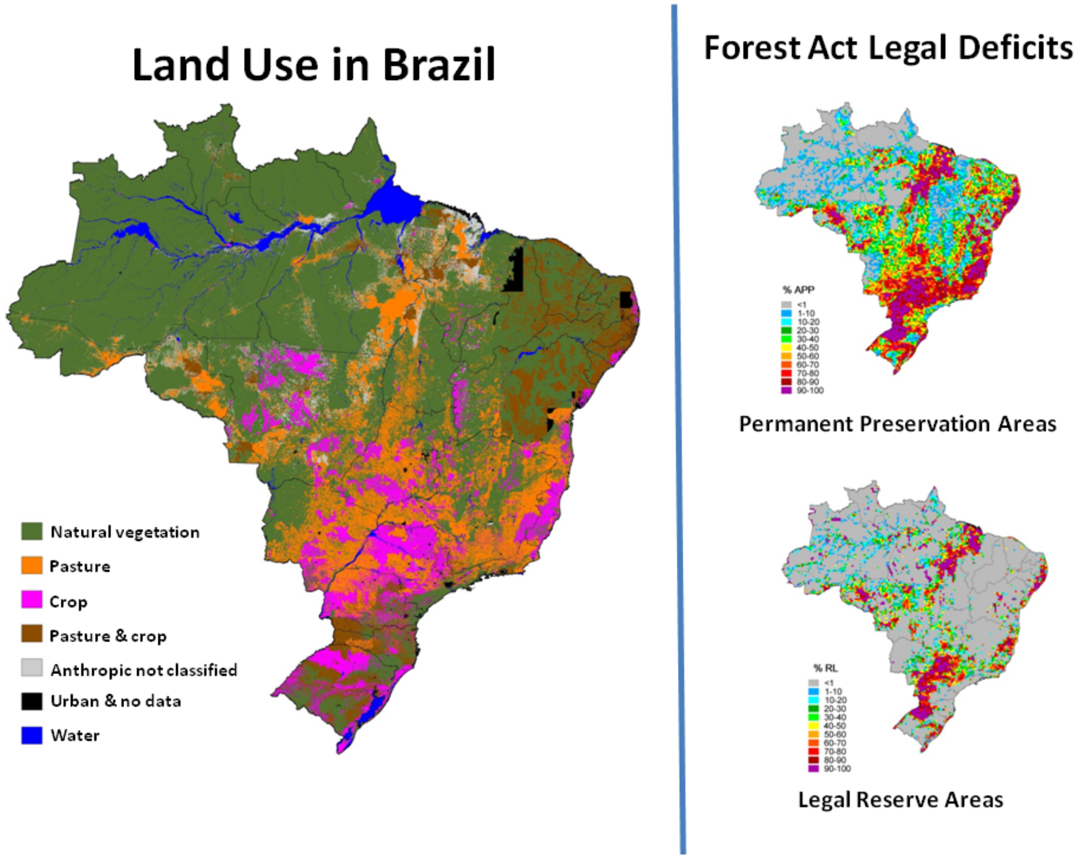


Figure 1. Land use in Brazil and the extent and geographical distribution of FA legal deficits.

The underlying rationales for the FA revision

To summarize, the underlying rationales for the revision of the FA are the following:

(i) the long history of non-compliance with the FA, involving extensive deforestation, has placed a large part of the Brazilian producers in an illegitimate situation;

(ii) national and international awareness about legality and environmental consequences of land use is increasing (e.g., certification, no-tariff barriers, social and environmental activism, improvements of surveillance technology using remote sensing) and this has placed the Brazilian agriculture sector in a vulnerable and uncomfortable position

(iii) total compliance with the FA as it presently stands, if achieved through the restoration of natural vegetation through planting, would be very costly;

(iv) there is a perception in the agriculture sector that the environmental restrictions on private farmland are too strict and prevent agriculture development, and also that conservation of natural vegetation should take place mainly on public land.

Given that natural vegetation protection requirements on private farmland in the present FA embraces approximately twice the area protected on public land, revisions of the FA needs to be based on careful assessments of a wide variety of relevant aspects: it is essential that revisions take into account conditions for agricultural and forestry practices, but also reflect how the Brazilian society understands and prioritize nature conservation and soil/water/biodiversity protection. The FA revision is about finding the balance between conservation and economic use of the landscape.

The Substitutive FA

The announced pillars in the substitutive FA are:

(i) major reductions of legal requirements for both PAAs and LRAs;
(ii) restricted restoration focusing on the more important PPAs of the riparian systems;
(iii) creation of a market based compensation scheme that allows farmers to compensate for the LRAs deficits by protecting natural vegetation outside the farms, aiming at protecting at least part of the natural vegetation that is presently not legally protected; and
(iv) suspension of deforestation permits during a time period when farmers adapt to the new rules.

If balanced, these pillars could stimulate both increased conservation and agricultural development, providing a way out of illegal land use for Brazilian farmers. Our judgment is that the substitutive FA in its present form is not balanced. If approved as it presently stands the substitutive FA may solve the illegality problem but fail in promoting additional conservation; there is a risk that agricultural production will grow based on unnecessary conversion of forests and other natural land to agriculture land.

Possible consequences of the suggested FA revision

The reduction of legal requirements for land reservation to protect natural vegetation will obviously reduce the need for planting native species on productive farmland to achieve legality of agriculture. The combining of reduced requirements for on-farm nature protection with market based off-farm protection compensation can promote development where agriculture makes best use of the current agriculture land while contributing to protection of presently unprotected natural vegetation. However, it is important to note that these two revision pillars are interlinked and need to be balanced: if the reductions in PPAs and LRAs become too far-reaching, off-farm compensation requirements become essentially zero (Sparovek *et al.*, 2011).

Some reductions in protection requirements are immediate while others may apply depending on survey results (Agro-ecological Zoning and Water Resource Plans among others). These surveys are to be made by the Federal States and other organizations during a five-year period when no new deforestation permits will be issued. If the lobby groups in favor of strong reductions in protection requirements are successful during the survey period, and if survey results and interpretation of the suggested legal mechanisms work in the same direction, the following outcome can be expected:

(i) no requirements on small and medium farms to address the existing LRAs deficit, which would affect 90% of the farms and 25% of the total area of farmland;
(ii) no requirements at all to address the present PPAs deficits, which represent a total of 43 Mha;
(iii) about 20% reduction in requirements to establish PPAs in riparian buffer areas because of changes in the definition concerning buffer strips for small rivers;
(iv) exclusion of the PPAs class "hill tops", which reduces the conservation requirement by 39 Mha; and
(v) increased possibilities to reduce LRAs requirements in non-forest physiognomies in the Legal Amazon Region.

At the same time, possibilities for off-farm compensation of LRAs deficits may become much extended in the substitutive FA. In the current version of the FA, compensation is applicable only if the area assigned for protection is located in the watershed where the LRAs deficit occurs. This restricts compensation as a market driven mechanism since there is usually a lack of natural land eligible for compensation protection in the watersheds where the deficits occur. In contrast, the substitutive FA suggests that compensation can take place anywhere within the Biome where the farm is located. Given that Brazil is dived into six large Biomes this means that farmers may compensate for LRAs deficits by protecting natural land thousands of kilometers away from their farm. Farmer will be able to buy or rent cheaply areas covered with natural vegetation in very remote regions with low suitability for agriculture and low risk of becoming subject to deforestation or other degradation. Buying or renting natural vegetation land located in regions experiencing agricultural expansion will likely cost more due to the higher opportunity cost. As a result, much of the compensation protection would likely become established in areas where the conversion pressure is low, and little would become established in regions experiencing agriculture expansion where compensation protection would more effectively contribute to nature protection.

By lowering the protection requirements and extending the compensation possibilities as described above, the substitutive FA may provide a cheap and easy solution of the illegality problem, but it will not likely be effective in promoting conservation in areas where natural land is presently under highest pressure from agriculture expansion. Neither will it provide much incentive in the agricultural sector for development towards more efficient and productive land use practices. Detailed quantitative information on the effect of the legal mechanisms on conservation is reported in Sparovek *et al.* (2011).

Intensification as an option for combining conservation and agriculture development

Development of crop production and beef cattle ranching can take place either through intensified production to increase yields or through land expansion. A large part of the crop production in Brazil is already intensive and have high yields (Martinelli *et al.*, 2010). Drastic yield improvements can hardly be expected for crops such as soy and sugarcane in the short to medium term. Increased production of these crops will therefore require cropland expansion. However, it may not require further conversion of natural lands. Recent analyses show that only about 7 Mha of natural vegetation areas are highly suitable for crop production. At the same time, pastures with high or medium suitability for crop production cover about 29 Mha and 32 Mha, respectively – an area almost as large as the present cropland area at 67 Mha.

In total, pastures occupy 211 Mha of land in Brazil and are mostly used for beef cattle production that occupies 158 Mha. A large part of this land is used very extensively. The average stocking rate is 1.1 head/ha and the off-take rate is 22 % year, resulting in a slaughter rate of 40 million head per year. By increasing the stocking rates to 1.5 head/ha and off-take to 30 % year – in our judgment a modest increase compared to estimated possible intensification – the same slaughter rate of 40 million head per year could be achieved, while releasing 69 Mha of pasture land for other uses.

Extensive cattle production requires that land costs are low and that the pasture areas can be extended to increase the total production. If increased protection of forests and other natural lands leads to reduced opportunities for pasture expansion, and at the same time existing pastures become increasingly considered for crop production, then it can be expected that the beef cattle industry intensifies and also improves the land management so as to avoid unnecessary degradation.

Summary

To summarize, Brazil is close to a substantial revision of its main legal conservation framework. This revision will influence the prospects for the management of soil and water resources, nature conservation and agriculture production. Future development from the present state of the revision process can go in two contrasting directions, either towards finding an adequate balance between conservation and agriculture development or towards promoting spatial agriculture expansion while disregarding nature conservation needs. Much of the outcome will be determined by the parliaments' perception of the relative importance of different objectives and to what extent these objectives are compatible.

References

Martinelli, L.A., Joly, C.A., Nobre, C.A., Sparovek, G., 2010. The false dichotomy between preservation of the natural vegetation and food production in Brazil. Biota Neotrop. 10(4) http://www.biotaneotropica.org.br/v10n4/en/abstract?point-of-view+bn00110042010 (in Portuguese).

Nepstad, D., Soares-Filho, B., Merry, F., Lima, A., Moutinho, P., Carter, J., Bowman, M., Cattaneo, A., Rodrigues, H., Schwartzman, S., McGrath, D.G., Stickler, C.M., Lubowski, R., Piris-Cabezza, P., Rivero, S., Alencar, A., Almeida, O., Stella, O., 2009. The end of deforestation in the Brazilian Amazon. Science. 326, 1350-1351.

Sparovek, G., 2010. The new logic of the Forest Act. Revista Consulex. 331, 37-39 (in Portuguese).

Sparovek, G., Barretto, A.G.O.P., Klug, I.L.F., Papp, L., Lino, J., 2011. The revision of the Brazilian Forest Act. Novos Estudos. 89, in press (in Portuguese).

Sparovek, G., Berndes, G., Klug, I.L.F., Barretto, A.G.O.P., 2010. Brazilian Agriculture and Environmental Legislation: Status and Future Challenges. Environmental Science & Technology. 44, 6046-6053.

METHODOLOGY

For most countries, data availability has been the limiting factor when determining land-use patterns and –dynamics, production system characteristics and local environmental impacts. A few countries were covered by a number of relevant studies, although very little information was found for others. Therefore, the comprehensiveness and precision of country profiles varies relative to the availability of relevant information.

Country profiles

Country profiles have been developed for Argentina, Bolivia, Brazil, Guatemala, Peru, USA, Ethiopia, Malawi, Mozambique, Nigeria, Sudan, Tanzania, Uganda, India, Indonesia, Malaysia, Pakistan and Ukraine. Each country profile includes six components; Areas used for cultivation of biofuel crops in 2008, historical developments,

Crop selection

The crop-selection was based on Winrock's consultant data sheets, where information was provided about the most important biofuel crops in the consultants' respective countries. Local experts were consulted in order to verify and limit the preliminary selection to a maximum of three crops for each country. Selected crops include currently important biofuel crops as well as crops with a potential to become important biofuel crops in a near future.

Areas used for cultivation of biofuel crops in 2008, for various purposes

Each country profile includes a table summarising the following for the selected crops:

- ***Total harvested area***

  In order to allow for high data consistency and comparability, FAOSTAT was the primary source of information for all countries. For Jatropha, which is not covered by FAOSTAT, data from GEXI (2008) was used.

- ***Cropland used for producing domestic biofuels***

  Production data from Agra CEAS and Ecofys was used to determine the amounts of biofuels, which was domestically produced in 2008, for different crops in each country. The amounts of domestically produced crop-specific biofuels were recalculated to corresponding areas of cropland, using the following equation:

Equation 1: Calculation of cropland area corresponding to domestic production of biofuels

$$\frac{Crop\ specific\ biofuel\ production}{Overall\ conversion\ efficiency * Crop\ yields\ (national\ average)}, \quad \frac{t\ biofuels}{\frac{t\ biofuels}{t\ crop} * \frac{t\ crop}{ha}}$$

The reason for calculating with *overall* conversion efficiency and not conversion efficiency *with allocation*[10] was that the main focus of this study is on *actual* land-use. Therefore, actual areas used for cultivation of crops for biofuel production was desired. Using conversion efficiencies *with allocation* would, for most crops, result in smaller areas of land than what is actually used for producing the feedstock. This means that, for some crops, potential by-products may also be produced on the same areas as given by Equation 1.

- ***Cropland used for producing biofuels or –feedstock for biofuels on the EU market in 2008.***

Trade data from Agra CEAS and Carlo Hamenlinck (Ecofys) was used to determine the amounts and origin of feedstock used to produce biofuels for the EU market in 2008. The amounts of specified feedstock originating from each country were recalculated to corresponding areas of cropland, using a similar methodology as described by Equation 1.

For countries producing biofuels or –feedstock for the EU market in 2008, more detailed agricultural land-use charts were constructed. These charts specify the total land-use in the respective countries for 2008, including:

1. Non-agricultural land
2. Pastures
3. Permanent crops
4. Annual crops

Crops used as feedstock for EU biofuels were described as a distinctive part of the total area under permanent- or annual crops. For each such crop, the following was specified:

5. Area used for domestic production of biofuels in 2008
6. Area used for domestic production of biofuels, which was traded to the EU in 2008
7. Area used for cultivation of feedstock, which was traded and processed (outside the country) into biofuels for the EU market in 2008
8. Area used for non-biofuel purposes

For “1-4” above, FAOSTAT data was used. “5-7” was calculated using a similar methodology as described by Equation 1. “8” was calculated by subtracting (5+6+7) from the total crop-specific harvested area, as defined by FAOSTAT.

Historical developments

In order to illustrate the developments between 1990 and 2008 with regard to cultivation of the selected crops, charts showing annual levels of production, harvested area and national average yields were constructed for each country.

[10] Allocation, when used, has been on the basis of RED allocation principles (i.e. using lower heating value)

FAOSTAT data was used for the purpose of consistency and comparability. This provided the basis for understanding past land-use dynamics in each country.

In order to further describe the findings from the charts (above), a review was made of relevant literature. In all cases, attempts have been made to spatially identify and describe potential expansion, as well as currently important regions for cultivation of the different crops.

Land-use dynamics from future production increases

In an attempt to describe the effects of potential production increases in a near future, various sources of information were used. For all countries, a review of relevant literature (e.g. journal articles and ILUC reports) was made. For some countries, suitability maps were found and used as a basis for understanding the risk of direct competition with other land-uses. Additional sources of information include local expert consultations, questionnaires and in-house experience.

Production system characteristics

See *Local environmental impacts and production system characteristics*.

Observed local environmental impacts

See *Local environmental impacts and production system characteristics*.

EU regional profile

An assessment of EU as a region was required for the task on local and environmental impacts (subtask 3.4) but not for the tasks on land-use (subtask 1.3). Therefore, a regional profile for EU was produced including only aspects related to environmental impacts. However, the amounts of cropland (for selected biofuel crops) used for production of biofuels were also included in the profile, to provide for a more complete picture as well as quantification of impacts attributable to biofuel production.

Local environmental impacts and production system characteristics

In many cases, biofuel related literature focuses on the effects from processing of feedstock into biofuels. Production of feedstock is often neglected, as if the supply of feedstock to biofuel plants is taken for granted. With rapid developments of large-scale biofuel projects, and corresponding land-use changes, the biofuel feedstock production phase, and the environmental issues related to it, need more attention. Therefore, the focus of this assessment has been on assessing local environmental impacts from the feedstock production phase.

The types of environmental impacts from biofuel feedstock production will depend on the production models employed, the governance conditions in place and the biophysical properties of the environment. Hence, the production model is one important variable to determine the environmental impacts of biofuel production. Therefore, this task was extended to also include production system characteristics.

The information has been arranged on a country level. In the end of each country profile there is one table presenting production system characteristics and one presenting *documented* environmental impacts for the selected biofuel crops. Selected production system components and local environmental impacts that have been assessed are described below.

Assessed production system components

The following production system components have been assessed for the selected biofuel crops:

Large-scale production

Large-scale crop production, fully mechanized and often operated by an urban enterprise. Management decisions are taken outside of the farm area, outside the region or even outside the country. Machinery is used for sowing, tillage, fertilising, pesticide application, and harvesting. Some working practices may be manual such as harvesting of sugarcane, oil palm and jatropha.

Small-scale production

Small-scale production is managed by a farming family and working practices are most often manual. However, in countries like USA, Argentina and Brazil, it can also be fully mechanised. The size of the farms varies between regions; in Africa and Asia, small-scale farms are mostly smaller than 5 hectares, while small-scale farms in the Americas can be up to 100 hectares.

In most countries in Africa, Asia and Latin America, smallholders produce primarily for their own subsistence and secondary for selling cash crops. Regarding crops like oil palm and sugarcane, smallholders often act as outgrowers for a larger company.

Mechanized farming system

Mechanised machinery, powered by fossil fuels, is used in all or part of the production system (soil preparation, sowing, planting, weeding and harvesting).

Manual farming system

Manual labour, hand-held tools and/or draught animals are used for soil preparation, sowing, planting, weeding and harvesting.

Tillage

The practice of tillage is used for multiple reasons; to prepare the soil for the seed by breaking the crust and affecting the soil structure by working the soil; incorporate organic material in the soil, particularly important if the soil is poorly drained and to combat weed mechanically. However, when turning around the soil – and thus aerating the soil, there are losses of carbon due to mineralization of organic matter as well as losses of soil moisture as well as disruption to soil micro-flora and micro-fauna. The problem of erosion may also increase with tillage, as the soil becomes totally exposed to water and wind. The fuel and machinery cost of tillage is high.

Reduced and no tillage

When the practice of no tillage is used, the seeds are sown directly in the residues of the last harvest. The advantage of direct sowing is that the soil is not turned around with corresponding loss of carbon and nitrogen (mineralization of organic matter) and moisture from the soil. Reduced or no tillage practices are good if there is a risk for soil erosion, as the soil is less exposed to water and wind and the biological soil stabilisation is not disturbed. On the other hand, weeds may be a larger problem without the weeding effect of tillage. Therefore, no-tillage farming systems can increase the dependence on herbicides. Reduced tillage practices are often used in combination with genetically modified seeds that are herbicide tolerant; the weed control is then handled by application of herbicides (i.e. soy production in USA, Brazil and Argentina).

Irrigated

Crop water demand is supplied by supplementing precipitation with additional water by e.g. pumping (may be fossil fuel driven) or building of canals that lead water to the fields. Sources of water for crop production are e.g. surface water from rivers, lakes, canals, dams and ground water. Irrigation can decrease water availability for other uses and cause conflicts downstream. Poorly managed irrigation can led to soil salinization. Excessive use of groundwater for irrigation can increase costs for domestic water supplies.

Rainfed

Rain is the only source of water for crop production in rainfed systems. Production systems may include rainwater harvesting e.g using terraces and bunds, small dams, etc. About 80% of all cultivated land is rainfed.

Mono-cropping

Mono cropping is the agricultural practice of growing the same crop repeatedly year after year on the same field, without rotation with other crops. This practice is common in large-scale production of certain crops as it is economically a very efficient system, allowing for specialization in equipment and overall crop production. However, mono cropping often faces problems of soil fertility decline, and weeds and pests since it allows for specialized weeds and pest to propagate. This implies that mono-cropping systems may be more dependent on pesticides and mineral fertilizers for maintaining productivity. Some crops are not possible to produce in mono-cropping systems but require crop rotation.

Multi-cropping

Multi-cropping is an agricultural practice of planting two or more species in the same field in the same year. The idea is that different plants use sunlight, water, and available nutrients in different ways and therefore use these resources more efficiently than a single crop does. It also means that the farmer spreads his risks and labour requirements. Other advantages are that the multi-cropping systems maintain a green cover over the soil through much of the year, making the soil less vulnerable to erosion. With multi-cropped fields there is also a more diverse supply of food and more than one source of income. Multi-cropping systems are often difficult to mechanize (although there are different levels of system complexity), as different crops require different management. Manual labour is therefore often needed.

Crop rotation

Repeated cultivation of a succession of crops (as sole or mixed crops). One cycle often takes years to complete. Crop rotation is an agricultural practice that reduces weed and pest propagation by interchanging between different kinds of crops (e.g. cereals, oil crops, legumes, tubers etc.) as different crops require different management and are susceptible to different pests.

Mineral fertilizer used

Chemical fertilizers, produced with the use of fossil fuels, containing crop nutrients (mainly N, P, K) are added to increase crop yields and complement and maintain soil fertility. Depending on application rates, practices and relation to precipitation, these nutrients can be leached or washed into water bodies and cause eutrophication.

Chemical pesticides used

Agricultural pests include insects, plant pathogens, weeds, mammals, birds, nematodes, and microbes that destroy the crop. Pesticide is the generic term for insecticides, herbicides, and fungicides, classified by the type of organism they are intended to control. Many pesticides are toxic to humans, bees or other animals and are therefore always a risk to handle. Depending on application rates and practices and relation to precipitation or wind, these pesticides can be leached, washed or spread into water bodies or nearby land and cause damage on ecosystems. Certain chemical pesticides are resistant to biodegradation and can accumulate in nature and have longstanding negative effects.

GMO seeds used

GMO means *genetically modified organism* and in is, in this context, a crop which genetic material has been altered. Examples of GMO crops frequently cultivated today include herbicide resistant soy, Bt maize and Bt cotton, resistant to certain insects or pests. Herbicide resistant soybean (roundup-ready) was modified to fit into a more cost effective farming system where tilling was not necessary and weeds were controlled with chemical spraying. By using round-up ready soybean, more herbicides (Roundup) can be applied to the fields without harming the crop. However, weeds getting resistant to Roundup is emerging as a growing problem. Similar problems have emerged for Bt cotton, created in order to reduce the use of pesticide used for bollworm, as secondary pests have replaced bollworm as the primary pest and spraying may still be needed. There is a concern that GMO crops will implicate an increased use of chemicals in agriculture. There are several environmental concerns with the use of GMO crops i.e. the crop plants engineered for herbicide tolerance and weeds will cross-breed, resulting in the transfer of herbicide resistant genes from the crops into the weeds would create ‘superweeds’ that would then be herbicide tolerant as well. A major concern has been if introduced genes may cross over into non-modified crops planted next to GM crops (GMO contamination). To limit the spread of genetically engineered plants, the GMO plants yield sterile seeds. This means that farmers cannot take seeds for sowing from the harvest, as farmers traditionally have done, but have to buy new seeds each year. The widespread introduction of GM tolerant herbicide crops may cause a shift in weed populations and thus reduce weed species diversity and ecosystem complexity on GM fields and neighbouring farms.

Land preparations with fire

Some biofuel crops (e.g. sugarcane) are produced in fields that are prepared with fire. There are also cases where forest have been cleared and burned to give space for agriculture (e.g. oil palm production). When biofuel crops are being produced on established agricultural land it may indirectly result in deforestation and burning. When biofuel crops are produced on agricultural land, food production can be pushed into forest areas where new land is cleared for production of food crops. That kind of indirect deforestation and land preparation by fires has not been included in this mapping of environmental impacts.

By-products from harvesting

Whether or not the harvesting of biofuel crops result in any useful by-products. By-products from the processing of feedstock into biofuels have not been included here.

Assessed environmental impacts

The following local environmental impacts from biofuel crop production have been assessed for the selected biofuel crops:

Deforestation

A large part of current deforestation occurs when forestland is opened up for agricultural purposes. The forest is cleared and sometimes burned resulting in GHG emissions and reduced carbon stock. Deforestation also disturbs biogeochemical cycling, susceptibility to erosion and losses in biodiversity. Forest areas are also important locations for food and fuel collection and income generation for many poor people across the world.

Loss of agro-diversity

Agro-biodiversity is a sub set of biodiversity and includes crop varieties and animals used in farming systems. Agricultural biodiversity (as opposed to non diverse production systems) is considered to contribute to the food security for poor people in rural areas.

Loss of biodiversity

There are several causes of biodiversity loss, e.g. conversion of forests and other ecosystems into agriculture.

Air pollution

The major part of air pollution in this context are gas emissions and smoke from agricultural land opened up with fire (forest land converted into agricultural land) and field preparation by fire (as in production of sugarcane and oil palm). GHG emissions from the use of fossil fuels in mechanised farming system are also considered.

Water pollution

An increased use of herbicides and pesticides causes water pollution. Water may also be polluted by siltation from erosion.

GMO contamination

The risk of gene flow from genetically modified DNA from crop to crop and crop to wild relatives through unintentional cross-fertilisation.

Eutrophication

When nutrients are washed away from the field and into the water of rivers and lakes, eutrophication might occur, resulting in algae blooming. This is also a consequence of erosion as siltation contains mostly topsoil, which is the most nutrient rich soil.

Soil fertility decline

Soil fertility is the ability of a soil to supply plant nutrients in quantities and proportions sufficient for the growth of the crop. When the extraction of nutrients from a field (by harvest) is larger than the amount of nutrients returned or added to the field (through manure, fertiliser, compost material, fallow period etc.) the soil's fertility will decline.

Erosion

Wearing of the land surface by water, wind or other geological agents. Erosion often becomes a problem when soil is left bare and exposed to precipitation, particularly if the field is located in an inclined area and the topsoil layer can be easily washed away. Erosion causes soil- and fertility losses in the field and soil deposition and siltation elsewhere, which can be beneficial in cultivated flooded areas or wetlands, but in rivers, dams, lakes and oceans it has several negative effects.

Quantifying environmental impacts

In order to quantify the environmental impacts attributable to (a) production of domestic biofuels and (b) EU demands for biofuels or biofuels feedstock, the share of the total crop-specific area that was used for (a) production of domestic biofuels and (b) production of feedstock used for production of EU biofuels, has been calculated for selected crops in all selected countries. Since crop cultivation for EU biofuels are regarded as having the same characteristics as crop cultivation for other purposes, local environmental impacts are also the same and the importance of (a) domestic biofuel production or (b) EU biofuel demands is proportional to the share of the total cropland that is used for (a) and (b) purposes, respectively. Since production of certain crop-biofuel combinations generates by-products that substitutes for other crop production, the net area requirement for those crops are lower than the actual area used for cultivation of feedstock for EU biofuels. For that reason, RED allocation principles have been used. Calculations have been made using FAOSTAT data for land-use and yields, and trade data developed for this project by Agra CEAS and Ecofys. Calculations were made using the same principle as described by Equation 1.

Land-use patterns

The extent to which crop production increases were obtained based on cropland expansion during 1990-2008 (Table 6) was determined by calculating (1) how large the total production would have been in 2008 if no yield increases had occurred, and (2) how large the total production would have been in 2008 if no expansion had occurred. The contribution of expansion as means of increasing production was then estimated by dividing (1) with the sum of (1) and (2). The same method was used for the period 2004-2008.

COUNTRY PROFILES - AMERICAS

This section includes country profiles for Argentina, Bolivia, Brazil, Guatemala, Peru, and the United States.

Argentina

Soybean is the selected biofuel crop for Argentina. As seen in Table 7:, about 9% of the total area under soybean cultivation in 2008 was used for domestic biodiesel production and 3.3% of the total area was used for production of biofuel feedstock for the EU market. It should be noted that co-products are produced along with the biodiesel, including a protein-rich press cake that is suitable for animal feeding. This reduces the land requirements for producing animal feed elsewhere (not necessarily in the same area though).

Table 7: Area used for production of Argentina's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	**Total harvested area in 2008** (kha)	**Cropland used for domestic biofuel production in 2008**		**Cropland used for production of feedstock for EU biofuels in 2008**	
		kha	% of total	kha	% of total
Soybean	16,387	1,445	8.8%	542	3.3%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Argentina is the 2nd largest country in Latin America (after Brazil) and agriculture land covers about half of the land area (about 274 Mha in total). Roughly one-quarter of agriculture land is arable land and the rest is pastureland. The arid region in Argentina – most of Patagonia to the south of Rio Colorado – has relatively little agricultural activity. Most of Argentina's agricultural production takes place on the fertile plains in the central and northeast parts of the country (the Argentine part of the Pampas).

In the last 1-2 decades, agriculture in Argentina has undergone substantial changes with very large increases in grain and soybean production as well as exports of cereals and oil seeds. There have also been increases in poultry and beef production and exports. As in many countries, increasing the agriculture output was achieved though both agriculture expansion on natural lands and intensification to increase yields, with negative consequences of high fertilizer and other chemical input. But there has been a development towards lower risks of pollution and soil erosion due to adoption of less aggressive pesticides and no-till practices (Viglizzo et al. 2010). Important crops in Argentina are sunflower, maize, wheat and soybean. Agriculture products make up a very substantial part of Argentina's export revenues.

Soybean

As seen in Figure 3, pastures constitute the largest share of the total agricultural land in Argentina. Permanent crops are uncommon, making cultivated land dominated by annual crops in general and soybean in particular. Soybean cultivation in 2008 constituted more than 50% of the total area under annual crops, making it the most important crop in Argentina's agriculture. Biodiesel production is a rather important application for soybean, and a significant share of the total production was exported to the EU in 2008. In addition, an almost equal amount of land as can be associated with the production of biodiesel for the EU market was used for production of exported feedstock for EU biodiesel. As already noted, co-products such as animal feed are likely to be produced together with the biodiesel.

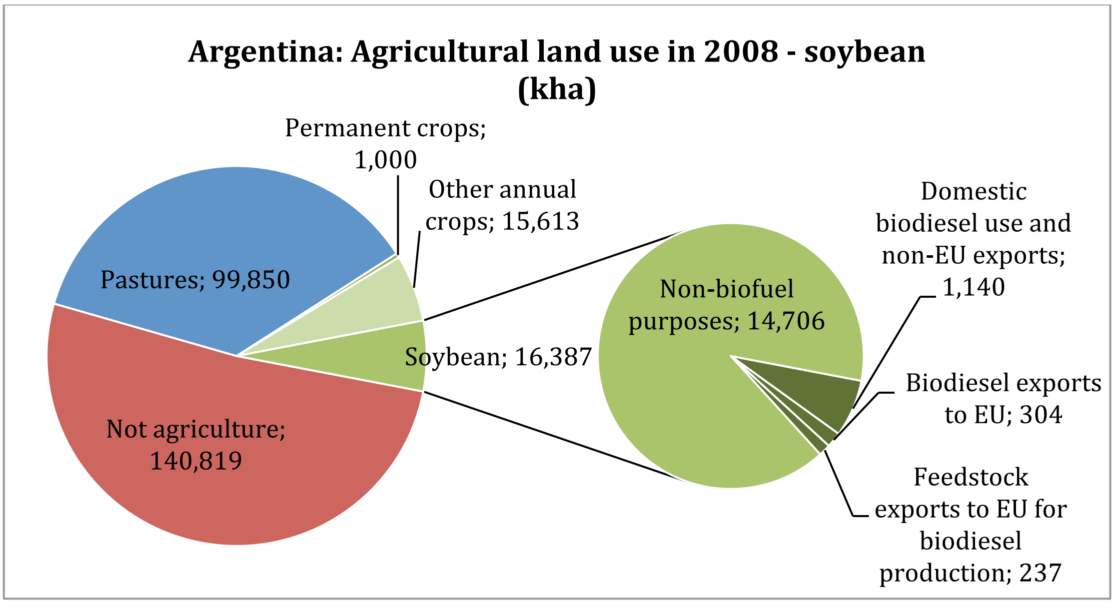


Figure 3: Agricultural land use in Argentina in 2008, focused on soybean production

Soy is the most important crop cultivated in Argentina and accounts for more than 50% of the area cultivated with grains in 2008 (Panichelli et al., 2009). Traditionally, soybean has mainly been produced in the Pampas region, including the provinces of Buenos Aires, La Pampa, Santa Fe, Entre Ríos and Córdoba. Until late 90:s rice and cotton destined for the Brazilian market were important crops in northern agriculture regions but due to reduced profitability rice and cotton areas have been replaced with soybean. USA, Brazil and Argentina together contribute to almost 80% of world soybean production and dominate the world exports of soybeans and soymeal.

Soybean is also considered to be among the most promising crops in Argentina for biofuel production (Mathews and Goldsztein 2008).

Historical developments

There has been a rapid growth in soybean production in Argentina (see the figure below). Direct seeding and no-till cropping systems have become the dominant production system (see Table 1 below). Farmers consider no-till cultivation as beneficial since it makes it possible to cultivate lower quality soils and generally results in improved yield stability. It also improves water use efficiency (lower soil evaporation and improved water infiltration capacity), reduces the erosion risk, and increases the soil C content (or slows soil C losses when croplands are established on land with high soil C content.

There has also been a very rapid increase in the use of GM soybean and Argentina today produces almost exclusively GM soybeans. In 2009, 91%, 99% and 71% of total soybean acreage were grown with GM glyphosate-tolerant cultivars in USA, Argentina, and Brazil, respectively (Meyer and Cederberg 2010). The high adoption rate was due to the easier and cheaper weed control enabling earlier seeding and no-tillage. However, glyphosate-resistant weed species associated with glyphosate-tolerant soybeans has become a concern. Reports indicate 30 000 infested sites on up to around 4.6 Mha in USA in 2010.The development in Brazil and Argentina is less analysed than in USA (see Section "Observed local environmental impacts" below).

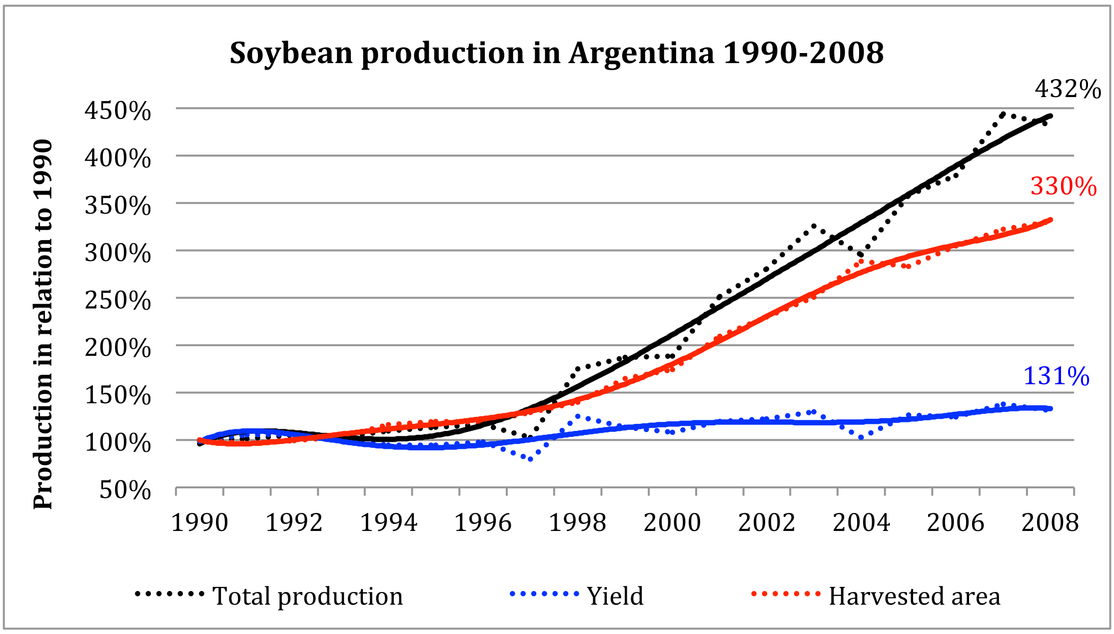


Figure 4: Change in soybean production, yields and harvested area in Argentina, 1990-2008

Land-use dynamics from future production increases

As noted, soy is traditionally cultivated in the Pampas region. Recent years, soybean production has been extended to less fertile areas in the northeast and -west of Argentina (Berkum *et al.* 2006) driving livestock production into less fertile lands (Dobson W.D. 2003). The transition from a traditional crop-livestock rotational model to a model entirely based on crops (started in the mid 1970s), shifted the agriculture frontier towards traditional cattle ranching areas and deforestation to make place for pasture. Under this land use regime, soybean expansion can be expected to take place on both pastureland and at the expense of forests. Further development of relevant legal frameworks, including both revision of existing regulation, new measures and strengthened enforcement, may counter this.

Assessments (e.g., Van Dam et al 2009) indicate a substantial potential for expanding cultivation for bioenergy without causing far reaching deforestation of food competition, but regional land-use planning may be required to ensure that expansion reflects a balance between various stakeholder groups, including those concerned about nature conservation. Further development of agriculture practices – including soil- and climate adapted crop rotations, and balanced increases in fertilization – may contribute to the sustainability of production. Biodiversity conservation strategies for the agricultural frontier areas may help protect natural vegetation.

Production system characteristics and local environmental impacts

Production system characteristics for soybean in Argentina are summarised in Table 8. As already noted, no-till farming dominates and almost all soybean producers in Argentina uses GM glyphosate-tolerant cultivars. Soybean is commonly rotated with other crops such as wheat, maize, rice, sorghum and sugarcane and Argentinian soybean cultivation employing no-till often include wheat and maize.

Table 8: Production system characteristics for soybean in Argentina

System component	Soybean
Large scale	80%
Small scale	20%
Mechanized farming system	
Manual farming system	
Tillage	18 %
Reduced and no tillage	72 %
Irrigated	
Rain fed	
Mono-cropping	
Multi-cropping	
Crop rotation	51%, especially rotation with wheat and in smaller part rotation with corn and sunflower
Mineral fertilizer used	soybean is a biological nitrogen fixer and no or little nitrogen is therefore needed to add
Chemical pesticides used	especially herbicides
GMO seeds for sowing	dominating seed for sowing, 98% of soy production) Modified for herbicide resistance
Land preparation with fire	
By-products (from harvesting)	

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Dros, 2004; Panichelli et al., 2009; Proforest, 2010; Tomei et al., 2010)

A recent LCA study (Panichelli et al., 2009) compared Argentinean soy biodiesel with soy biodiesel in Brazil and USA, rapeseed biodiesel in EU and Switzerland, and palm oil biodiesel in Malaysia. It was found that Argentinean soy biodiesel had the highest non-renewable energy use and global warming potential. It also had the highest aquatic ecotoxicity and human toxicity. A comparison with a fossil low-sulphur diesel option showed that the Argentinian soy biodiesel had higher impact when considering land use competition, terrestrial and aquatic ecotoxicity, human toxicity, eutrophication and acidification, and global warming potential. The fossil option had higher impact only for the category non-renewable energy use.

The most significant contributor to the environmental impact of Argentinian soy biodiesel varied depending on impact category. Deforestation for soybean cultivation, nitrate leaching during soybean cultivation, and pesticide use in feedstock production were among the major factors. Avoiding deforestation was emphasized as the main option for improving the environmental performances Argentinian soy biodiesel where the use of marginal and set-aside agricultural land was recommended an option for further consideration. Further implementation of crops' successions, soybean inoculation, reduced tillage and less toxic pesticides were other options pointed out as important for improving the environmental performance.

Related to the problem of glyphosate-resistant weeds, new GM crops that are resistant to more herbicides than only glyphosate can be expected (e.g., crops with genes that confer resistance to herbicides with other mode of actions than glyphosate, for example 2,4-D and dicamba). Multi-herbicide-tolerant GM soybeans are proposed as potentially inducing strong growth of herbicide use in U.S. soybean cultivation in the coming years and Argentina might experience a similar development. Since there has not been much development of new herbicides, a significant proportion of the projected increase will be of older, less environmentally friendly herbicides (Meyer and Cederberg 2010).

Observed local environmental impacts from soybean production in Argentina are summarised in Table 9. It should be noted that even though lacking information prevented linking soy cultivation with biodiversity losses, such links are likely given the link with deforestation.

Table 9: Observed local environmental impacts from soybean production in Argentina

Environmental impact	Soybean
Deforestation	(red)
Loss of agro-biodiversity	
Loss of biodiversity	
Air pollution	
Water pollution	(red)
GMO contamination	
Eutrophication	
Soil fertility decline	(red)
Erosion	

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Dros, 2004; Panichelli et al., 2009; Proforest, 2010; Tomei et al., 2010)

Local environmental impacts allocated to domestic biofuel production

The share of the total soybean area that was harvested for domestic biofuel production was 8.8% in 2008. However, the net area requirement is lower since soybean biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 2.9% of the total soybean area in 2008. Since soybean cultivation for domestic biofuels has the same characteristics as soybean cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total soybean area used for production of domestic biofuels (2.9%). It should be noted that soybeans for production of domestic biofuels in 2008 was cultivated on 1445 kha, which is a significant amount of land.

Local environmental impacts allocated to EU biofuel demands

The share of the total soybean area that was harvested for EU biofuel production was 3.3% in 2008. However, the net area requirement is lower since soybean biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 1.1% of the total soybean area in 2008. Since soybean cultivation for EU biofuels has the same characteristics as soybean cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total soybean area used for EU biofuel production (1.1%).

References

Dros, J.M., 2004. *Managing the Soy Boom: Two scenarios of soy production expansion in South America*. Amsterdam: A I D E nvironment, Commissioned by WWF.

Mathews, J. and Goldsztein, H., 2008. Capturing latecomer advantages in the adoption of biofuels: The case of Argentina. *Energy Policy*, 37(1), pp.326-337.

Meyer, D. and Cederberg, C., 2010. *Pesticide use and glyphosate- resistant weeds – a case study of Brazilian soybean production*. SIK report 809. Available at: http://www.sik.se/archive/pdf-filer-katalog/SR809.pdf Accessed on May 23, 2011.

Panichelli, L., Dauriat, A. and Gnansounou, E., 2009. Life cycle assessment of soybean-based biodiesel in Argentina for export, *International Journal of Life Cycle Assessment*, 14(2), pp.144–159.

Proforest, 2010. *Agricultural production models and methods for UK biofuels*. Oxford: Renewable Fuels Agency Research Programme. Available at: http://www.proforest.net/objects/publications/agricultural-production-models-and-methods-for-uk-biofuels Accessed on May 23, 2011.

Tomei, J., Semino, S., Paul, H., Joensen, L., Monti, M., and Jelsøe, E., 2010. Soy production and certification: the case of Argentinean soy-based biodiesel. *Mitigation and Adaptation Strategies for Global Change*, 15(4), pp.371–394.

Viglizzo, E. F., Frank, F. C., Carreño, L. V., Jobbágy, E. G., Pereyra, H., Clatt, J., Pincén, D. and Ricard, M. F., 2011. Ecological and environmental footprint of 50 years of agricultural expansion in Argentina. *Global Change Biology*, 17(2), pp.959–973.

Bolivia

Selected biofuel crops for Bolivia include sugarcane and soybean. As seen in Table 10, about 18% of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production and about 7% of the total area was used for production of fuel ethanol for the EU market. No domestic production of soybean biodiesel in 2008 was identified, although small amounts of biodiesel feedstock for the EU market.

Table 10: Area used for production of Bolivia's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	160	28	17.8%	11	6.8%
Soybean	786	-	-	1.2	0.2%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

As seen in Figure 5, pastures constitute the largest share of Bolivia's total agricultural area. Permanent crops are uncommon, making cultivated land dominated by annual crops. Even though a rather large share of the total sugarcane production can be associated with ethanol production, sugarcane plays a rather small role in Bolivia's agriculture.

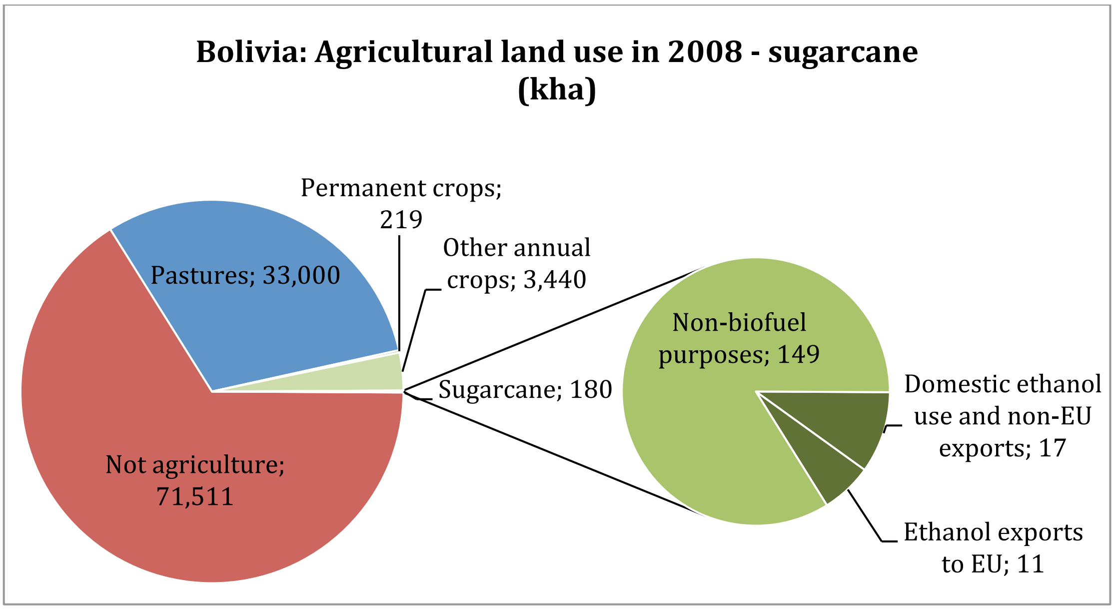


Figure 5: Agricultural land use in Bolivia in 2008, focused on sugarcane production

Historical developments

Between 1990 and 2008, sugarcane production in Bolivia increased with 81%. As seen in Figure 6, the production increase has been made possible entirely by an increased harvested area (+91%), while average yields in 2008 were lower than in 1990 (-6%).

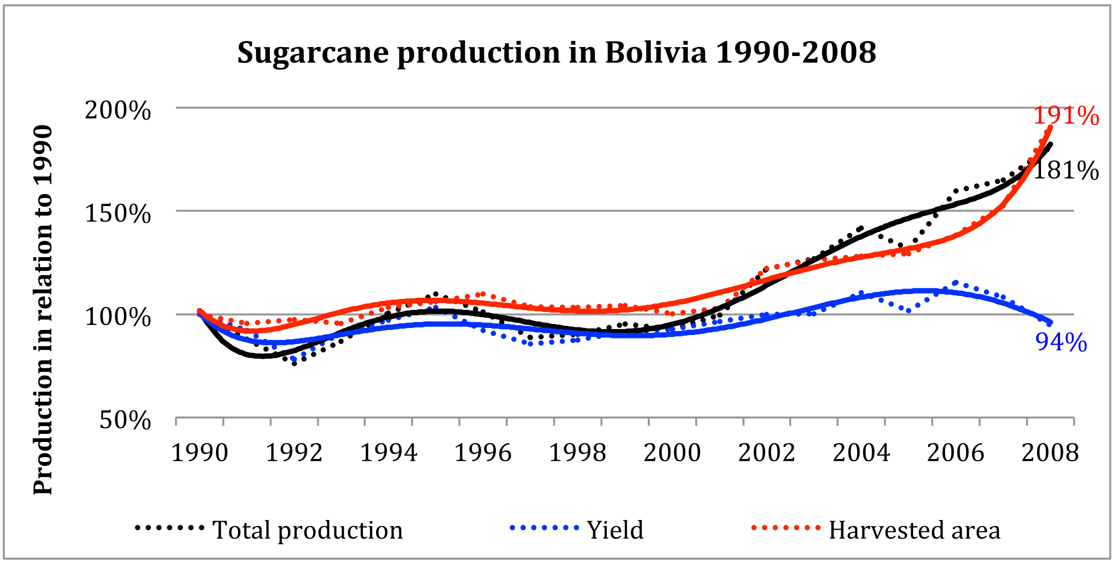


Figure 6: Change in sugarcane production, yields and harvested area in Bolivia, 1990-2008

Sugarcane cultivation started in the end of the 16th century in the department of Santa Cruz with local varieties, called *Listada* and *Cayaña*. Industrial sugarcane production started in Bolivia in 1941 as close to 3,000 hectares of sugarcane fields were established in the department of Santa Cruz. Currently, "almost all" of the sugarcane is produced in Santa Cruz, more specifically in nine municipalities: Andrés Ibáñez, La Guardia, El Tomo, Cotoca, Warnes, Portachuelo, Montero, Mineros, and General Saavedra. These municipalities are located in the eastern parts of Santa Cruz, close to the departmental capital Santa Cruz de la Sierra (Burgos Lino 2007; Mendoza 2010 in Boliviabella 2010)

Land-use dynamics from future production increases

As discussed in the soybean section, Santa Cruz, Beni, and smaller parts of La Paz, Tarija and Chuquisaca (i.e. the eastern and northern parts of Bolivia) have fewer environmental constraints (FAO 200-) and are thus most suitable for sugarcane cultivation than the other departments. It is likely that sugarcane would mainly expand close to the current main production areas, i.e. in the eastern parts of the Santa Cruz. Nevertheless, sugarcane and –mill establishments in other provinces of Santa Cruz as well as other departments suitable for sugarcane cultivation may also occur. For example, one 11-20 kha sugarcane project is currently being discussed in the northern parts of La Paz (Malky Harb and Ledezma Columba 2010).

Given the abundance of undeveloped land (see the soybean section), expansion of sugarcane is likely to be at the expense of natural vegetation. Depending on where the expansion would occur, it would cause conversion of deciduous or evergreen broadleaf forests or savannahs. Hackenberg (2011) supports this, reporting that expansion of sugarcane is unlikely to occur on existing cropland or pastures but most likely on natural vegetation, such as grasslands and woodlands (savannahs).

As for soybean, sugarcane yields are lower than the regional average (55% of the average in Latin America). This is due to poor management, bad seed quality and dependence on just one variety (*Norte Argentino*). There is therefore a potential to significantly increase production by improving agricultural practices and introducing other varieties. For this purpose, a project for introducing new varieties was initiated in 2004 by the Centre for Sugarcane Research and Technology Transfer (CITTCA) (Soruco et al. 2007). Hackenberg (2011) also stresses the need for irrigation.

Soybean

Soybean is Bolivia's primary commercial crop and the most important field crop in the country, constituting 52% of total cropland and 59% of total crop production. About 85% is processed and exported and about 15% is used domestically. Soybean products make up an estimated 19 percent of total Bolivian exports and are by far the largest agricultural export. (USDA 2005a; Dros 2004)

According to Bolivia's National Institute of Statistics (NIS), 99% of the soybean production is from the department of Santa Cruz, with small acreages also in Tarija and Chuquisaca. Soybeans can be cultivated year-round, although the summer production is the most important, constituting 70-75% of the total annual production. Summer soy is planted in November/December and harvested in March/April, while winter soy is sown in June/July and harvested in October/November. Soybean yields in Bolivia were about 58% of the regional average in 2008 (FAOSTAT), even though soybean is cultivated on fertile soils. This is mainly due to low inputs (e.g. fertilizers, pesticides), less advanced technologies and less developed crop varieties (USDA 2005a; USDA 2005b).

Historical developments

Between 1990 and 2008, soybean production in Bolivia increased with 441%. As seen in Figure 7, the production increase has been made possible by an increased harvested area (+448%), while yields have remained rather unchanged during the period.

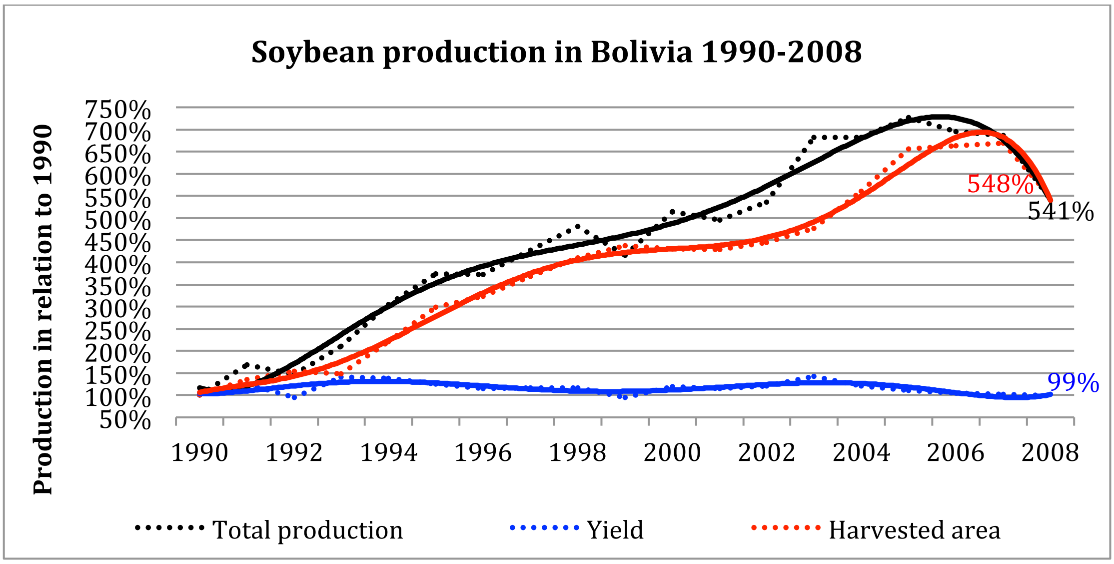


Figure 7: Change in soybean production, yields and harvested area in Bolivia, 1990-2008

The expansion of soybean cultivation in Bolivia has been significant over the past 20 years. This was primarily achieved by clearing native savannah/woodland and forestland in the department of Santa Cruz. FAO reports that soybean initially gained interest in Santa Cruz in the 1970's, when international soybean prices escalated. By the 1980's, soybean had an entrenched production base and became Bolivia's most important oilseed crop (USDA 2005a).

Land-use dynamics from future production increases

The departments of Potosi, Oruro, Cochabamba and most of La Paz, Tarija and Chuquisaca (i.e. the western parts of Bolivia) are unsuitable for soybean production due to environmental constraints (dry and/or cold areas, low soil suitability, erratic rainfall and cold stress risk, steep slopes and mountains, severe and very severe land degradation) (FAO 200-). Santa Cruz, Beni, Pando and smaller parts of La Paz, Tarija and Chuquisaca (i.e. the eastern and northern parts of Bolivia) have fewer such environmental constraints (FAO 200-) and are thus more suitable for soybean cultivation. As Pando is highly undeveloped and almost entirely covered by broadleaf forests, soybean expansion is less likely to happen there. This coincides well with where soybean and other commercial crops are typically being produced; the fertile eastern lowlands.

The eastern lowlands are generally comprised by vast areas of pasture, savannah (woodlands) and forest, which could provide opportunities for future expansion (USDA 2005b). Soybeans are mainly produced in the savannah region of Santa Cruz, which still holds large areas of undeveloped land. Soybean is also produced at the forest frontier in Santa Cruz, being a historically significant driver of deforestation (USDA 2005a, USDA 2005b, Müller et al. 2011). The most likely scenario in case of a future expansion of soybean production is that it expands on natural vegetation in the department of Santa Cruz, mainly on savannah woodlands but also on forestland. This is supported by Hackenberg (2011) who reports that expansion of soybean is unlikely to occur on existing cropland or pastures but most likely to occur on natural grasslands and woodlands.

Expansion may also occur in Beni and in the eastern parts of Chuquisaca and Tarija, although to a lesser extent. In Beni it would likely be at the expense of forests and in Chuquisaca and Tarija at the expense of savannahs.

As previously noted, average soybean yields in Bolivia were about 58% of the regional average in 2008 (FAOSTAT), even though soybean is cultivated on fertile soils. Therefore, there is a potential to significantly increase production by using more inputs and irrigation, and better agricultural practices and crop varieties (USDA 2005a; USDA 2005b; Hackenberg 2011).

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane and soybean in Bolivia are summarised in Table 11.

Table 11: Production system characteristics for sugarcane and soybean in Bolivia

System component	Sugarcane	Soybean
Large scale	65% >50 ha	30% >50 ha
Small scale	35% <50 ha	70% <50 ha
Mechanized farming system		Dominant
Manual farming system	Harvesting and loading on trucks are often performed manually	
Tillage		
Reduced and no tillage		
Irrigated		
Rain fed		
Mono-cropping		
Multi-cropping		
Crop rotation		
Mineral fertilizer used		
Chemical pesticides used		
GMO seeds for sowing		
Land preparation with fire		
By-products (from harvesting)		

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Altieri, 2009; Blanco-Canqui and Lal, 2010; Kaimowitz et al., 1999; Baas, 2011; Müller et al., 2011; Pacheco, 2006; Dros, 2004; Burgos Lino 2007)

Mechanized production of soybean has caused extensive deforestation in the Santa Cruz region during the last 30 years (Müller et al. 2011). Observed local environmental impacts from sugarcane and soybean production in Bolivia are presented in Table 12. It should be noted that even though lacking information prevented linking sugarcane cultivation with biodiversity losses, such links are likely given the link with deforestation.

Table 12: Observed local environmental impacts from sugarcane and jatropha production in Bolivia

Environmental impact	Sugarcane	Soybean
Deforestation	Red	Red
Loss of agro-biodiversity	White	White
Loss of biodiversity	White	Red
Air pollution	Red	Red
Water pollution	White	Red
GMO contamination	White	White
Eutrophication	White	White
Soil fertility decline	White	Red
Erosion	White	Red

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Altieri, 2009; Blanco-Canqui and Lal, 2010; Kaimowitz et al., 1999; Baas, 2011; Müller et al., 2011; Pacheco, 2006; Dros, 2004)

Local environmental impacts allocated to domestic biofuel production

The share of the total sugarcane area that was harvested for domestic biofuel production was 18.8% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (18.8%).

Since no production of domestic biofuels from soybean has been identified for 2008; no local environmental impacts from cultivation of soybean can be allocated to domestic biofuel production in Bolivia.

Local environmental impacts allocated to EU biofuel demands

The share of the total sugarcane area that was harvested for EU biofuel production was 6.8% in 2008. Since sugarcane cultivation for EU biofuel production has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total sugarcane area used for EU biofuel production (6.8%).

Since no feedstock for EU biofuels in 2008 has been traced to soybean produced in Bolivia; no local environmental impacts from cultivation of soybean in Bolivia can be allocated to EU biofuel demands.

References

Altieri, M. A., 2009. The Ecological Impacts of Large-Scale Agrofuel Monoculture Production Systems in the Americas. *Bulletin of Science, Technology & Society,* 29(3), pp.236-244.

Baas, L., 2011. Children on Bolivian Sugar Cane Plantations. In G. K. Lieten, ed. *Hazardous Child Labour in Latin America*. Springer. Ch 10.

Blanco-Canqui, H. and Lal, R., 2010. No-Till Farming. In *Principles of Soil Conservation and Management*. Springer. Ch 8.

Boliviabella, 2010. *Santa Cruz produces 64% of Bolivia's food*. Available at: http://www.boliviabella.com/santa-cruz-produces-64-of-bolivias-food.html Accessed on June 17, 2011

Burgos Lino, G., 2007. *Agroenergy: Myths and Impacts in Latin America. Chapter 8, Bolivia: sugarcane production in Santa Cruz.* Pastoral Land Commission, Network for Social Justice and Human Rights. Available at: http://www.social.org.br/cartilha%20agroenergia%20ingles.pdf Accessed on June 17, 2011.

FAO, 200-. *FAO country profile: Bolivia. Misc. maps*. Available at: http://www.fao.org/countryprofiles/ Accessed on June 16, 2011.

Hackenberg, N., 2011. *Expert consultation: Norbert Hackenberg, consultant for Winrock International for the EU Biofuel Baseline project*.

Kaimowitz, D., Thiele, G. and Pacheco, P., 1999. The Effects of Structural Adjustment on Deforestation and Forest Degradation in Lowland Bolivia. *World Development*, 27(3), pp.505-520.

Malky Harb, A., F., Ledezma Columba, J., C., 2010. *Financial and economic feasibility of sugar cane production in northern La Paz*. Latin American and Carribean Environmental Economics Program (LACEEP). Working Paper Series No. 2010-WP13. Available at: http://www.laceep.org/images/stories/working_papers/2010-wp13_malky.pdf Accessed on June 17, 2011.

Mendoza, L., 2010. *En Santa Cruz se produce el 64% de los alimentos de Bolivia.* Available at: http://eju.tv/2010/04/en-santa-cruz-se-produce-el-64-de-los-alimentos-de-bolivia/ Accessed on June 17, 2011

Müller, R., Müller, D., Schierhorn, F. and Gerold, G., 2011. Spatiotemporal modelling of the expansion of mechanized agriculture in the Bolivian lowland forests. *Applied Geography,* 31(2), pp.631-640.

Pacheco, P., 2006. Agricultural expansion and deforestation in lowland Bolivia: the import substitution versus the structural adjustment model. *Land Use Policy,* 23(3), pp.205-225.

Soruco, O., Antelo Aguilar, S., Abelardo Enríquez, E. P., 2007. *Revealing success. What happened in nine applied technology innovation projects (PITAs)? Chapter 1: Sweet, lasting success.* Global Plant Clinic, CABI, Egham, UK. Available at: http://www.jefferybentley.com/RevealingSuccessFIT22.pdf Accessed on June 17, 2011

Stagnari, F., Ramazzotti, S. and Pisante, M., 2010. Conservation Agriculture: A Different Approach for Crop Production Through Sustainable Soil and water Management: A Review. *Sustainable Agriculture Reviews*, 1, pp.55-83.

Timilsina, G. R., and Shestha, A., 2010. How much hope should we have for biofuels? *Energy*, 36(4), pp.2055-2069.

USDA, 2005a. *Commodity Assessment Report. Bolivia: Agricultural Overview*. USDA Foreign Agriculture Service: Production Estimates and Crop Assessment Division. Available at: http://www.fas.usda.gov/pecad/highlights/2005/10/bolivia_12oct2005/ Accessed on June 16, 2011.

USDA, 2005b. *GAIN report BL5001: Bolivia Oilseeds and Products. Annual Soybean Report 2005.* USDA Foreign Agricultural Service: Global Agricultural Information Network (GAIN). Available at: http://www.fas.usda.gov/gainfiles/200503/146119282.pdf Accessed on June 16, 2011.

Brazil

Selected biofuel crops for Brazil include sugarcane, soybean and oil palm. As seen in Table 13, more than half of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production but only a small share ended up on the EU market. About 10% of the soybean area in 2008 was used for biodiesel production, although co-products such as animal feed are likely to be produced along with the biodiesel and this reduces the land requirements for producing animal feed elsewhere (not necessarily close though). About 4% of the total soybean area was used for producing soybean as feedstock for biodiesel production targeting the EU market during the same year (mostly Brazilian-produced biodiesel was exported but also some soybean was exported as feedstock for domestic biodiesel production in EU). No data on domestic biodiesel from oil palm in 2008 has been found, although small amounts of palm oil as feedstock for EU biofuels have been traced to Brazil.

Table 13: Area used for production of Brazil's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	8,140	4,266	52.4%	91	1.1%
Soybean	21,057	2,090	9.9%	782	3.7%
Oil palm	66	No data	No data	0.2	0.3%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

As seen in Figure 8, pastures constitute the largest share of Brazil's total agricultural area and permanent crops are uncommon in relation to annual crops, which are dominating the cultivated land. Sugarcane cultivation constitutes more than 13% of the total land under annual/semi-annual crops making it an important crop in Brazil's agriculture, particularly in the state of Sao Paolo. Ethanol production is a main application for sugarcane, although not for the EU market.

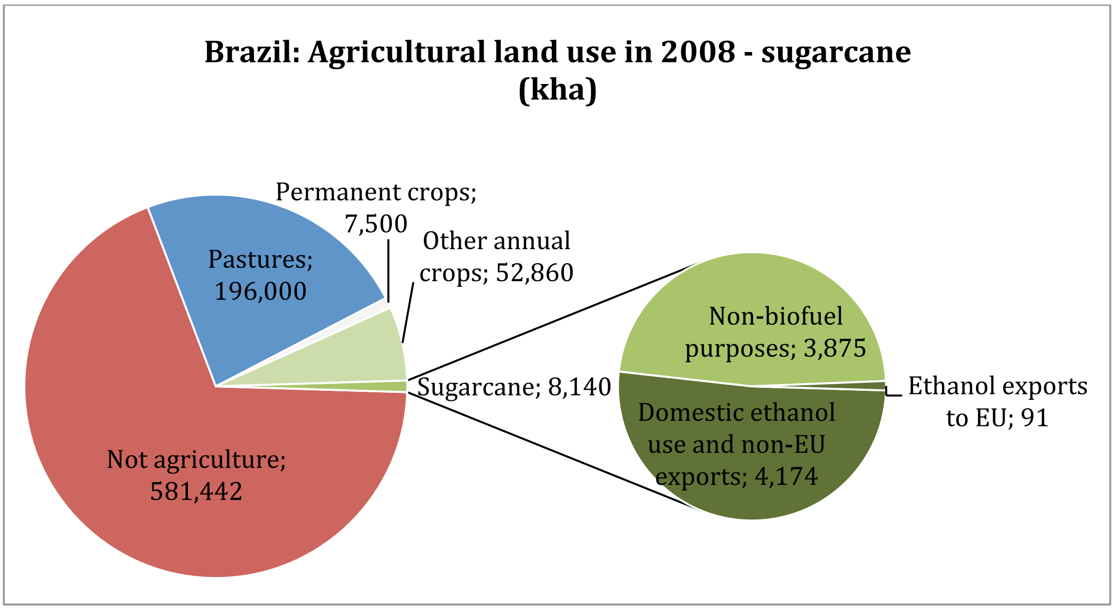


Figure 8: Agricultural land use in Brazil in 2008, focused on sugarcane production

Historical developments

There has been a steady increase in the area dedicated to Sugarcane production. During the period 2002-2009, the sugarcane area in the State of São Paulo increased from 2.7 to almost 5 million ha (SPIEA 2010a). There is also expansion outside this state. The midwest region is a new area of expansion for sugarcane cultivation, especially the State of Goiás, which experienced a 345% increase in the sugarcane production between the 1998/99 and 2008/09 harvests to contribute about 5% of the national production. The eastern part of Mato Grosso do Sul and the southeast of Minas Gerais – also in the Cerrado area – follow this trend of sugarcane expansion to new areas (UNICA 2011).

In 2008/09, about 564 million ton of sugarcane was harvested on 7.115 million ha of land, and about 60% of the sugarcane was used to produce ethanol. The north and northeast contributed about 10 % of total production; the remaining came from the central-southern part of Brazil, with about 60% from the State of São Paulo (IBGE 2009a). Sugarcane is the dominating crop in this state where it occupies an area almost twice as large as the aggregated area of the next five largest crops (IBGE 2009b).

About 27.2 billion liters of ethanol was produced in 2008. About 17% (4.6 billion liters) was exported and about 13% of the total ethanol exports (0.6 billion liters) were going to EU countries.

Recent decades' sugarcane expansion appears not to have contributed much to direct deforestation in the traditional agricultural region where most of the expansion took place (Sparovek et al. 2009). The amount of forests on farmland in this area is below the minimum stated in law and the situation did not change over the studied period. Sugarcane expansion resulted in a significant reduction of pastures and cattle heads. Modelling studies have illustrated how CO_2 emissions from direct and indirect land-use change associated with expansion of sugarcane can significantly reduce the GHG savings from displacing gasoline with sugarcane ethanol (see e.g. Fargione et al.

2008; Gibbs et al. 2008; Lapola et al. 2010). However, it has not been possible to quantify such emission with high confidence due to lack of empirical data and limited knowledge about underlying processes, especially when it comes to indirect emissions. Even so, results indicate that a possible migration of cattle production, caused by sugarcane expansion on pastures, reached further than to the municipalities surrounding the municipalities that experienced significant expansion of sugarcane (Sparovek et al. 2009).

Occurring at much smaller rates, expansion of sugarcane in regions such as the Amazon and the Northeast region was related to direct deforestation and competition with food crops (Sparovek et al. 2009). These regions are not expected to experience substantial increases of sugarcane in the near future, but mitigating measures are warranted.

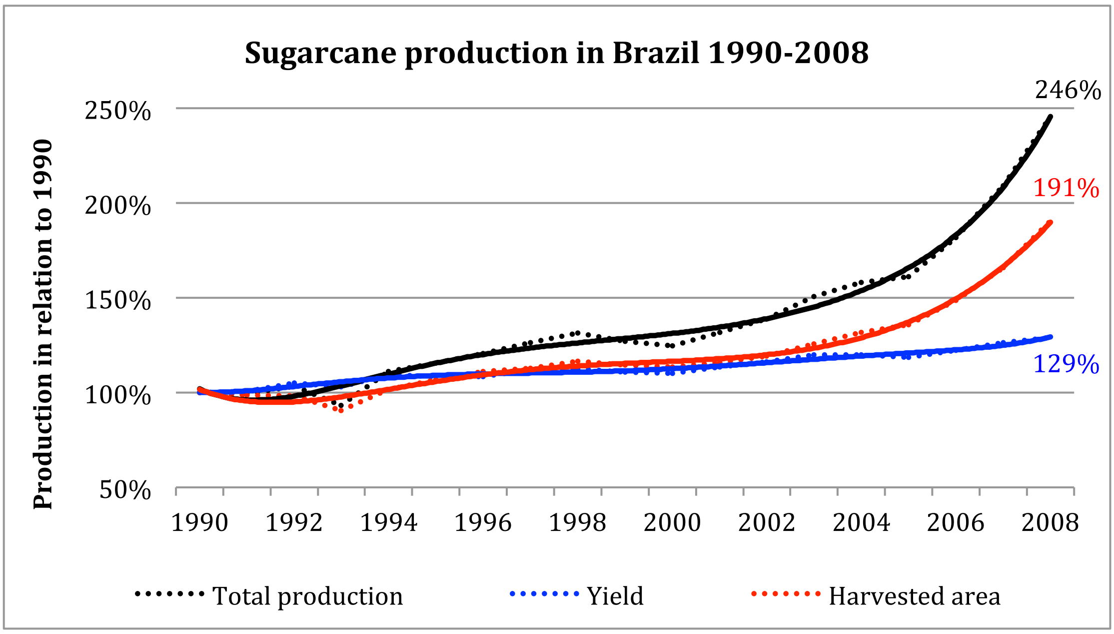


Figure 9: Change in sugarcane production, yields and harvested area in Brazil, 1990-2008

Land-use dynamics from future production increases

It has been projected that the sugarcane area will increase further and both increasing domestic demand and increasing import demand are expected to drive this projected increase. Presently (2011) the Brazilian ethanol exports to EU is down to a low level and to a large extent displaced by subsidised corn ethanol that has become in surplus in the U.S due to the 2008 financial crisis. The financial crisis in 2008 also caught the Brazilian sugarcane sector with a high debt situation due to the high investments in the construction of new mills and expansion of the existing ones. The mills could not find money to run the plants during the crushing season and had to sell the stocks of ethanol and sugar at very low prices, making things even worse. Due to the shortage of money the mills had to reduce the fertilizer and herbicide applications as well as the renewal of older cane fields, which will lead to lower yields for two or three subsequent crops.

Investors from outside the sector and those in better financial shape reduced the speed of construction of new mills and waited to see if they could get a better deal buying plants from groups in financial trouble. This also reduced the speed of construction of greenfield facilities.

Contributing to that Brazilian ethanol exports are presently low, a government policy – intended to help the auto industry overcome the crisis in good shape – to facilitate credit to the car buyers has resulted in a large growth of the flex-fuel vehicle (FFV) fleet during the past two years. This has in turn resulted in rapidly increasing domestic ethanol demand since around 70% of FFVs run on ethanol (this percentage varies depending on the relative prices of ethanol/gasoline). Recent years' weather has also played a role. Too much rain in the second half of 2009 reduced the cane sugar content and shortened the harvesting period; less cane was crushed and this cane contained less sugar than usual. 2010 was drier than the average and that has reduced the expectation of cane yields for the 2011 season. The international sugar prices have also been very high, mainly due to bad cane performance in India.

Nevertheless, the longer-term trend is towards increasing ethanol production and reduced production costs of sugarcane ethanol. The land use consequences of future expansion will depend on several factors, including: (i) the outcome of the present revision of the Forest Act, which is the most important legal framework for regulating conservation and restoration on private land (see also separate section about the Brazilian Forest Act); (ii) development of international mechanisms such as REDD and various certification schemes, sustainability standards and other systems influencing land use; and (iii) whether Brazil become successful in developing alternative expansion strategies for its agriculture, where especially important is to stimulate productivity improvements in meat/diary production to make room for cropland expansion that does not require the conversion of forests and other natural ecosystems.

The Brazilian sugarcane agro-ecological zoning (ZAE-Cana project) that was recently established to guide the sugarcane expansion – includes several components:

- The identification of areas without any environmental constraints that are already degraded or under human use that have potential for sugarcane cultivation.
- The exclusion of the biomes of Amazon, Pantanal and Upper Paraguay River Basin for sugarcane expansion.
- The indication of degraded land or pasture areas as preferable areas for sugarcane expansion, minimizing any competition with food production.

Specific areas were also excluded from the agro-ecological zoning for sugarcane: protected areas, indigenous reserves and areas with high conservation value for biodiversity.

It remains to see whether the agro-ecological zoning approach become successful in mitigating negative outcomes of the future sugarcane expansion. The version of the zoning approach that was approved by the government (Decreto 6961/09, which is not a law) does not include any kind of clear prohibition of sugarcane expansion. The zoning report was approved as a general guideline that could be considered in future public credit concessions. Assessments of the compliance of Brazilian agriculture with the existing legislation show a large deficit in protection of natural vegetation on private farmland (Sparovek et al. 2010). Again, the outcome of the present revision of the Forest Act will critically influence the future growth of Brazilian agriculture.

Soybean

As already described, pastures constitute the largest share of Brazil's total agricultural area and permanent crops are uncommon in relation to annual crops, which are dominating the cultivated land. Soybean cultivation constituted about 35% of the total land under annual crops in 2008, making it a very important crop in Brazil's agriculture. As seen in Figure 10, biodiesel production is a rather important application for soybean, although no biodiesel was traded to the EU in 2008. However, significant amounts of land can be associated with exports of feedstock for EU biofuels. As already noted, co-products such as animal feed are likely to be produced together with the biodiesel.

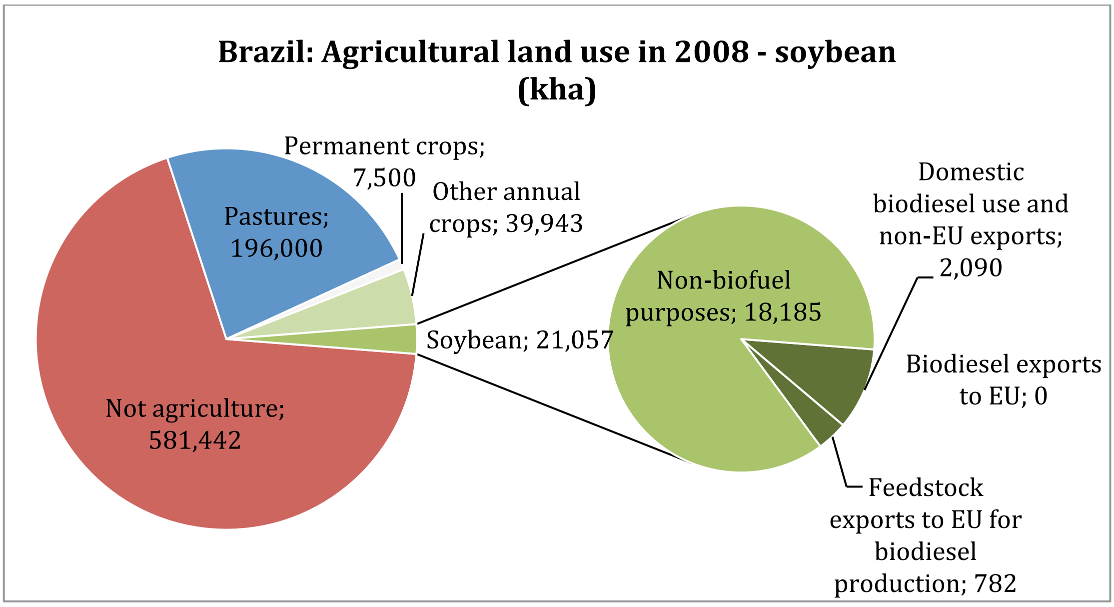


Figure 10: Agricultural land use in Brazil in 2008, focused on soybean production

Historical developments

Soybean plantations occupy some 35% of Brazil's cultivated land and it is the most important crop in terms of harvested area (FAOstat 2011). Agronomic advances have made it possible to cultivate the soils in the Cerrado biome and this has – together with infrastructure development efforts – contributed to that a significant part of the Cerrado is now converted into agriculture land. Increasing soy demand has been one important driver behind this expansion.

The cultivation of soy as biofuel feedstock has increased as a consequence of national biodiesel programs. This program has a significant social component but also environment and fuel security considerations provide rationale for the program. There is a debate over the extent to which deforestation is a result of the soy expansion (e.g., Fearnside 2005). Some studies report that soy can be a significant cause of deforestation (Morton *et al* 2006), but it appears that recent evidence point to that deforestation is primarily driven by the expansion of cattle ranching, and that soybean is expanding into land previously under pasture, causing little new deforestation (Mueller 2003, Brandao *et al* 2005, Brown *et al* 2005, Greenpeace-Brazil 2009).

However, there are indications that there can exist in some places an indirect link between soybean expansion and deforestation; in the State of Mato Grosso, an increase in soybeans occurred in regions previously used for pasture, which may have displaced pastures further north into the forested areas, causing indirect deforestation there (Barona et al. 2010).

As in Argentina and USA (the other two major soy producers) GM soybean cultivation dominates and – as in Argentina – mostly no-till cultivation is employed. The problems associated glyphosate-resistant weed species associated with glyphosate-tolerant soybeans will likely lead to increased occurrence of multi-herbicide-tolerant GM soybeans and increased use of older, less environmentally friendly herbicides (Meyer & Cederberg 2010).

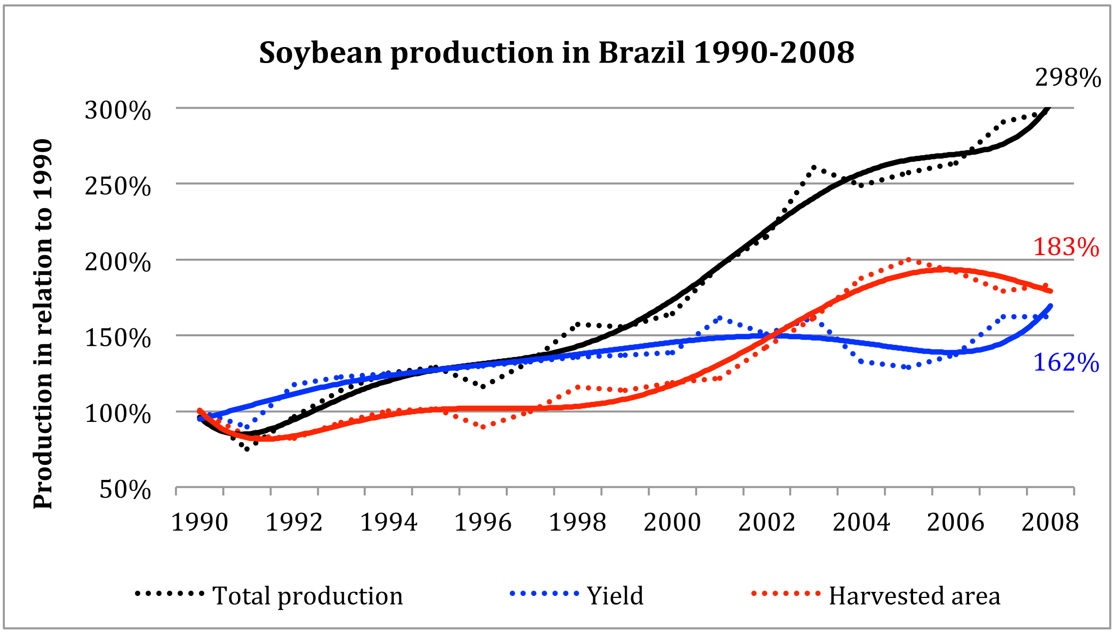


Figure 11: Change in soybean production, yields and harvested area in Brazil, 1990-2008

Land-use dynamics from future production increases

As for sugarcane, future expansion of soy will depend on (i) the outcome of the present revision of the Forest Act; (ii) development of international mechanisms such as REDD and various certification schemes and sustainability standards; and (iii) the productivity development in agriculture (notably cattle production) since this determines the agriculture expansion pressure at a given level of demand growth.

More research is needed to improve the understanding of the indirect effects of possible future soybean expansion. Besides that soybean expansion on pastures can induce pasture expansion elsewhere, there may exist other indirect links. For example, Fearnside (2005) suggests that soybean establishment induce infrastructure improvements, which in turn stimulates crop expansion. Nepstad *et al* (2006) report that growth of the soy industry has driven up land prices in the Amazon, allowing cattle ranchers to sell their land at high capital gains and purchase new land further north where pasture expansion leads to deforestation.

Oil Palm

Historical developments

Brazil currently has about 70,000 hectares of oil palm plantations, i.e., a relatively small area compared to other agricultural crops. Brazil is producing both for the domestic and international markets. Most of Brazil's oil palm plantations are located in the state of Para, out of which the company Agropalma accounts for 80%. Deforestation occurred in the 1980's, in the initial phase of establishing Agropalma's oil palm plantations. Currently it is mandatory for new plantations to be limited to grasslands and other degraded land, or the company will loose its environmental permit.

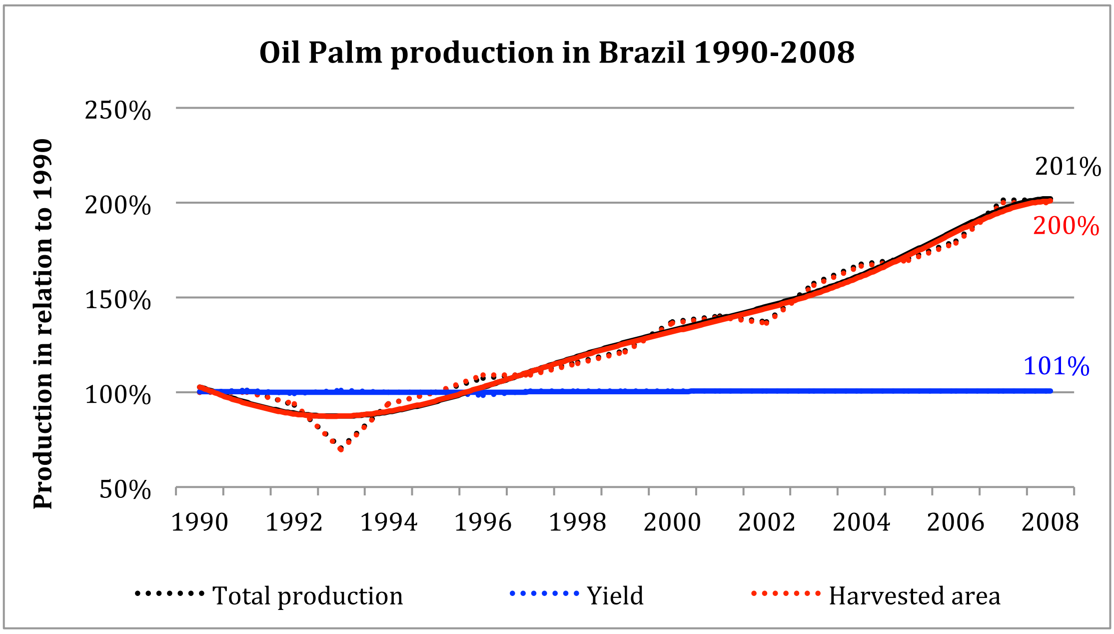


Figure 12: Change in oil palm production, yields and harvested area in Brazil, 1990-2008

Land-use dynamics from future production increases

Oil palm is expected to increase substantially in Brazil. In the long run, the aim is to reach one million hectares of oil palm. Brazil is producing both for the domestic and international markets. In 2008, Brazil signed a deal with Malaysia's Land Development Authority FELDA to establish 100,000 hectares (250,000 acres) of oil palm plantations on forestland in the state of Amazonas.

In May 2010, the Brazilian government launched The Program for the Sustainable Production of Palm Oil, which is designed to stimulate utilization of degraded lands and prohibit the expansion of production in forest areas. A component of the program is the proposed bill outlining new agro-ecological zoning rules for palm oil, coordinated by the Brazilian Agricultural Research Corporation (Embrapa). According to these zoning rules, the cultivation of palm oil will be restricted to land that is already occupied by humans, with an emphasis on degraded or low productivity areas. Removal of native vegetation for palm production is strictly forbidden. It is also forbidden to use protected areas such as national parks, indigenous areas and conservation units. Given these restrictions, the total area suitable for the production of palm oil amounts to about 31.8 million hectares.

There is concern that the plan for large-scale oil palm plantations on degraded land in Amazonas will effectively reduce the amount of forest/trees that landowners are required to keep on their property from 80% coverage to 50% (see also the separate section on the Brazilian Forest Act).

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, soybean and oil palm in Brazil are summarised in Table 14.

Table 14: Production system characteristics for sugarcane, soybean and oil palm in Brazil

System component	Sugarcane	Soybean	Oil Palm
Large scale	73%	Dominating production system	Dominant
Small scale	27% (less than 150 ha)	15-20% of production, partly mechanised partly manual production systems	3-4 %, "Social Fuel Seal" provides tax incentives to involve smallholders
Mechanized farming system			Land preparation
Manual farming system	Planting, agrochemical application or harvesting can be manual		Harvesting
Tillage	Dominant	50%	
Reduced and no tillage	Increasingly used	50%	Perennial crop
Irrigated	Very limited scale	Very limited scale	
Rain fed			
Mono-cropping			Dominant
Multi-cropping			(e.g. with maize and cassawa)
Crop rotation	Horticulture crops, legume crops and cereals may be grown between the sugarcane cycles of 5-8 years	E.g. corn, millet, sorghum, or cotton	Perennial crop
Mineral fertilizer used		Soybean is a nitrogen fixer. Therefore, no or little nitrogen is needed to add	
Chemical pesticides used		Particularly herbicides	
GMO seeds for sowing	Varieties under development, planned to be available commercially 2015		
Land preparation with fire	Pre-harvest burning when manual harvest is employed		
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field		

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information

Sources: (Dros, 2004; FAO, 2010; Flaskerud, 2003; Goldemberg et al., 2008; Martinelli and Filoso, 2008; Ortega et al., 2004; Proforest, 2010; Vermeulen, 2006)

Observed local environmental impacts from sugarcane, soybean and oil palm production in Brazil are summarised in Table 15.

Table 15: Observed local environmental impacts from sugarcane, soybean and oil palm production in Brazil

Environmental impact	Sugarcane	Soybean	Oil Palm
Deforestation	Red	Red	Red
Loss of agro-biodiversity			
Loss of biodiversity	Red	Red	Red
Air pollution	Red		
Water pollution	Red	Red	
GMO contamination	Green		
Eutrophication	Red		
Soil fertility decline		Red	
Erosion	Red	Red: Especially when conventional tillage is practiced	

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Dros, 2004; FAO, 2010; Flaskerud, 2003; Goldemberg et al., 2008; Martinelli and Filoso, 2008; Ortega et al., 2004; Proforest, 2010; Vermeulen, 2006)

Local environmental impacts allocated to domestic biofuel production

The share of the total sugarcane area that was harvested for domestic biofuel production was 52.4% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (52.4%). It should be noted that sugarcane for production of domestic biofuels in 2008 was cultivated on 4266 kha, which is a significant amount of land.

The share of the total soybean area that was harvested for domestic biofuel production was 9.9% in 2008. However, the net area requirement is lower since soybean biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 3.3% of the total soybean area in 2008. Since soybean cultivation for domestic biofuels has the same characteristics as soybean cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total soybean area used for production of domestic biofuels (3.3%). It should be noted that soybeans for production of domestic biofuels in 2008 was cultivated on 1445 kha, which is a significant amount of land. It should be noted that soybean for production of domestic biofuels in 2008 was cultivated on 2090 kha, which is a significant amount of land.

Since no production of domestic biofuels from oil palm has been identified for 2008; no local environmental impacts from cultivation of oil palm can be allocated to domestic biofuel production in Brazil.

Local environmental impacts allocated to EU biofuel demands

The share of the total sugarcane area that was harvested for EU biofuel production was 1.1% in 2008. Since sugarcane cultivation for EU biofuel production has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total sugarcane area used for EU biofuel production (1.1%).

The share of the total soybean area that was harvested for EU biofuel production was 3.7% in 2008. However, the net area requirement is lower since soybean biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 1.2% of the total soybean area in 2008. Since soybean cultivation for EU biofuels has the same characteristics as soybean cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total soybean area used for EU biofuel production (1.2%). It should be noted that soybeans used for EU biofuel production in 2008 was cultivated on 1137 kha, which is a significant amount of land.

Since only very small fractions (0.3%) of the total oil palm area in Brazil was used for production of feedstock for EU biofuels in 2008; no local environmental impacts from cultivation of oil palm in Brazil can be allocated to EU biofuel demands.

References

Barona, E., Ramankutty, N., Hyman, G. and Coomes, O., 2010. The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environmental Research Letters*, 5(2), pp.024002

Brandao, A., Castro de Rezende, G. and Da Costa Marques, R., 2005. *Agricultural Growth in the Period 1999–2004, Outburst in Soybeans Area and Environmental Impacts in Brazil*. IPEA Discussion Paper No. 1062. Available at: http://ssrn.com/abstract=660442 Accessed on May 30, 2011.

Brown, J., Jepson W. and Price, K., 2004. Expansion of mechanized agriculture and land-cover change in Southern Rondônia, Brazil. *Journal of Latin American Geography*, 3(1), pp.96–102.

FAOstat, 2011. Available at http://faostat.fao.org/ Accessed on May 14, 2011.

Fearnside, P.M., 2005. Deforestation in Brazilian Amazonia: history, rates and consequences. *Conservation Biology*, 19(3), pp.680-688.

Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P., 2008. Land clearing and the biofuel carbon debt. *Science*, 319(5867), pp.1235–1238.

Gibbs, H.K., Johnston, M., Foley, J., Holloway, T., Monfreda, C., Ramankutty, N. and Zaks, D., 2008. Carbon payback times for crop-based biofuel expansion in the tropics: The effects of changing yield and technology. *Environmental Research Letters*, 3(3):034001

Greenpeace-Brazil, 2009. *Amazon Cattle Footprint. Mato Grosso: State of Destruction*. Available at www.greenpeace.org/international/press/reports/amazon-cattle-footprint-mato Accessed on May 30, 2011.

IBGE, 2009a. *Municipal Agricultural Production – 2008*. Available at: http://www.ibge.gov.br/english/presidencia/noticias/noticia_impressao.php?id_noticia=1479 Accessed on September 30, 2010.

IBGE, 2009b. Available at: http://www.sidra.ibge.gov.br Accessed on April 11, 2011.

Lapola, D.M., Schaldach, R., Alcamo, J., Bondeau, A., Koch, J., Koelking, C. and Priess, J.A., 2010. Indirect land-use changes can overcome carbon savings from biofuels in Brazil. *Proceedings of the National Academy of Sciences of the USA*, 107(8), pp.3388-3393.

Meyer, D. and Cederberg, C. (2010) *Pesticide use and glyphosate- resistant weeds – a case study of Brazilian soybean production*. SIK report 809, 2010

Morton, D., DeFries, R., Shimabukuro, Y., Anderson, L., Arai, E., Espiritu-Santo, F., Freitas, R. and Morisette J., 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proc. Natl Acad. Sci. USA*, 103(39), pp.14637–14641.

Mueller, C., 2003. *Expansion and Modernization of Agriculture in the Cerrado – The Case of Soybeans in Brazil's Center-West*. Available at: http://e-groups.unb.br/face/eco/cpe/TD/306nov2003CMueller.pdf Accessed on May 30, 2011.

Nepstad, D., Stickler, C. and Almeida O., 2006. Globalization of the Amazon soy and beef industries: opportunities for conservation. *Conservation Biology*, 20(6) pp.1595–1603.

Sparovek, G., Barretto, A., Berndes, G., Martins, S. and Maule, R., 2009. Environmental, land-use and economic implications of Brazilian sugarcane expansion 1996–2006. *Mitigation and Adaptation Strategies for Global Change,* 14(3), pp.285–298.

Sparovek, G., Berndes, G., Klug, I. and Barretto, A., 2010. Brazilian agriculture and environmental legislation: status and future challenges. *Environmental Science and Technology*, 44(16), pp.6046–6053.

SPIEA, 2010a. Available at: http://www.iea.sp.gov.br/out/banco/menu.php Accessed on September 2, 2010.

SPIEA, 2010b. Available at: http://www.iea.sp.gov.br/out/verTexto.php?codTexto=7448 Accessed on September 2, 2010.

UNICA, 2011. Available at: http://english.unica.com.br/dadosCotacao/estatistica/ Accessed on April 12, 2011.

Personal communication on future outlook:

Manoel Regis Lima Verde Leal, CTBE - Bioethanol Technology Center,

Arnaldo Walter, Faculdade de Engenharia Mecanica – UNICAMP, Campinas University, Brazil

Guatemala

Selected biofuel crops for Guatemala include sugarcane and jatropha. As seen in Table 10, about 9% of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production and about 1% of the total area was used for production of fuel ethanol for the EU market. Jatropha was cultivated on small amounts of land in 2008, although mainly for biodiesel purposes.

Table 16: Area used for production of Guatemala's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	287	26	9.1%	3	1.1%
Jatropha	0.7 [1)]	0.7	100%	-	-

1) Not including wild jatropha or jatropha used for fencing

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

As seen in Figure 13, cultivated land constitutes a slightly larger share of the total agricultural land than pastures. Permanent crops, such as banana and oil palm, are common, although slightly more land is used for the cultivation of annual crops. Sugarcane cultivation constitutes about 22% of the area under annual crops, making it an important crop in Guatemala's agriculture and ethanol production is a rather important application.

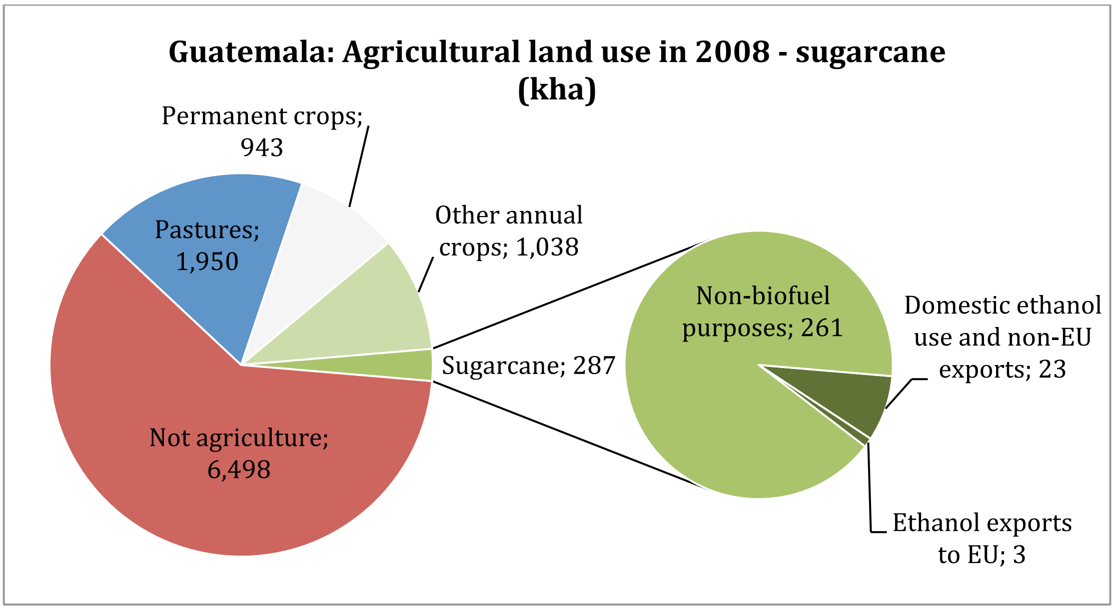


Figure 13: Agricultural land use in Guatemala in 2008, focused on sugarcane production

Historical developments

Between 1990 and 2008, sugarcane production in Guatemala increased with 165%. As seen in Figure 14, the increase has been made possible by an increased harvested area (+156%), while yields have remained rather unchanged during the period. During this period, sugarcane has taken up an increasingly larger share of the total area under cultivation in Guatemala, from 8.7% in 1990 to 21.6% in 2008 (FAOSTAT).

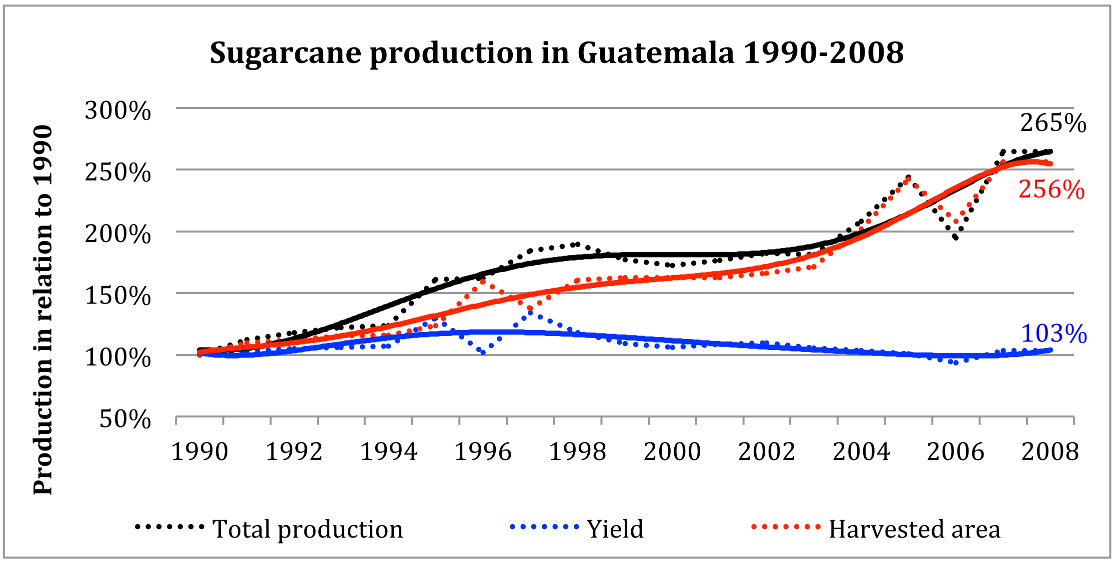


Figure 14: Change in sugarcane production, yields and harvested area in Guatemala, 1990-2008

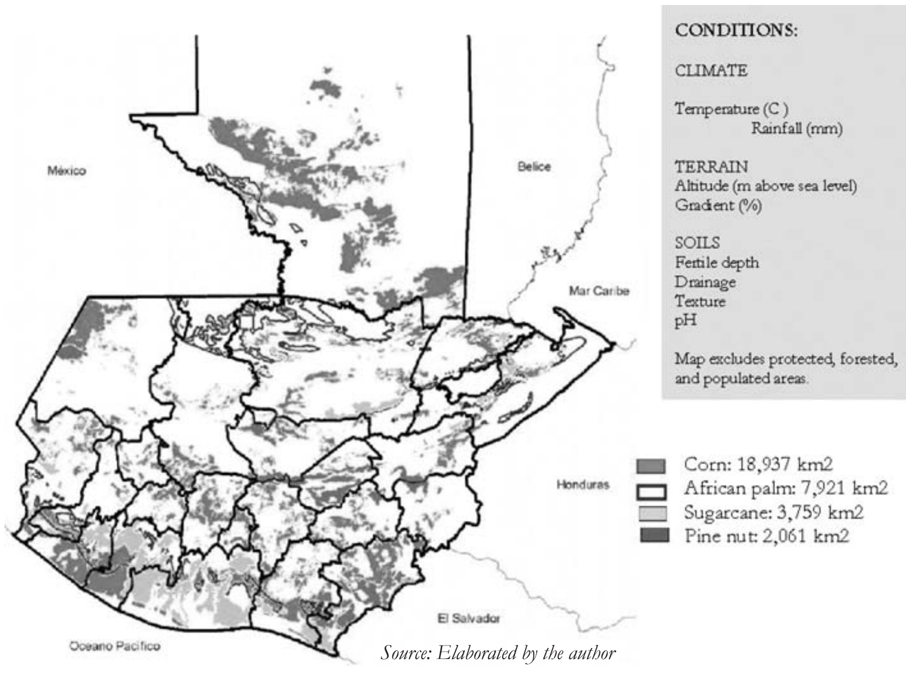
The main sugarcane area is along the Pacific coast, in the southwestern part of the country. Besides one sugar mill that recently moved to the Atlantic lowlands on the eastern coast, 13 of the 14 sugar mills in the country are located near Puerto Quetzal at the Pacific coast (USDA 2009). The Global Mechanism (2009) reports that large forest areas have been converted to pastures and cultivation of crops, such as oil palm and sugar cane. However, no reports have been found on large-scale conversion of natural vegetation specifically due to sugarcane expansion. Instead, expansion of sugarcane since 1990 seems to have occurred mainly at the expense of pastures and other cash crops, such as cotton, soybean and maize (Fradejas 2009; Suarez 1996).

Guatemala is experiencing fast deforestation. 36.3% or about 3.94 million hectares of Guatemala is forested. Of this, 49.7 per cent is classified as primary forest, the most biodiverse form of forest. Between 1990 and 2005, Guatemala lost 17.1 per cent of its forest cover, or around 810,000 hectares (Mongabay 2010). While there is no general agreement on the causes of forest cover change, Assunção et al. (2007) reports that the conflict and competition that exist between the agriculture and forestry sectors and agricultural versus forestland use seems to be the main reason. Therefore, even though no evidence has been found for sugarcane expansion being a main cause of deforestation in Guatemala, deforestation is likely to have occurred as a direct or indirect effect from recent sugarcane expansion.

Land-use dynamics from future production increases

Little information has been found on potential effects from a sugarcane expansion in Guatemala. Since existing sugar mills are concentrated near Puerto Quetzal, expansion of sugarcane along the Pacific coast is likely to be preferable for the sugar and ethanol industry. Since much of the vegetation in this area has already been cleared for agriculture, such an expansion would be at the expense of competing crops, such as maize, beans, banana and cotton. Naturally, price developments for the competing crops determine which crops that would be most profitable to replace. This is supported by Duarte (2011) who reports that sugarcane is most likely to expand on existing cropland, and likely replacing cash crops such as maize and beans. He reports that sugarcane production in Guatemala is "extremely efficient" and that farmers can expect the biggest revenues from replacing their current crops with sugarcane. FAOSTAT data supports that sugarcane production in Guatemala is very efficient, with average sugarcane yields reported to be even higher than in Brazil. Whether replaced crops would be displaced to other areas has not been possible to determine.

Fradejas (2009) developed a suitability map for maize, sugarcane, oil palm and jatropha in Guatemala (Figure 15). Areas close to the Pacific coast are considered most suitable for sugarcane, supporting that sugarcane expansion is likely to occur in this area. Smaller areas in the central parts and close to the eastern coast are also considered suitable, as well as some small areas in the northern parts. Since most of the remaining forests in Guatemala are found in the northern and, to some extent, in the far eastern parts, sugarcane expansion in most areas considered suitable by Fradejas (2009) are not likely to be at the (direct) expense of natural vegetation. This is supported by Duarte (2011), who reports that sugarcane is unlikely to expand on natural vegetation. This since forests in most sugarcane areas (Pacific and Atlantic lowlands) have been cleared since many years to enable land for agriculture and pastures.



Source: (Fradejas 2009)

Figure 15: Areas suitable for maize, sugarcane, oil palm, and pine nut (Jatropha) in Guatemala

Sugarcane expansion on pastures is possible mainly in the Pacific or Atlantic lowlands or between the cultivated lowlands and the highlands. Highlands are typically unsuitable for sugarcane cultivation. Duarte (2011) reports that expansion on pastures is very likely to occur. As for replacement of crops, it has not been possible to determine whether replaced pastures would be displaced to other areas or not.

Jatropha

Jatropha is native to Guatemala and grows in many regions, where it has traditionally been used for fencing. Guatemala was among the first countries to cultivate Jatropha for commercial purposes, and is therefore more advanced in these activities than neighbouring countries. The first commercial attempts started in 2002 and have increased steadily, although the production scale is still small. Combined processing capacity of biodiesel from jatropha and recycled vegetables in 2009 was estimated at 15000 litres per day. In 2008, jatropha projects occupied 650 ha and supplied feedstock to five biodiesel plants with a total capacity of 7500 litres per day (USDA 2009; GEXI 2008).

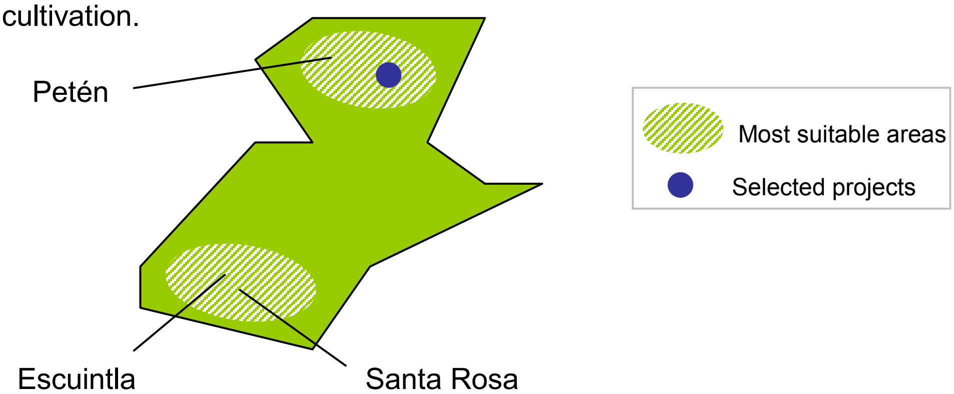
Land-use dynamics from future production increases

The Ministry of Agriculture (MAGA) has identified 206 100 hectares of marginal and semi-marginal land that could be used for the cultivation of Jatropha. Primarily, MAGA is interested in promoting jatropha production in the northern region of the Peten, which is highly undeveloped (USDA 2009; Fradejas 2009).

As illustrated in Figure 16, jatropha production is possible primarily near the Pacific coast, but also in Petén in northern Guatemala. Due to competition with sugarcane plantations near the Pacific coast most of the current jatropha plantations have been placed in the north (GEXI 2008). It is unlikely that jatropha in a near future can be sufficiently profitable to compete with other crops in areas near the Pacific coast. Therefore, expansion in the northern parts is more likely to occur.

Regional Distribution

Climatic conditions in Guatemala make it possible to plant Jatropha in many regions. The most favourable climatic and agronomic conditions are reported to be on the South Coast. However, due to high land prices and competitive sugar cane plantations, most Jatropha plantations are located in the north and north-east, which are also suitable for cultivation.



Source: GEXI 2008

Figure 16: Regional distribution of suitable land for jatropha cultivation in Guatemala

Since jatropha production is promoted in undeveloped parts in northern Guatemala, it is unlikely to compete with existing cropland in a near future. Instead deforested and degraded marginal land is likely to be targeted. This is supported by Duarte (2011) who reports that jatropha expansion on pastures is very likely and expansion on existing cropland is unlikely. Since a criterion for assessing the suitability of land was to avoid deforestation, expansion on natural vegetation can be regarded as less likely. This is supported by Duarte (2011) who reports that this is an unlikely scenario.

However, since the northern parts of Guatemala contain most of the remaining natural forests, potential displacement of other activities onto natural vegetation (forestland) might occur. Which types of knock-on effects that could occur and the risk of them happening is very difficult to assess. It should be considered though that food production would have to increase as population increases. Therefore, as jatropha is expanding on land suitable for food crop cultivation (Fradejas 2009), new land might have to be claimed in case of a large-scale jatropha expansion, in order to secure the food supply.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane and jatropha in Guatemala are summarised in Table 17.

Table 17: Production system characteristics for sugarcane and jatropha in Guatemala

System component	Sugarcane	Jatropha
Large scale		
Small scale		
Mechanized farming system		
Manual farming system		
Tillage		
Reduced and no tillage		Perennial crop
Irrigated	60%	
Rain fed	40%	
Mono-cropping		
Multi-cropping		
Crop rotation		Perennial crop
Mineral fertilizer used		
Chemical pesticides used		
GMO seeds for sowing		
Land preparation with fire		
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field	

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (FAO/PISCES, 2009; Fradejas, 2009; Morales, 2008; Murillo et al., 2003; WRM, 2010).

Observed local environmental impacts from sugarcane and jatropha production in Guatemala are summarised in Table 18.

Table 18: Observed local environmental impacts from sugarcane and jatropha production in Guatemala

Environmental impact	Sugarcane	Jatropha
Deforestation		
Loss of agro-biodiversity		
Loss of biodiversity		
Air pollution		
Water pollution		
GMO contamination		
Eutrophication		
Soil fertility decline		
Erosion		

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (FAO/PISCES, 2009; Fradejas, 2009; Morales, 2008; Murillo et al., 2003; WRM, 2010).

Local environmental impacts allocated to domestic biofuel production

The share of the total sugarcane area that was harvested for domestic biofuel production was 9.1% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (9.1%).

Regarding jatropha, the entire production in 2008 was used for biodiesel production in some sense. Therefore, all local environmental impacts from jatropha production can be allocated to domestic biodiesel production.

Local environmental impacts allocated to EU biofuel demands

The share of the total sugarcane area that was harvested for EU biofuel production was 1.1% in 2008. Since sugarcane cultivation for EU biofuel production has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total sugarcane area used for EU biofuel production (1.1%).

Since no feedstock for EU biofuels in 2008 has been traced to jatropha produced in Guatemala; no local environmental impacts from cultivation of jatropha in Guatemala can be allocated to EU biofuels demands.

References

Fradejas, A. A., 2009. *Red Sugar Green Deserts. Chapter: The human right to food versus the new colonizers of agriculture in Guatemala - sugarcane and African palm.* Available at: http://www.fao.org/docs/eims/upload/276609/monocultures.pdf Accessed on May 4, 2011.

Assunção L., de la Torre Ugarte, D., Moreira J. R. & Zarrilli, S., 2007. *Prospects for a biofuels industry in Guatemala: Main findings and results of the mission undertaken by the UNCTAD Biofuels Initiative*. United Nations Conference on Trade and Development. Available at: http://www.unctad.org/en/docs/ditcted200711_en.pdf Accessed on May 4, 2011.

Mongabay, 2010. *Mongabay website: Guatemala Forest Information and Data*. Available at: http://rainforests.mongabay.com/deforestation/2000/Guatemala.htm Accessed on May 6, 2011.

USDA, 2009. *Guatemala Biofuels Annual: Biodiesel and Ethanol*. Available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/General%20Report_Guatemala_Guatemala_5-26-2009.pdf Accessed on May 6, 2011.

The Global Mechanism, 2009. *Increasing finance for sustainable land management: Guatemala.* Available at: http://global-mechanism.org/dynamic/documents/document_file/guatemala.pdf Accessed on May 6, 2011.

Suarez, N. R., 1996. *Sugar and Sweetener Situation and Outlook 1996: The Central American Sugar Industry.* Economic Research Service, U.S. Department of Agriculture, Washington, DC

Duarte, C., 2011. *Expert consultation: Carlos Duarte, consultant for Winrock International for the EU Biofuel Baseline project*.

GEXI, 2008. *Global Market Study on Jatropha Project Inventory: Latin America*. The Global Exchange for Social Investment. Available at: http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Jatropha-Project-Inventory_LATIN-AMERICA.pdf Accessed on May 12, 2011.

Peru

Selected biofuel crops for Peru include sugarcane and oil palm. As seen in Table 19, 5.3% of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production and 3.6% of the total area was used for production of fuel ethanol for the EU market. No data on oil palm biodiesel production has been found.

Table 19 Area used for production of Peru's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	69	3.7	5.3%	2.5	3.6%
Oil Palm	14	-	-	-	-

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

As seen in Figure 17, pastures constitute the largest share of Peru's total agricultural area. Permanent crops are uncommon, making cultivated land dominated by annual crops. Sugarcane plays a small role in Peru's overall agriculture (although large in certain areas) and ethanol is not a main application.

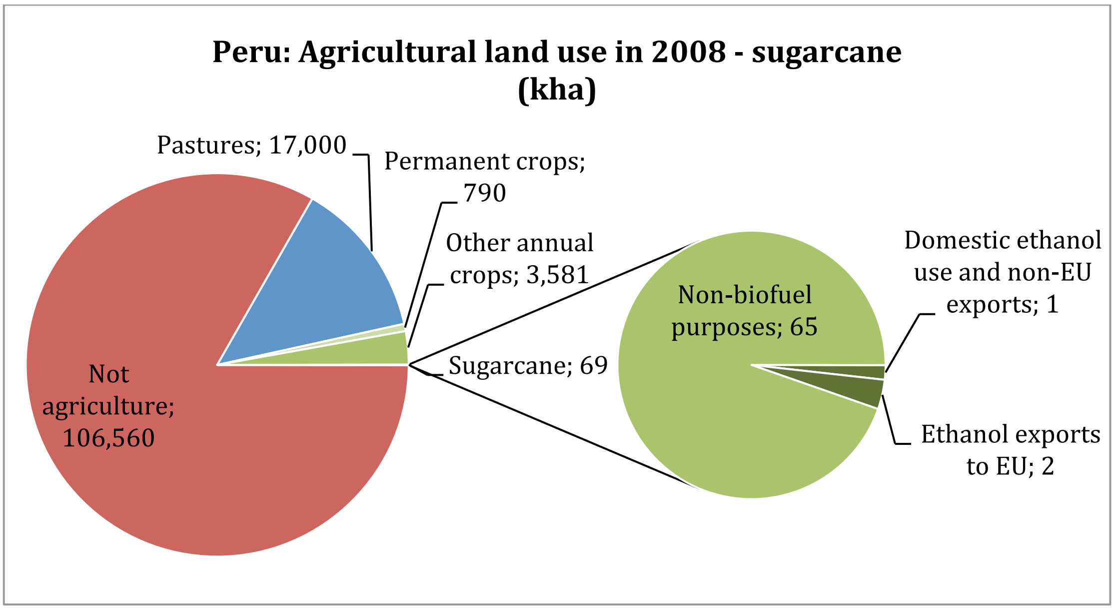


Figure 17: Agricultural land use in Peru in 2008, focused on sugarcane production

Historical developments

Between 1990 and 2008, sugarcane production in Peru increased with 40%. As seen in Figure 18, the production increase has been made possible mainly by increasing yields (+25%). The harvested area increased with 12% during the period.

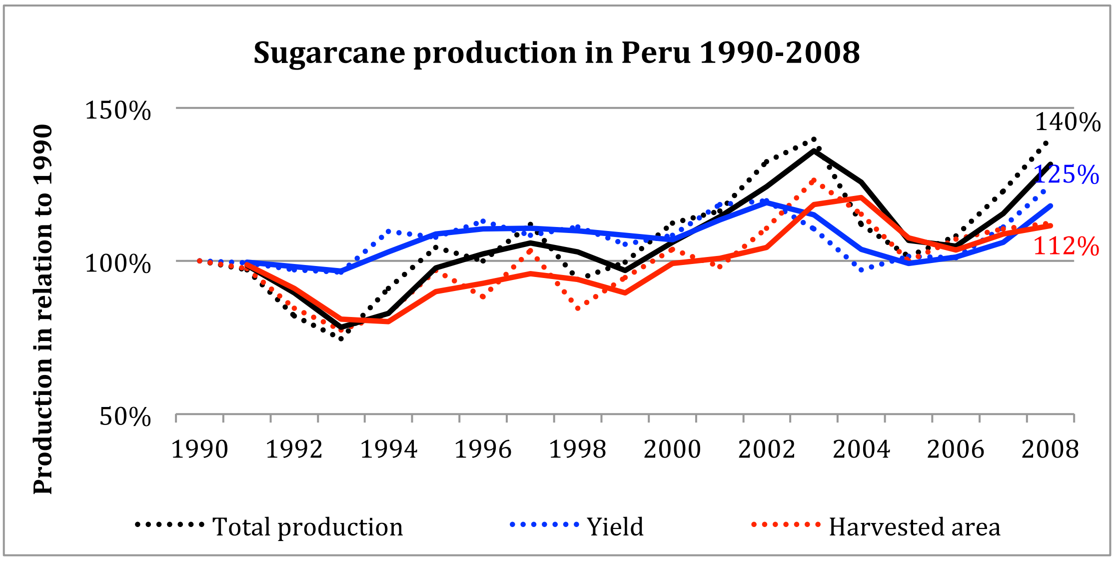


Figure 18: Change in sugarcane production, yields and harvested area in Peru, 1990-2008

The origins of the Peruvian sugar industry go back to the latter part of the Sixteenth Century when production was first introduced by Spanish colonists in the fertile river valleys of the otherwise barren, desert-like north coast. Because of the absence of rainfall due to the effects of the cold pacific current along the coast, agriculture there has always depended upon networks of irrigation, using water from the numerous rivers carrying seasonal rainfall down from the high Andes. At first north coast plantations were relatively small-scale, but during the Seventeenth Century their size increased, mostly at the expense of the remaining Indian communities. Skyrocketing sugar prices during the second half of the Seventeenth Century led to expansion of sugarcane to virtually all the coastal river valleys from Lambayeque in the north to Lima in the center. In the Trujillo region alone there were eighteen sugar plantations while several also appeared in the central and northern highlands (Klaren 2005).

Over time, sugarcane cultivation was concentrated to the northern coast while cotton came to replace sugar as the dominant crop along the central coast. One reason for the shift to the north was the ability to operate on a year-round basis due to the unique ecological conditions, which gave Peru a competitive advantage over Cuba and other sugar producing countries with seasonal limitations of growing and harvesting (Klaren 2005).

Today, sugar mills in Peru are located along the coast and have a total milling capacity of 37,000 MT of cane per day. Since sugar cane in Peru is produced year round, mills do not need to be very large. Yields and cane age vary greatly from one producer to another. Yields range from 53 to 190 MT of cane per hectare and age varies from 13 to 18 months between cuts. Average yields in CY 2010 were 126 MT per hectare. The Peruvian northern coast has excellent conditions for growing sugar cane due to high temperatures and lack of rain. All cultivation is surface irrigated, allowing producers to cut the supply of water at a given time to obtain higher sucrose yields. Under normal weather conditions, and provided the cane is milled on time, sucrose yields are around 12 percent (USDA 2011).

Land-use dynamics from future production increases

Most of Peru´s arable land is in the Costa (coastal) regions where the bulk of agricultural production takes place in the river valleys along the coast. In the Sierra (Andean) regions, agriculture is largely subsistence and in the Amazon (jungle) regions, agriculture has developed much more slowly (Khwaja 2010). The northern coast, which is most suitable for sugarcane growing, is undergoing an economic improvement process driven by private investments. Land is being purchased by both Peruvian and foreign investors, and property is being consolidated. The efficiency brought about by economies of scale is improving return rates, which attracts more investment, generating a beneficial cycle (USDA 2011).

Considering the possibility of year-round cultivation, future expansion of sugarcane is most likely to occur along the northern coast. Since the Costa region mainly consists of barren land, large-scale deforestation from sugarcane expansion is unlikely; there is even a potential to convert sand dynes into sugarcane production, something already happening (USDA 2011). However, since much irrigation is needed for such land conversion, water availability might become a constraint in case of a large sugarcane expansion in the Costa region (Khwaja 2010). Expansion in the Amazon region may also take place due to the high climatic production potential (FAO 200-). Since most of the Amazon region is undeveloped, expansion of sugarcane could drive deforestation, directly or indirectly. Expansion in the Sierra region is unlikely due to environmental constraints (FAO 200-).

Even though sugarcane is dominating in the northern Costa area, some potential still exists to shift from other crops, such as cotton. The potential of shifting from cotton (or other crops) to sugarcane is larger further south along the coast, but that would mean seasonal instead of year-round cultivation and thus lower productivity.

Oil Palm

Edible palm oil has been used for decades from commercial production of oil palm in agricultural lands, but areas are now expanding. In addition to the 14 kha of oil palm in production, 15 kha of oil palm are in growth and 12.6 are in nurseries (Garcia, 2010).

Historical developments

Between 1990 and 2008, oil palm production in Peru increased with 129%. As seen in Figure 19, the production increase has been made possible entirely by an increased harvested area (+337%), while yields decreased during the period (-32%).

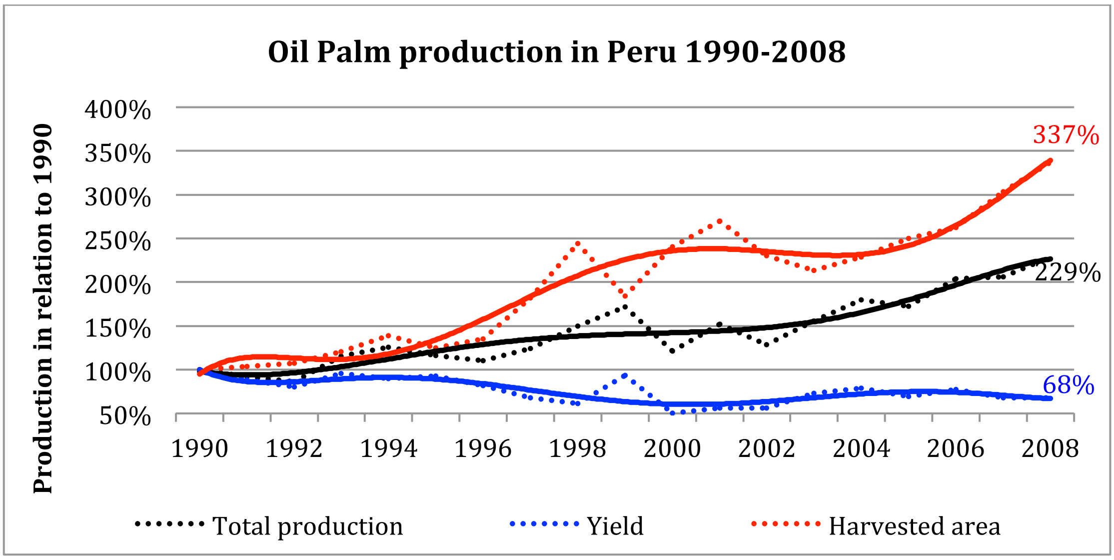


Figure 19: Change in oil palm production, yields and harvested area in Peru, 1990-2008

Oil palm is a rather new crop in Peru compared to sugarcane and little information exist on historical developments. Compared to sugarcane, which is preferably cultivated in the barren lands of the Costa region, oil palm is grown in the Amazon region. Oil palm has been expanding on already deforested areas but has also caused deforestation of primary forests, for example in the Barranquita district in the region of San Martin, as documented by the Peruvian Environmental Law Society (Khwaja 2010). In addition, Garcia (2010) reports that oil palm plantations have been established on existing farmland rather than abandoned or degraded land.

Land-use dynamics from future production increases

Large-scale oil palm expansion is likely in the Amazon regions only. Currently, oil palm is expanding in the Amazonian provinces of Ucayali, San Martin and Loreto, where deforested land is targeted for conversion into oil palm plantations. Such an expansion of oil palm for biodiesel in the poorly developed Amazon region is being pushed as part of Peru's anti-narcotics strategy, by creating alternatives to drug plant cultivation (Khwaja 2010). However, historical evidence, as previously discussed, show difficulties in enforcing that plantations are not established on natural vegetation or existing cropland. Therefore, oil palm may expand onto degraded land, existing cropland or natural vegetation, although the intention seems to be to expand onto degraded land.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, oil palm and jatropha in Peru are summarised in Table 20.

Table 20: Production system characteristics for sugarcane, oil palm and jatropha in Peru

System component	Sugarcane	Oil Palm	Jatropha
Large scale	Large scale production at the coast dominant, but starting up also in the Amazon region	Dominant	11)
Small scale	Traditional production		
Mechanized farming system		Land preparation	Land preparation, e.g. in Amazon regions where secondary vegetation needs to be cleared for sowing
Manual farming system		Harvesting	
Tillage			
Reduced and no tillage		Perennial crop	Perennial crop
Irrigated	Drip irrigation in large scale production in coastal areas		Coastal areas
Rain fed			
Mono-cropping			
Multi-cropping			However, since Jatropha is toxic, there are limitations to intercropping with edible crops
Crop rotation		Perennial crop	Perennial crop
Mineral fertilizer used			
Chemical pesticides used			
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field		Fruit husks planned to be used for biogas production

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information

Sources: (Brittaine and Lutaladio, 2010; Garcia, 2010; Khwaja, 2010; NL EVD Internationaal, 2009; Schweizer, 2009; USDA, 2009)

[11] It is difficult to estimate, from the information available, which production system is dominant today – large scale or small scale. By 2013, however, it is anticipated that nearly 50 percent of jatropha planting will be large scale.

Oil palm plantations in Peru have in some cases been found to divert the course of streams and drying up watercourses. Primary forests have been cleared for the development of oil palm plantations, primarily in the San Martin region, despite legal measures imposed. In some areas, oil palm plantations are established on farmland rather than abandoned or degraded land which can cause loss of agro-biodiversity (Garcia, 2010). Observed local environmental impacts from sugarcane, oil palm and jatropha production in Peru are summarised in Table 21.

Jatropha is part of the native flora in Peru. Production for biodiesel is still at an experimental stage and a number of jatropha pilot projects are implemented in the Amazon region (Garcia, 2010). Peru has implemented legislation that makes it obligatory to blend a minimum of 2.5% of biodiesel into fossil diesel fuel (NL EVD Internationaal, 2009). Current and planned production targets both domestic and international markets. By 2013, it is anticipated that nearly 50% of jatropha plantings will be large-scale, of which more than 20% will be plantations larger than 1 000 hectares. Areas that are used, or targeted, for jatropha are previously cleared forests, although often with secondary vegetation. Jatropha is observed to improve soil structure and is strongly believed to control and prevent soil erosion (Brittaine and Lutaladio, 2010). Fruit husks can be used for biogas production (Achten et al, 2007).

Table 21: Observed local environmental impacts from sugarcane, oil palm and jatropha production in Peru

Environmental impact	Sugarcane	Oil Palm	Jatropha
Deforestation		Red	Red
Loss of agro-biodiversity		Red	Red
Loss of biodiversity		Red	Red
Air pollution			
Water pollution	Red	Red	Red
GMO contamination	Green		Green
Eutrophication			
Soil fertility decline			
Erosion	Red		

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Brittaine and Lutaladio 2010; Garcia 2010; Khwaja 2010; NL EVD Internationaal 2009; Schweizer 2009; USDA 2009)

Local environmental impacts allocated to domestic biofuel production

The share of the total sugarcane area that was harvested for domestic biofuel production was 5.3% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (5.3%).

Since no production of domestic biofuels from oil palm has been identified for 2008; no local environmental impacts from cultivation of oil palm can be allocated to domestic biofuel production in Peru.

Local environmental impacts allocated to EU biofuel demands

The share of the total sugarcane area that was harvested for EU biofuel production was 3.6% in 2008. Since sugarcane cultivation for EU biofuel production has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total sugarcane area used for EU biofuel production (3.6%).

Since no feedstock for EU biofuels in 2008 has been traced to oil palm produced in Peru; no local environmental impacts from cultivation of Peruvian oil palm can be allocated to EU biofuel demands.

References

Achten et al., 2007. Jatropha biodiesel fueling sustainability? *Biofuels, Bioproducts and Biorefining*, 1(4), pp.283-291.

Brittaine, R. and Lutaladio, N., 2010. *Jatropha: A Smallholder Bioenergy Crop. The Potential for Pro-Poor Development*. Rome: Food and Agriculture Organization of the United Nations (FAO) and International Fund for Agricultural Development (IFAD) (Integrated Crop Management Vol. 8–2010).

FAO, 200-. *FAO country profile: Peru. Misc. maps*. Available at: http://www.fao.org/countryprofiles/ Accessed on June 16, 2011.

Garcia, H., 2010. Understanding the Bioenergy and Food security policy in landscape in Peru. In Y. Khwaja, ed. *Bioenergy and food security – The BEFS Analysis for Peru supporting the policy machinery in Peru*. Rome: Food and Agriculture Organization of the United Nations (FAO). Ch 2.

Khwaja, Y. ed., 2010. *Bioenergy and food security – The BEFS Analysis for Peru supporting the policy machinery in Peru*. Rome: Food and Agriculture Organization of the United Nations (FAO). Available at: http://www.fao.org/docrep/013/i1713e/i1713e00.pdf Accessed on June 28, 2011.

Klaren, P.F., 2005. The Sugar Industry in Peru. *Revista de Indias*, 65(233) pp. 33-48.

NL EVD Internationaal, 2009. *Peru: Natural Plant Oil Production in Ucayali*. Available at: http://www.fibronot.nl/download/Bioshape-in-Peru.pdf Accessed on May 24, 2011.

Schweizer, T., 2009. *Agricultural potential of bioenergy production in Peru. With special focus on the impact on smallholders using the example of Jatropha curcas*. Stuttgart: University of Hohenheim. (Master thesis at the Institute for farm management)

USDA, 2011. *Peru: Sugar Annual Report*. Available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Commodity%20Report_SUGAR%20ANNUAL_Lima_Peru_4-8-2009.pdf Accessed on May 24, 2011.

United States

Selected biofuel crops for USA include maize and soybean. As seen in Table 22, very little maize ethanol for the EU market has been traced to USA, but about 28% of the total area under maize cultivation in 2008 was used for domestic ethanol production. About 11% of the total area under soybean cultivation in 2008 was used for domestic biodiesel production and about 4% of the total area was used for production of biodiesel or -feedstock for the EU market. It should be noted that ethanol and biodiesel are not the sole products associated with these areas; co-products include for example animal feed.

Table 22: Area used for production of USA's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	**Total harvested area in 2008** (kha)	**Cropland used for domestic biofuel production in 2008**		**Cropland used for production of feedstock for EU biofuels in 2008**	
		kha	% of total	kha	% of total
Maize	31,796	8,994	28.3%	0.3	0.0%
Soybean	30,223	3,290	10.9%	1,270	4.2%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Maize

As seen in Figure 20, pastures constitute a slightly larger share of the total agricultural land in USA than cultivated land. Permanent crops are uncommon, making cultivated land dominated by annual crops. Maize cultivation in 2008 constituted about 19% of the total area under annual crops, making it an important crop in USA's agriculture. Ethanol for domestic use is an important application for maize, although very little was exported to the EU in 2008. As already noted, co-products, such as animal feed, is likely to be produced on the same land as maize ethanol.

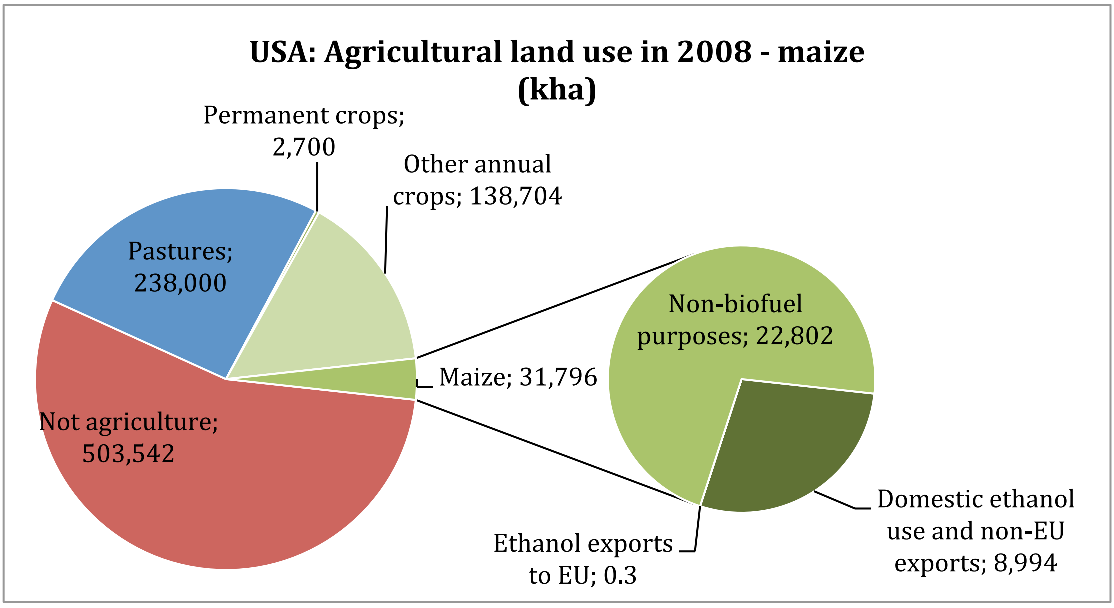


Figure 20: Agricultural land use in USA in 2008, focused on maize production

Historical developments

Between 1990 and 2008, maize production in USA increased with 52%. As seen in Figure 21, the increase has been made possible mainly by increasing yields (+30%), although to some extent also by an increased harvested area (+17%). Maize acreage in the United States has varied since 1900 from a high of 116 million acres in 1917 to a low of 64 million acres in 1969 (Larson and Cardwell 1999).

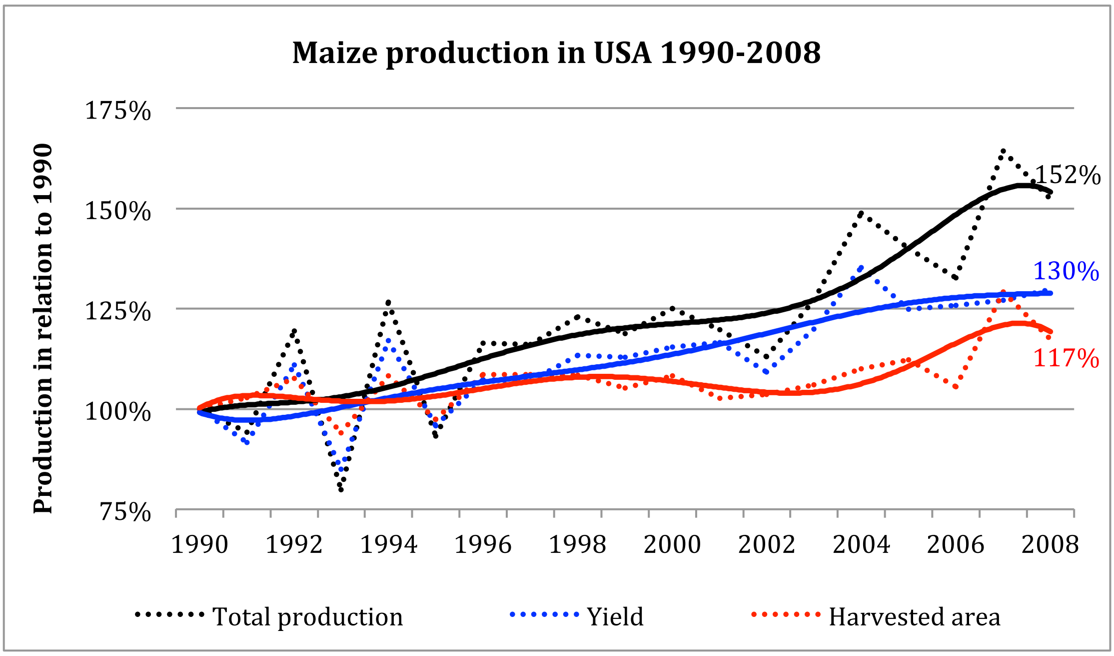
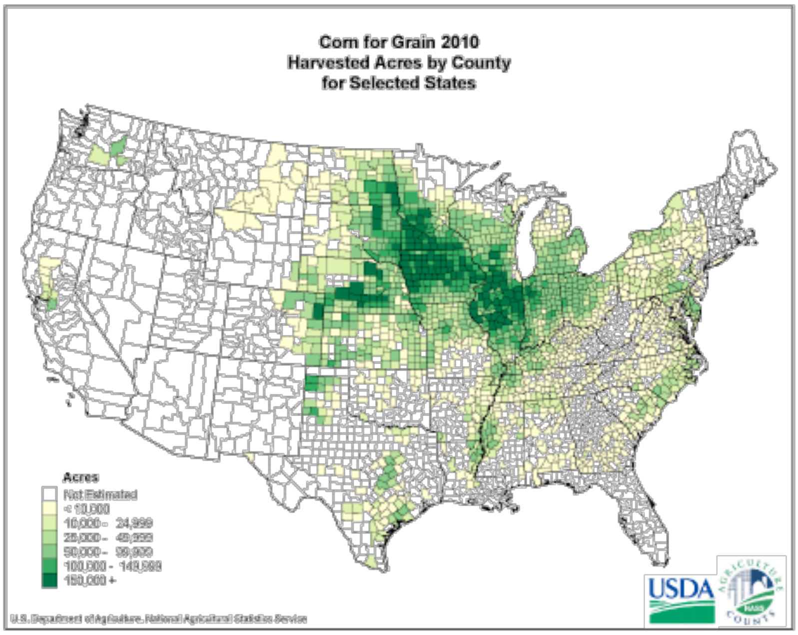


Figure 21: Change in maize production, yields and harvested area in USA, 1990-2008

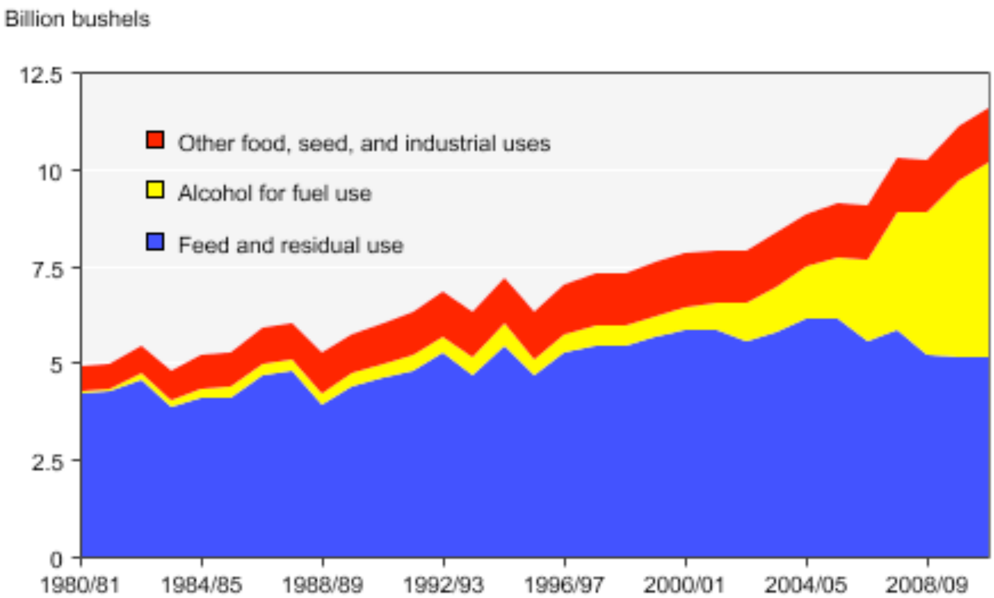
Maize is cultivated in most U.S. States, although, as illustrated in Figure 22, production is concentrated to the Heartland region (Illinois, Iowa, Indiana, eastern portions of South Dakota and Nebraska, western Kentucky and Ohio, and the northern two-thirds of Missouri), also known as the *Corn Belt*. Iowa and Illinois are particularly important, constituting about one-third of the total maize production (USDA-ERS 2011a).



Source: (USDA-NASS 2011)

Figure 22: Geographical overview of maize cultivation in USA

As already mentioned, maize acreage in the United States has, although fluctuated, not increased during the past century. The recent increase can, at least to some extent, be the result of the *Federal Agriculture Improvement and Reform Act of 1996*, which allows farmers to make their own crop planting decisions based on the most profitable crop for a given year. As illustrated in Figure 23, much of the increase since 2000 can be explained by an increased demand for ethanol fuel (USDA-ERS 2011a).



Source: (USDA-ERS 2011)

Figure 23: Different uses of maize in USA during 1980-2009

Most of the fields in the Corn Belt now planted to grains were opened from forests or prairie in the last half of the 19th Century (Runge 2002). Wescott (2007) suggests that recent maize expansion has been made possible mainly by adjusting crop rotations between corn and soybeans.

Land-use dynamics from future production increases

The Energy Independence and Security Act of 2007 (EISA) restricts where feedstock for biofuels can be produced for compliance with the U.S. Renewable Fuels Standards RFS2. For planted crops/crop residue from agricultural land and planted trees/tree residue from actively managed tree plantations on non-federal land, feedstock must come from land cleared/cultivated prior to December 19, 2007 (USDA 2010). Therefore, a potential expansion of maize production for ethanol purposes is not likely to occur on natural vegetation. However, since exported ethanol does not need to comply with the EISA standard, maize for such purposes may therefore be produced on land cleared after 2007. An anonymous reviewer indicated though that such a scenario is unlikely, due to legislation and other incentives for protecting remaining natural vegetation.

USDA (2010) suggests that an increased production of maize is possible mainly in the *central east region*, including Delaware, Iowa, Illinois, Indiana, Kansas, Missouri, Ohio, Oklahoma, Maryland, Minnesota, Nebraska, North Dakota, Pennsylvania, South Dakota, Wisconsin and Virginia. The *northeast region*, including Connecticut, Massachusetts, Maine, Michigan, New Hampshire, New Jersey, New York, Rhode Island, Vermont and West Virginia, also hold potential to increase maize production. This means that much of the expected increase in maize production is predicted to occur near the current main maize production areas.

Soybeans compete most directly with maize and on the largest amount of land. Thus, much of the expansion in maize plantings is likely to come from soybean plantings. In the Corn Belt, where maize and soybeans are frequently used in rotations, planting maize one year and soybeans the next, some of the acreage shift can occur by changing rotational practices. For example, the rotation might be changed to planting maize 2 years successively, with soybeans planted every third year (Wescott 2007). This is supported by results from various CGE models:

- The GTAP model (Hertel et al. 2010 in Edwards et al. 2010), reports that 25% of a potential 252 kha increase in maize acreage would be on the expense of soybean.
- The IMPACT model (Edwards et al. 2010), reports that 18% of a potential 54.4 kha increase in maize acreage would be on the expense of soybean.
- Searchinger et al. (2008) reports that 41% of a potential 4 Mha increase in maize acreage would be on the expense of soybean.

Other sources of land for increased maize plantings include pastures, reduced fallow, acreage returning to production from expiring Conservation Reserve Program (CRP) contracts, and shifts from other crops such as cotton (Wescott 2007; USDA 2010). Again, CGE models suggest similar scenarios:

- GTAP (Hertel et al. 2010 in Edwards et al. 2010) reports that 22% of a potential 252 kha increase in maize acreage would occur on pastures and 25% would be on the expense of wheat production.
- Searchinger et al. (2010) reports that 33% of a potential 7.864 Mha increase in maize acreage would be on the expense of wheat production.

Even though a direct expansion of maize on natural vegetation seems unlikely, unless potentially on land previously under CRP contracts, maize expansion on pastures or replacement of other crops could result in a displacement of such agricultural activities into other areas, potentially on natural vegetation. Little detailed information about such dynamics has been found in scientific literature and in CGE models. In an attempt to assess which types of ecosystems that are more or less likely to be converted in case of a direct maize expansion or a resulting displacement of agricultural activities on natural vegetation, an overlay has been made of the USDA-NASS's (2011) map on maize production with a map over areas where maize production is predicted by the USDA (2010) to increase in a near future (i.e. the *central east region* or the *northeast region*, as previously discussed).

As seen in Table 23, most states that are likely to increase corn production contain *forest and woodland systems*, five states contain *grassland systems* and three states contain *shrubland, steppe and savannah systems*. Three states contain little natural vegetation making a potential direct or indirect expansion on natural vegetation unlikely.

Table 23: Existence of grassland-, forest and woodland- and shrubland steppe and savannah systems in the central east and northeast regions, by state

Most natural vegetation already converted - potential expansion on natural vegetation is unlikely	**Potential direct or indirect expansion on *grassland systems* possible**	**Potential direct or indirect expansion on *forest and woodland systems* possible**	**Potential direct or indirect expansion on *shrubland, steppe and savannah systems* possible**
Delaware, Iowa, Illinois	North Dakota, South Dakota, Nebraska, Kansas, Oklahoma	Minnesota, Wisconsin, Indiana, Missouri, Ohio, Pennsylvania, Maryland, Virginia, Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Rhode Island, Vermont and West Virginia, Wisconsin, Michigan, Oklahoma	Wisconsin, Michigan, Oklahoma

It should be noted that management of natural vegetation in the United States is managed on a state-by-state basis and different states have differently strict regulations. There is also a distinction between national land (national forests) and private land, which is typically less regulated. Therefore, state regulations for the states in Table 23 need to be carefully assessed in order to evaluate the legislative protection for natural vegetation. In addition, other incentives to protect natural vegetation (e.g. CRP contracts) in each state need to be assessed to fully understand where potential direct or indirect conversion of natural vegetation is likely to occur.

Indirect effects outside the United States, e.g. displacement of soybean production to Latin America, as discussed by for example Morton et al. (2006 in Searchinger et al. 2008), have not been treated in this study.

Soybean

As already described, pastures constitute a slightly larger share of the total agricultural land in USA than cultivated land. Permanent crops are uncommon, making cultivated land dominated by annual crops. As seen in Figure 24, soybean cultivation in 2008 constituted about 18% of the total area under annual crops (about the same as maize) making it an important crop in USA's agriculture. Biodiesel is a rather important application for soybean and a significant share of the produced biodiesel was exported to the EU in 2008, as well as smaller amounts of unprocessed feedstock for EU biodiesel. As already noted, co-products, such as animal feed, are likely to be produced on the same land as soybean biodiesel.

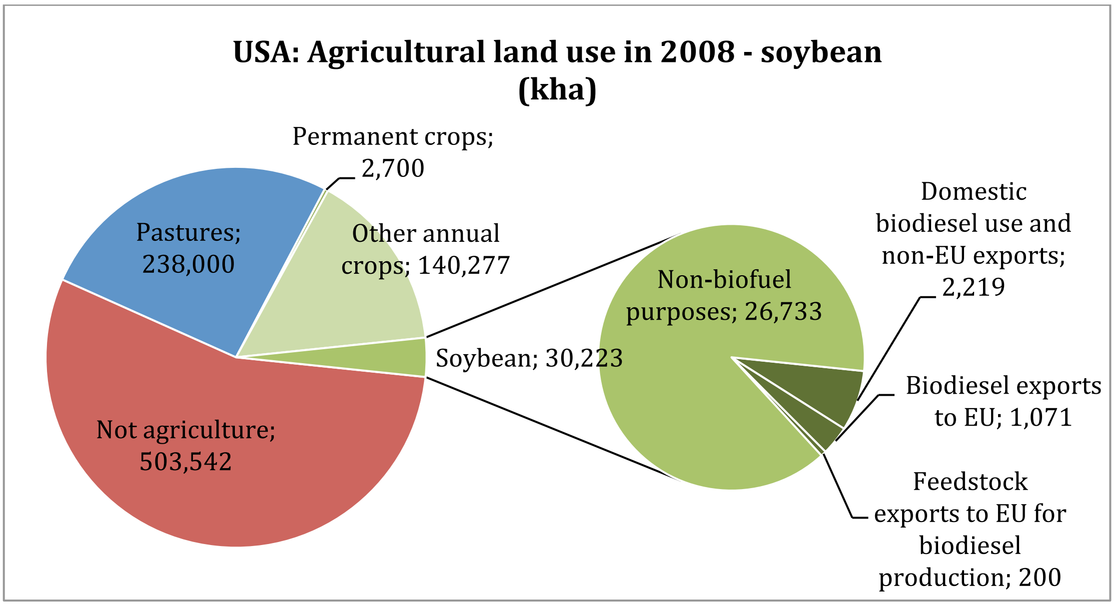


Figure 24: Agricultural land use in USA in 2008, focused on soybean production

Large-scale production of soybean in USA did not occur until the 20th century. Today, soybean is the second most planted field crop in the United States only trailing corn.

Historical developments

Between 1990 and 2008, soybean production in USA increased with 54%. As seen in Figure 25, the increase has been made possible both by an increased harvested area (+32%), and increasing yields (+17%).

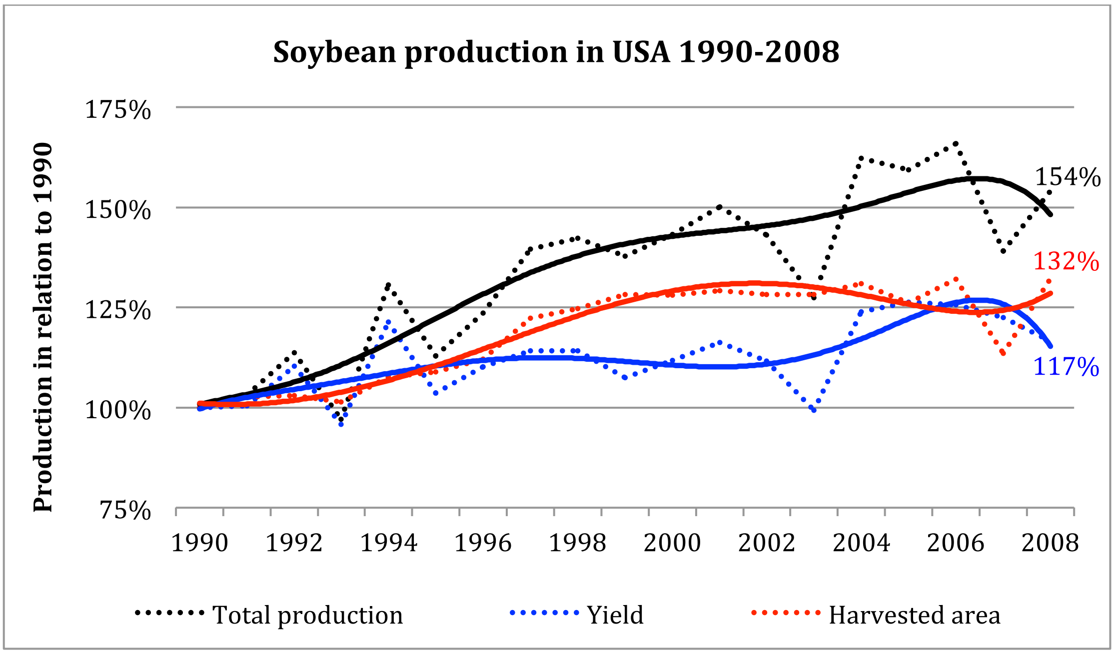
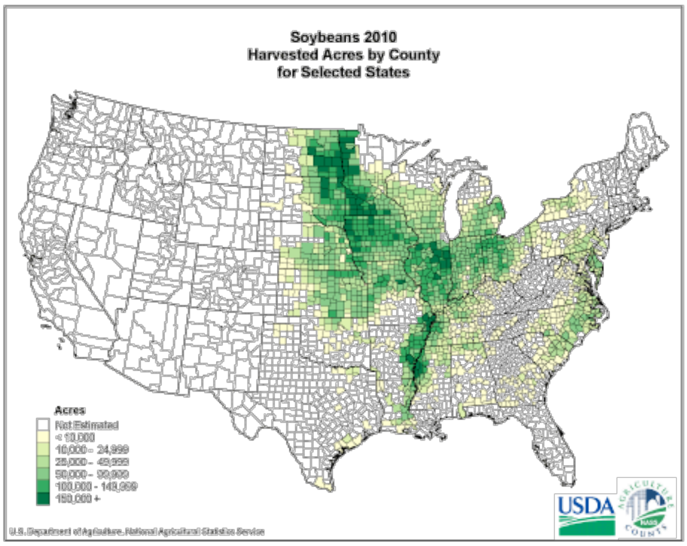


Figure 25: Change in soybean production, yields and harvested area in USA, 1990-2008

During the 20th century, soybean expansion was favoured by increased planting flexibility, steadily rising yield improvements from narrow-rowed seeding practices, a greater number of 50-50 corn-soybean rotations, and low production costs (partly due to widespread adoption of maize-tolerant varieties). Today, as illustrated in Figure 26, more than 80% of U.S. soybean acreage is concentrated in the upper Midwest (i.e. the Corn Belt), although significant amounts are still planted in the historically important areas of the Delta (western Arkansas, eastern Mississippi and northeastern Louisiana) and Southeast. Acreage tends to be concentrated where soybean yields are highest (USDA-ERS 2011b).



Source: (USDA-NASS 2011)

Figure 26: Geographical overview of soybean cultivation in USA

Most of the fields in the Corn Belt now planted to grains were opened from forests or prairie in the last half of the 19th Century (Runge 2002).

Land-use dynamics from future production increases

In contrary to the case with ethanol and maize, an increased demand for biodiesel may have little effects on soybean acreage. Bauen et al. (2010) reports that soybean acreage is only influenced by demand for soybean meal, i.e. within certain limits an increase in price for soy oil will not lead to an increase in the area of soybeans grown. ABIOVE (2009 in Bauen et al. 2010) states that: "It is a mistake to believe that the private sector will make decisions based on just 1/5 of the product (i.e. the oil), without a defined market for the other 4/5 (i.e. the meal)". Therefore, Bauen et al. (2010) assumes that neither soybean acreage nor yields would be affected by increased demand for soy oil. They do suggest that this assumption should be investigated further, and since the USDA (2010) reports that the EISA requires an increased U.S soybean production in order to meet the national targets for advanced biofuels, this study suggests that soybean expansion in the U.S due to an increased demand for biodiesel, national as well as international, cannot be discarded.

As for maize, the Energy Independence and Security Act of 2007 (EISA) restricts where feedstock for biofuels can be produced for compliance with the U.S. Renewable Fuels Standards RFS2. For planted crops/crop residue from agricultural land and planted trees/tree residue from actively managed tree plantations on non-federal land, feedstock must come from land cleared/cultivated prior to December 19, 2007 (USDA 2010). Therefore, a potential expansion of soybean production for biodiesel purposes is not likely to occur on natural vegetation. However, since exported biodiesel does not need to comply with the EISA standard, soybean for such purposes may therefore be produced on land cleared after 2007. An anonymous reviewer indicated though that such a scenario is unlikely, due to legislation and other incentives for protecting remaining natural vegetation.

USDA (2010) suggests that an increased production of soybean is possible in the *central east region* (including Delaware, Iowa, Illinois, Indiana, Kansas, Missouri, Ohio, Oklahoma, Maryland, Minnesota, Nebraska, North Dakota, Pennsylvania, South Dakota, Wisconsin and Virginia), the *northeast region* (including Connecticut, Massachusetts, Maine, Michigan, New Hampshire, New Jersey, New York, Rhode Island, Vermont and West Virginia) and the *southeast region* (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Texas) As for maize, much of the expected increase in soybean production is predicted to occur near the current main soybean production areas.

As already discussed in the U.S. maize section, soybeans and maize, even though rotated for mutual benefit, are in direct competition on a large amount of land. In the Corn Belt, where soybean is typically rotated with maize, acreage shifts are therefore possible by changing rotational practices (Wescott 2007). However, in the Delta region, particularly in eastern Arkansas where rotation with maize is less common, such soybean-maize acreage shifts are not feasible.

Considering that an increased maize acreage in areas where soybeans and maize are typically rotated, automatically result in increased soybean acreage. Therefore, some possibilities for maize expansion, as discussed in the U.S maize section, can also be relevant for soybeans. Examples on areas where soybean acreage can be increased include pastures, reduced fallow, areas returning to production from expiring CRP contracts, and shifts from other crops such as cotton, wheat or rice (primarily in the Delta region).

As for maize, soybean expansion on natural vegetation is in most cases not likely to occur. However, soybean expansion on pastures or replacement of other crops could result in a displacement of such agricultural activities into other areas, potentially on natural vegetation. Little detailed information about such dynamics has been found in scientific literature and in CGE models. In an attempt to assess which types of ecosystems that are more or less likely to be converted in case of a direct soybean expansion or a resulting displacement of agricultural activities on natural vegetation, an overlay has been made of the USDA-NASS's (2011) map on soybean production with a map over areas where maize production is predicted by the USDA (2010) to increase in a near future (i.e. the *central east region* or the *northeast region*, as previously discussed).

As seen in Table 24, most states that are likely to increase corn production contain *forest and woodland systems*, six states contain *grassland systems* and five states contain *shrubland, steppe and savannah systems*. Five states contain little natural vegetation making a potential direct or indirect expansion on natural vegetation unlikely.

Table 24: Existence of grassland-, forest and woodland- and shrubland steppe and savannah systems in the central east, northeast and southeast regions, by state

Most natural vegetation already converted - potential expansion on natural vegetation is unlikely	**Potential direct or indirect expansion on *grassland systems* possible**	**Potential direct or indirect expansion on *forest and woodland systems* possible**	**Potential direct or indirect expansion on *shrubland, steppe and savannah systems* possible**
Delaware, Iowa, Illinois, Florida, Louisiana	North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas	Minnesota, Wisconsin, Indiana, Missouri, Ohio, Pennsylvania, Maryland, Virginia, Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Rhode Island, Vermont, West Virginia, Wisconsin, Michigan, Oklahoma, Alabama, Arkansas, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Texas	Wisconsin, Michigan, Oklahoma, Tennessee, Texas

It should be noted that management of natural vegetation in the United States is managed on a state-by-state basis and different states have differently strict regulations. There is also a distinction between national land (national forests) and private land, which is typically less regulated. Therefore, state regulations for the states in Table 23 need to be carefully assessed in order to evaluate the legislative protection for natural vegetation. In addition, other incentives to protect natural vegetation (e.g. CRP contracts) in each state need to be assessed to fully understand where potential direct or indirect conversion of natural vegetation is likely to occur.

Correlation between maize and soybean production

As described in the U.S. maize and -soybean sections, and illustrated in Figure 27, maize-soybean rotations are very common, particularly in the Corn Belt, and they are thus typically cultivated in the same areas. Since farmers may change rotational practices based on which crop that would be most profitable to produce, maize and soybean acreage may thus be shifted.

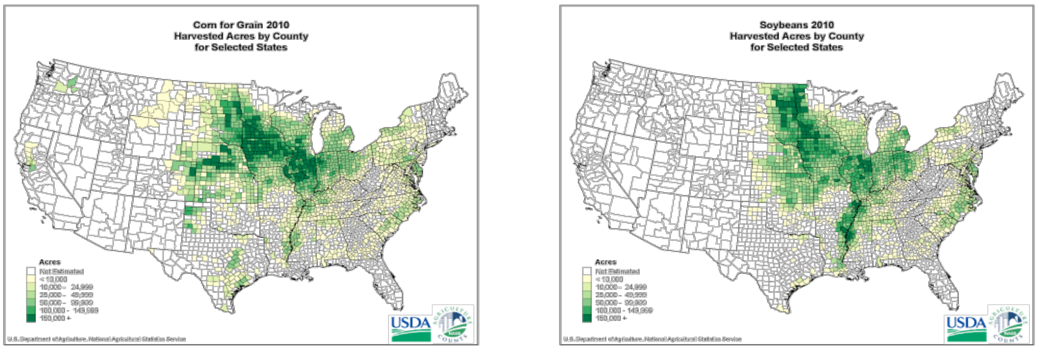


Figure 27: Geographical distribution of maize (left) and soybean (right) in USA

Source: (USDA-NASS 2011)

In an attempt to better understand how much the correlation between maize and soybean production affect their total annual changes in acreage, the annual changes in harvested area for maize and soybean, respectively, have been plotted in Figure 28 for the period 1990-2008.

It is obvious that not all of the annual changes in maize or soybean acreage can be explained by opposite changes for the other crop. In some years there has been an increased acreage for both crops, while other years show a mutual decreased acreage. However, in some years there seem to be a clear negative correlation between the crops, particularly apparent in the recent years 2006-2009. This means that even though the maize-soybean correlation is indisputable (due to the fact that maize-soybean rotations are very common), it cannot explain all, or even most, of the historical dynamics in maize and soybean acreage.

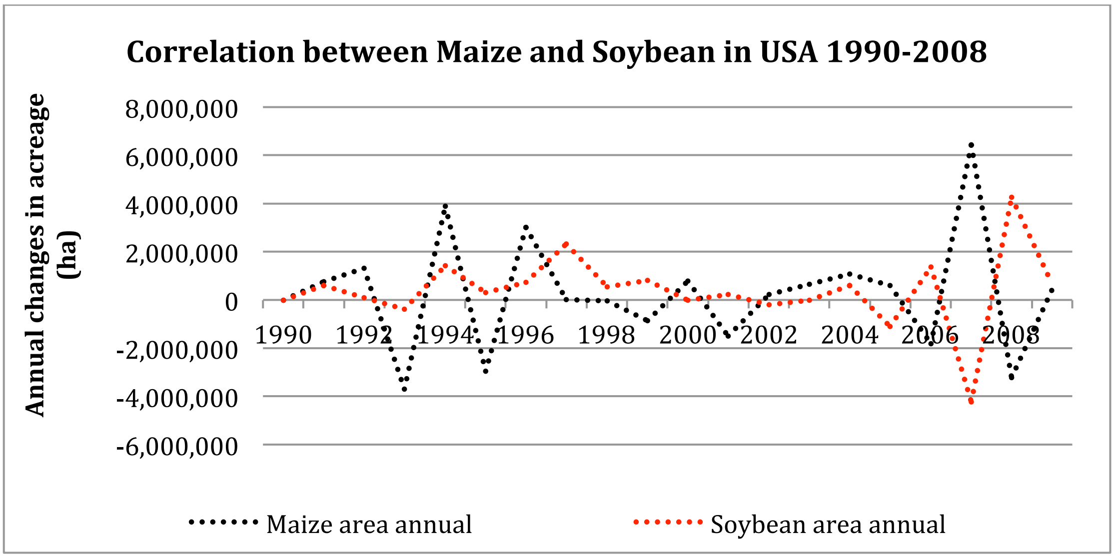


Figure 28: Annual changes in maize and soybean acreage 1990-2008

Source: FAOSTAT data

Production system characteristics and local environmental impacts

Production system characteristics for maize, soybean and sugarcane in USA are summarised in Table 25.

Table 25: Production system characteristics for maize, soybean and sugarcane in USA

System component	Maize	Soybean	Sugarcane
Large scale	Dominant	65%	Dominant
Small scale		35%	
Mechanized farming system			
Manual farming system			
Tillage		12%	
Reduced and no tillage		88%	
Irrigated	15%	7.5 %	
Rain fed			Dominant
Mono-cropping			
Multi-cropping			
Crop rotation	E.g. alfalfa, soybeans and wheat	E.g. corn, wheat, rice sorghum	
Mineral fertilizer used		Soybean is a biological nitrogen fixer and no or little nitrogen is therefore needed to add	
Chemical pesticides used		Particularly herbicides)	
GMO seeds for sowing	"Bt maize" produces toxins that kill certain insect pests, particularly the European corn borer and the South-western corn borer and represent 57 per cent of maize grown in the USA	92%	
Land preparation with fire			Burning after harvest
By-products (from harvesting)			Tops and leaves from mechanical harvesting are left on the field

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information

Sources: (Ackerman et al., 2003; CAST, 2009; Dale et al., 2002; de Fraiture et al., 2008; Goldemberg et al., 2008; Proforest, 2010; Rice, 2007; USDA, 2009a).

Observed local environmental impacts from maize, soybean and sugarcane production in USA are summarised in Table 26.

Table 26: Observed local environmental impacts from maize, soybean and sugarcane production in USA

Environmental impact	Maize	Soybean	Sugarcane
Deforestation			
Loss of agro-biodiversity			
Loss of biodiversity			
Air pollution			
Water pollution			
GMO contamination			
Eutrophication			
Soil fertility decline			
Erosion			

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information

Sources: (Ackerman et al., 2003; CAST, 2009; Dale et al., 2002; de Fraiture et al., 2008; Goldemberg et al., 2008; Proforest, 2010; Rice, 2007; USDA, 2009a).

Local environmental impacts allocated to domestic biofuel production

The share of the total maize area that was harvested for domestic biofuel production was 28.3% in 2008. However, the net area requirement is lower since maize biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 15.4% of the total maize area in 2008. Since maize cultivation for domestic biofuels has the same characteristics as maize cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total maize area used for production of domestic biofuels (15.4%). It should be noted that maize for production of domestic biofuels in 2008 was cultivated on 8994 kha, which is a significant amount of land.

The share of the total soybean area that was harvested for domestic biofuel production was 10.9% in 2008. However, the net area requirement is lower since soybean biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 3.6% of the total soybean area in 2008. Since soybean cultivation for domestic biofuels has the same characteristics as soybean cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total soybean area used for production of domestic biofuels (3.6%). It should be noted that soybeans for production of domestic biofuels in 2008 was cultivated on 3290 kha, which is a significant amount of land.

Local environmental impacts allocated to EU biofuel demands

The share of the total maize area that was harvested for EU biofuel production was close to 0% in 2008. Therefore, no local environmental impacts from cultivation of maize can be allocated to EU biofuel demands.

The share of the total soybean area that was harvested for EU biofuel production was 4.2% in 2008. However, the net area requirement is lower since soybean biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 1.4% of the total soybean area in 2008. Since soybean cultivation for EU biofuels has the same characteristics as soybean cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total soybean area used for EU biofuel production (1.4%). It should be noted that soybeans used for EU biofuel production in 2008 was cultivated on 1444 kha, which is a significant amount of land.

References

Bauen, A., Chudziak, C., Vad K. and Watson, P., 2010. *A causal descriptive approach to modelling the GHG emissions associated with the indirect land use impacts of biofuels*. Available at: http://www.dft.gov.uk/pgr/roads/environment/research/biofuels/pdf/report.pdf Accessed on April 28, 2011.

Edwards, R., Mulligan, D. and Marelli, L., 2010. *JRC Scientific and Technical Reports: Indirect Land Use Change from increased biofuels demand. Comparison of models and results for marginal biofuels production from different feedstocks.* Available at: http://ec.europa.eu/energy/renewables/consultations/doc/public_consultation_iluc/study_4_iluc_modelling_comparison.pdf Accessed on April 27, 2011.

Hertel, T. W., Tyner W. E. and Birur D. K., 2010. Global Impacts of Biofuels. *Energy Journal*, 31(1), pp.75-100.

Larson, W. E.; Cardwell, V. B., 1999. *History of U.S. Corn Production.* University of Minnesota: Minneapolis. Available at: http://www.mindfully.org/Farm/US-Corn-Production1999.htm Accessed on April 14, 2011

Morton, D. C. et al., 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proc Natl Acad Sci USA*, 103(39), pp.14637-14641.

Runge, C. F., 2002. *King Corn: The History, Trade and Environmental Consequences of Corn (Maize) Production in the United States*. Midwest Commodities & Conservation Initiative: Minnesota, USA. Available at: http://www.worldwildlife.org/what/globalmarkets/agriculture/WWFBinaryitem7205.pdf Accessed on April 14, 2011.

Sandretto, C. & Payne, J., 2006. *Agricultural Resources and Environmental Indicators, 2006 Edition / EIB-16, chapter 4.2: Soil Management and Conservation*. U.S. Department of Agriculture, Economic Research Service. Available at: http://www.ers.usda.gov/publications/arei/eib16/eib16_4-2.pdf Accessed on April 14, 2011

Searchinger, T. et al., 2008. *Supporting Online Material for Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change*. Available at: http://www.sciencemag.org/content/suppl/2008/02/06/1151861.DC1/Searchinger.SOM.pdf Accessed on April 27, 2011.

USDA, 2010. *USDA Biofuels Strategic Production Report*. Available at: http://www.usda.gov/documents/USDA_Biofuels_Report_6232010.pdf Accessed on April 27, 2011.

USDA-ERS, 2011a. *U.S. Department of Agriculture, Economic Research Service: Corn Briefing Room.* Available at: http://www.ers.usda.gov/Briefing/Corn/ Accessed on April 14, 2011.

USDA-ERS, 2011b. *U.S. Department of Agriculture, Economic Research Service: Soybean and Oil Crops Briefing Room.* Available at: http://www.ers.usda.gov/Briefing/Corn/ Accessed on April 14, 2011.

USDA-NASS, 2011. *U.S. Department of Agriculture, National Statistics Service: Charts and Maps.* Available at: http://www.nass.usda.gov/Charts_and_Maps/Crops_County/index.asp Accessed on April 14, 2011.

USGS, 2009. *The Gap Analysis Program (GAP) national land cover viewer.* Available at: http://lc.gapanalysisprogram.com/landcoverviewer/Default.aspx Accessed on April 27, 2011.

Wescott, P. C., 2007. *Ethanol Expansion in the United States: How Will the Agricultural Sector Adjust*? U.S. Department of Agriculture, Economic Research Service. Available at: http://www.ers.usda.gov/Publications/FDS/2007/05May/FDS07D01/ Accessed on April 14, 2011

COUNTRY PROFILES – AFRICA

This section includes country profiles for Ethiopia, Malawi, Mozambique, Nigeria, Sudan, Tanzania and Uganda.

Regional conclusions

Africa is an interesting region in regard to its potential to produce biofuel crops. However, socio-economic challenges, e.g. food insecurity, poverty and lack of infrastructure, are often large in African countries, which calls for careful consideration when assessing the region's potential to supply the EU with biofuels. Drawing generalised conclusions about Africa as a region is further difficult, due to lack of data and information.

Common for all African countries are high yield gaps, meaning that neither of the countries are close to producing as much crops as they have the potential to do, using the same amount of land as currently under cultivation. In addition, most African countries have large areas of unutilized land that can be suitable for producing biofuel crops. However, a few of the African countries, Malawi, Nigeria and Uganda, do not have an abundance of land suitable for rain-fed cultivation. Instead most suitable land is already cultivated, although with relatively low yields. From an investor perspective, African countries with large land areas suitable for cultivation have become increasingly interesting for biofuel projects.

For many of the African nations, a potential expansion is likely to occur on grasslands (savannahs). In addition, as shown in the separate project report on legislation, *Legislative readiness for RED*, conversion of grasslands seems to be universally poorly considered in environmental legislation. There seems to be a higher legislative support for protecting forest areas compared to grasslands, although not particularly strong either. Expansion of biofuel feedstock production on natural vegetation (most likely grasslands) is therefore likely to occur relatively unrestricted.

Common for all African countries is also that large parts of the population are very poor and highly dependent upon agriculture for their livelihood. This means that biofuel investments can compete with land needed for survival, even if marginal land is being targeted. On the other hand, production of energy crops may provide for a much-needed income for smallholders, processing of biofuels may create employment opportunities as well as a technology-transfer while export of biofuels may create a money-transfer into the country. It is therefore important to carefully evaluate potential impacts and benefits of biofuel production in Africa and to support domestic processing of biofuels.

Ethiopia

Selected biofuel crops for Ethiopia include sugarcane, castor and jatropha. As seen in Table 27, domestic biofuel production has not been possible to identify or estimate, for neither of the crops. However, small amounts of feedstock for EU sugarcane ethanol in 2008 have been traced to Ethiopia.

Table 27: Area used for production of Ethiopia's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	21	-	-	0.1	0.5%
Castor	7	-	-	0	-
Jatropha	1,7	-	-	0	-

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

Historical developments

Between 1993 and 2008, sugarcane production in Ethiopia increased by 35%, although with a peak in 2003. As seen in Figure 29, the increase has been made possible almost entirely by an increased harvested area, while yields have remained rather unchanged during the period.

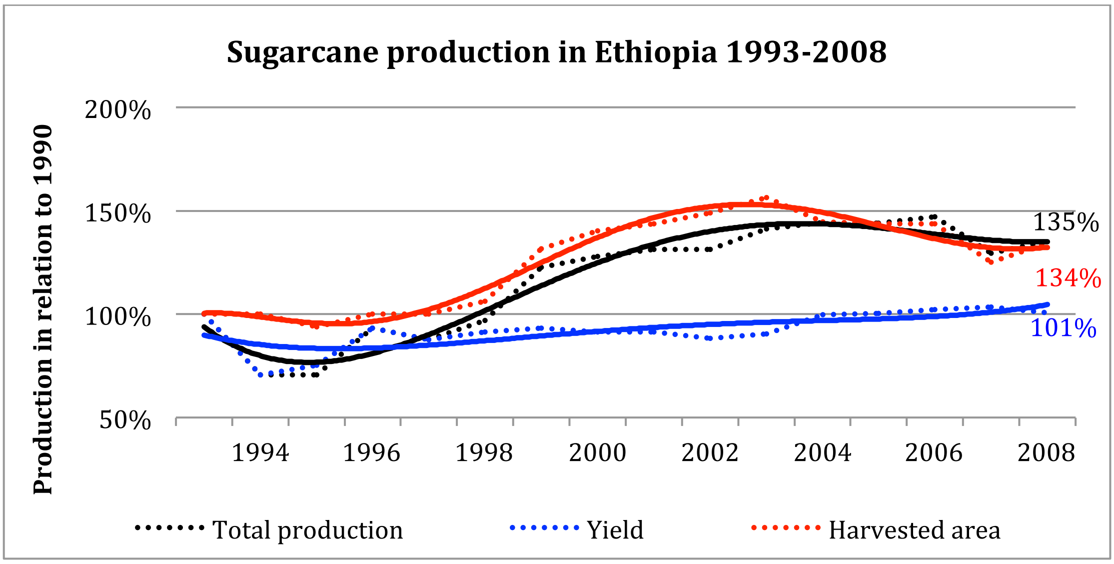


Figure 29: Change in sugarcane production, yields and harvested area in Ethiopia, 1993-2008

The recent developments of sugarcane production have occurred mainly in the Amahara region in the northwestern part of the country (Lawek & Shiferaw, 2008).

The land used is both acquired by companies and used by out growers. According to Lawek and Shiferaw (2008) most of the expansion and development has occurred on forestland and arable cropland, since these are more fertile than marginal land or pastures.

Land-use dynamics from future production increases

Since sugarcane required irrigation it is likely that future expansion of sugarcane production will occur near river basins. Fessehaie (2009) highlights six river basins, which have potential for irrigated sugarcane plantations. The two largest are the Baro-Akabo basin in west Ethiopia (600 000 hectares of irrigable area) and the Abbay river basin in central/northwest Ethiopia (500 000 hectares). The Baro-Akabo basin contains mainly savannah whereas the Abbay basin contains both savannah and forestland (FAO, 2011a), making it likely that an expansion of sugarcane in these areas can occur on savannah or forested land. The Abbay basin also contains large areas of cropland (FAO, 2011a), making it a possible scenario that sugarcane can expand onto existing cropland. Fessehaie (2009) also see potential for irrigated sugarcane production in Lower Wabishebelle in Gode, Kelafo in the southeastern part of Ethiopia (120 000 hectares). This area is mainly located on shrubland and barren land, making it likely that an expansion in this area would occur on shrubland.

Smaller suitable areas include the river basins in Tekense in northern Ethiopia, and Ome-Ghibe and Lower Genale, both in the southern part of Ethiopia (Fessehaie, 2009). The Tekense river basin contains mainly savannah, whereas Ome-Ghibe and Lower Genale contain large forest areas. In addition, all areas contain relatively large areas of cropland, making an expansion on existing cropland another alternative.

The Abbay and Ome-ghibe river basins contain high densities of livestock (FAO, 2011b), making it likely that an expansion of sugarcane in these areas will occur on pastures. The other four areas contain relatively low densities of livestock. As mentioned, forest land and arable cropland land has historically been chosen for sugarcane production, instead of pastures (Lawek & Shiferaw, 2008), indicating that pastures probably are less likely to be used for an expansion in comparison to cropland and natural vegetation. Expansion on pastures is only a feasible alternative in areas close to the river deltas.

According to FAOSTAT data, the average yield for sugarcane in 2008 was 107 tonnes per hectare. Fessehaie (2009) reports that the potential yield in Ethiopia is 154 tonnes per hectare. Even though the yield-gap for sugarcane seems to be smaller than the national average for rainfed crops, Ethiopia still has a theoretical possibility to increase production with about 44%, by intensifying the cultivation or improving agricultural practices.

Castor

Historical developments

Between 1993 and 2008, castor production in Ethiopia increased by 40%. As seen in Figure 30, the increase has been made possible entirely by an increased harvested area, while yields have remained rather unchanged during the period.

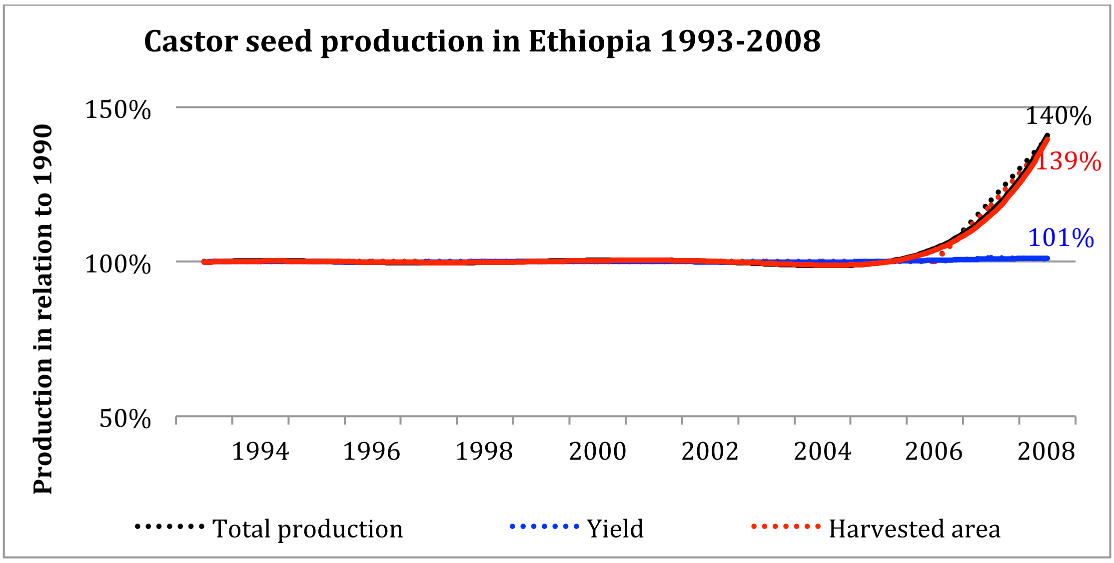


Figure 30: Change in castor production, yields and harvested area in Ethiopia, 1990-2008

Cultivation of castor in Ethiopia occupies a smaller land area than cultivation of jatropha or sugarcane (Lawek & Shiferaw, 2008). The largest area used for castor production is found in Oromia in central Ethiopia, which contains both large-scale and small-scale outgrower production. Castor has also been cultivated in Amahara in the northwest and SNNPR in southwestern Ethiopia. Most of the previous expansion has occurred on forestland and cropland (Lawek & Shiferaw, 2008).

Future production increases and resulting land-use dynamics

In contrary to sugarcane, castor has higher tolerance towards water stress. According to Fessehaie (2009) castor could be grown on lands in Afar in northeast Ethiopia, Kobo in northwest and Awash in central Ethiopia. However, these areas are densely populated and many small-scale farmers use them for growing sweet potato, taro and yam (Fessehaie 2009). It is therefore likely that arable land used for cultivation of these crops could be used for a potential expansion of castor production, since much of the expansion up until today has occurred on cropland.

Much of the land in Afar is barren, with some shrubland, savannah and other grassland (FAO, 2011a). An expansion of castor in the Afar region is therefore likely to occur on shrub- and grasslands, considering past developments. Afar has relatively little cropland that could be converted to castor production (FAO, 2011a). The Kobo region is mostly covered by Savannah, although with some cropland (FAO, 2011a), which could potentially be used to expand on. Awash has a varying land cover including forest, shrubland, savannah and other grassland. Like Kobo, Awash has large areas of cropland.

It is likely that areas currently used for castor production, such as Oromia in central Ethiopia, could be used for further expansion of castor. FAO (2011a) reports that there are still substantial amounts of uncultivated land suitable for castor production in the area. What regards natural vegetation, most of the land around the already existing cropland is savannah, although some forestland, which could be converted to castor production. According to Fessehaie (2009) companies are already starting to clear dry forests to make room for castor plantations.

Except for the western parts of Kobo, all four areas discussed above have a high density of livestock (FAO, 2011b). Since castor can be grown on marginal land, such as degraded pastures, expanding castor production on degraded pastureland can be a viable alternative in order to avoid conversion of undisturbed natural vegetation. Fessehaie (2009) reports that land formerly used for grazing are currently being converted into castor production.

Jatropha

The latest developments of jatropha cultivation have mainly occurred in Benishangul in the western part of Ethiopia. Areas in Amahara in the northwest and SNNPR in southwestern Ethiopia have also been cultivated, to a smaller extend. Most expansion has so far taken place on forest- and cropland (Lawek & Shiferaw, 2008). Country experts estimate the current land under Jatropha cultivation as 1,700 ha. This number is very likely to rise significantly as several foreign investors have applied for or already secured land titles. According to public sources, five Jatropha projects have already gone operational. Among the major investors are, according to public sources, Sunbiofuels, Global Energy and BioX Group (GEXI 2008)

According to Fessehaie (2009) Ethiopia holds around 23 million hectares of land that could be suitable for jatropha production. The five areas with the largest potential in terms of suitable area include Oromia in central Ethiopia (17 million hectare), Benshagul Gumz in the west (3 million hectares), Gambela in west (almost 3 million hectare), Somali in the southeast (1,5 million hectare) and Amhara in the central/south of Ethiopia (almost 1 million hectare).

Oromia, which according to Fessehaie (2009) has the largest area suitable for jatropha cultivation, is covered mostly by savannah but also largely by forest- and cropland. If an expansion occurs, it seems likely that savannah and forest will be converted. If an expansion occurs on Benshagul Gumz, it is likely to replace savannah. Amhara and Gambela are both to a large extent covered by savannahs and forests. Amhara also has large areas of cropland, which could be used for cultivation. Somali, on the other hand is mostly covered with shrubland and some barren land, making it likely that shrubland will be converted in case of a jatropha expansion.

The Ministry of Mines and Ministry of Energy in Ethiopia formulated a *Biofuel Development and Utilization Plan* in 2007. It reports that arable land should be preferred for biofuel feedstock production since that can be more economically viable than other types of land (Lawek & Shiferaw, 2008). If this is enforced, it is likely that already existing cropland will be used for production in all mentioned areas.

Since parts of Amahara and Oromia have large quantities of livestock (FAO, 2011b) expanding jatropha production on degraded pastureland can be a viable alternative in order to avoid conversion of undisturbed natural vegetation.

Yield-gap and available land for cultivation of rainfed crops

According to the Deininger et al (2011), Ethiopia's yield gap for rainfed crops is close to 80%. Therefore, by improving agricultural practices and/or intensifying cultivation, Ethiopia has a theoretical potential to increase the total production of rainfed crops with about 80%, without having to expand onto new land. Since large areas in

Ethiopia are occupied by rainfed cropping, achieving higher yields might be a profitable strategy.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, jatropha and castor bean in Ethiopia are summarised in
Table 28.

Table 28: Production system characteristics for sugarcane, jatropha and castor bean in Ethiopia

System component	Sugarcane	Jatropha	Castor bean
Large scale	Estates		Private companies
Small scale	Outgrowers		Outgrowers
Mechanized farming system			
Manual farming system	Harvesting		
Tillage			
Reduced and no tillage		Perennial crop	
Irrigated			
Rain fed			
Mono-cropping			
Multi-cropping			
Crop rotation		Perennial crop	
Mineral fertilizer used			
Chemical pesticides used			
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field		

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Anderson and Belay, 2008; Ayenew, 2007; Dove Biotech Ltd; FAO, 2005; Friends of the Earth, 2010; Heckett and Aklilu, 2008; IENICA, 2002; US Forest Service).

Observed local environmental impacts from sugarcane, jatropha and castor bean production in Ethiopia are summarised in Table 29.

Table 29: Observed local environmental impacts from sugarcane, jatropha and castor bean production in Ethiopia

Environmental impact	Sugarcane	Jatropha	Castor bean
Deforestation	[red]	[red]	[red]
Loss of agro-biodiversity	[white]	[red]	[red]
Loss of biodiversity	[red]	[red]	[red]
Air pollution	[red]	[white]	[green]
Water pollution	[red]	[white]	[green]
GMO contamination	[green]	[white]	[green]
Eutrophication	[red]	[white]	[green]
Soil fertility decline	[red]	[red]	[green]
Erosion	[red]	[red]	[red]

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information

Sources: (Anderson and Belay, 2008; Ayenew, 2007; Dove Biotech Ltd; FAO, 2005; Friends of the Earth, 2010; Heckett and Aklilu, 2008; IENICA, 2002; US Forest Service).

Local environmental impacts allocated to domestic biofuel production

Since no production of domestic biofuels from sugarcane, jatropha or castor has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in Ethiopia in 2008.

Local environmental impacts allocated to EU biofuel demands

The share of the total sugarcane area that was harvested for EU biofuel production was 0.5% in 2008. Since sugarcane cultivation for EU biofuel production has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total sugarcane area used for EU biofuel production (0.5%).

Since no feedstock for EU biofuels in 2008 has been traced to sugarcane, jatropha or castor produced in Ethiopia; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Anderson, T. and Belay, M. eds., 2008. *Rapid Assessment of Biofuels Development Status in Ethiopia and Proceedings of the National Workshop on Environmental Impact Assessment and Biofuels*. Addis Abeba: MELCA Mahiber.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

Dove Biotech Ltd., UNDATED. *Castor Bean (Ricinus Communis) An International Botanical Answer to Biodiesel production & Renewable energy*, Bangkok: Dove Biotech Ltd.

FAO, 2005. *AQUASTAT- FAO's Information System on Water and Agriculture: Ethiopia*. Available at: http://www.fao.org/nr/water/aquastat/countries/ethiopia/index.stm Accessed on February 21, 2011.

FAO, 2011a. *FAO country profile: Ethiopia. Map - Land cover*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO, 2011b. *FAO country profile: Ethiopia. Map – Livestock Bovine*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

Fessehaie, R., 2009. *The status of bio-fuels in Ethiopia: Opportunities and challenges*. Presentation at UUCN Regional Workshop on Bio-Fuls Production and Invasive Species, 20-22 April 2009, Nairobi, Kenya.

Friends of the Earth, 2010. *Africa: up for Grabs – The scale and impact of land grabbing for agrofuels*. Brussels: Friends of the Earth Europe.

Lawek, H. & Shiferaw, Y. (2008). *Rapid Assessment of Biofuels Development Status in Ethiopia And Proceedings of the National Workshop on Environmental Impact Assessment and Biofuels*. MELCA Mahiber, Publication No. 6.

GEXI, 2008. *Global Market Study on Jatropha Project Inventory: Africa*. The Global Exchange for Social Investment. Available at: http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Jatropha-Project-Inventory_AFRICA.pdf Accessed on May 12, 2011.

Heckett, T., and Aklilu, N. eds., 2008. *Agrofuel Development in Ethiopia: Rhetoric, Reality and Recommendations*. Addis Ababa: Forum for Environment.

IENICA, 2002. *Castor*. Available at: http://www.ienica.net/crops/castor.htm Accessed on February 24, 2011.

US Forest Service, UNDATED. *Ricinus communis L*. Available at: http://www.fs.fed.us/global/iitf/pdf/shrubs/Ricinus%20communis.pdf Accessed on February 24, 2011.

Malawi

Selected biofuel crops for Malawi include sugarcane and jatropha. As seen in Table 27, about 10% of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production, although none was exported to the EU. No biofuels for the EU market in 2008 have been traced to Malawi.

Table 30: Area used for production of Malawi's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	23	2	9.5%	0	0%
Jatropha	5	-	-	-	-

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

Historical developments

Between 1990 and 2008, sugarcane production in Ethiopia increased by 40%. As seen in Figure 31, the increase has been made possible almost entirely by an increased harvested area, while yields have remained rather unchanged during the period.

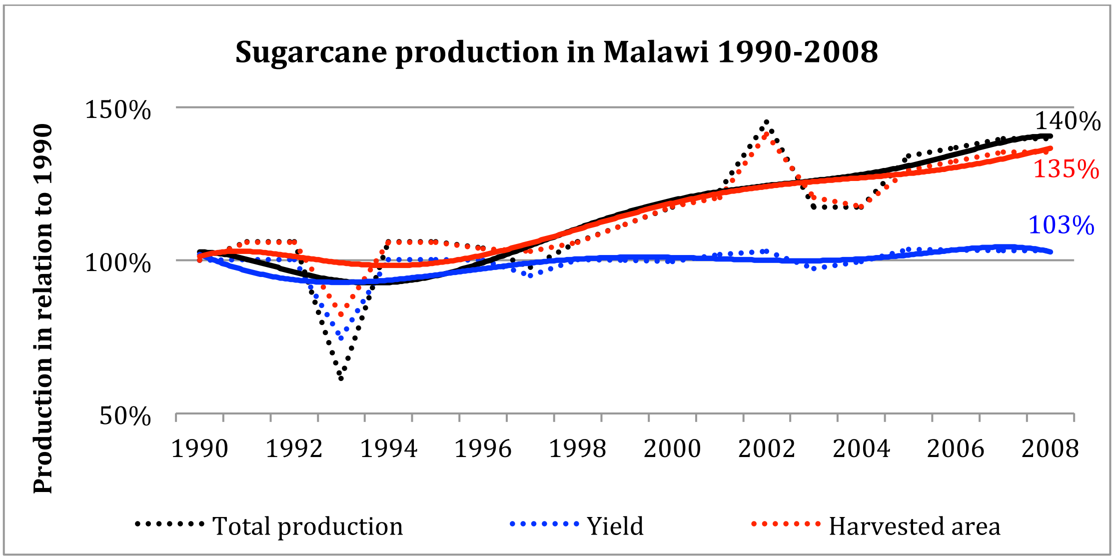


Figure 31: Change in sugarcane production, yields and harvested area in Malawi, 1990-2008

To promote sugarcane production the Malawian government established two schemes for smallholder farmers to produce sugar (Malawi government, 2005). These are located in Kasinhula in the Chikwawa district in southern Malawi and in Dwangwa in the Nikhotakota district near Lake Malawi. Dwanga is surrounded by forest areas, whereas Kasinhula contains mainly savannah with smaller forest areas (FAO, 2011).

Land-use dynamics from future production increases

According to the Malawian government (2005), there is a potential for expanding production in both areas hosting previously mentioned schemes. In that case, expansion is likely to occur on forest and/or savannah, considering the land cover in the areas (FAO, 2011). In addition to expanding existing schemes the Malawian government (2005) expresses that new schemes should be implemented, since there is a large demand for sugar. The schemes are currently promoting sugarcane for sugar production, but it is likely that an increased demand of sugarcane for ethanol production could be an additional driver for expanding the schemes and establishing new ones.

Cultivation of sugarcane requires irrigation but water management in Malawi is poor (FAO/WFP, 2005). Irrigation is uncommon even though almost one third of the country area consists of water. In fact all districts in Malawi have access to a water body, either a lake or a river (FAO, 2008). This means that sugarcane cultivation could, in theory, occur in all parts of the country.

Malawi is mostly covered by savannah, but has large areas of forest, especially along the coast of Lake Malawi (FAO, 2011). Considering the need for irrigation, it is possible that forest areas will be converted if production expands, since the lake can provide water resources without potential downstream effects and might in that sense be regarded as a beneficial water source.

Almost the entire food-crop production in Malawi is constituted by maize (90% of all cultivated land), but also by some cassava, pulses, sweet potato, fruit and vegetables (FAO, 2008). In the case of sugarcane becoming a profitable choice for farmers, it is likely that maize that will be replaced, provided that the area is irrigable.

Most grazing in Malawi occurs in the central parts and in some of the southern parts of the country (FAO, 2006). If sugarcane continue to expand in the regions where it mainly occurs today, it is less likely to occur on pastures, besides potentially in the southern parts near Kasinhula.

Jatropha

Legislation on biofuels already exists in Malawi, focusing on ethanol. It is currently opened up for including also Jatropha and other biofuel crops, under the responsibility of a Government task force including representatives from the Departments of Energy, Forestry and Agriculture. Jatropha must be grown on degraded land or as fences to prevent impediment of food production (GEXI 2008).

Jatropha has been promoted for several years as part of the agroforestry extension package in the 90s (Pratt and Satali 2001). Malawi has launched a multimillion-dollar program focusing on large-scale farming of the jatropha plant, normally planted around homesteads as a hedge/living screen, mainly in the Dedza and Ntcheu Districts. Climate Change Corporation reports that they have secured agreements with rural communities to plant jatropha on 20,000 hectares of land. It has also signed contracts with two of Malawi's leading tobacco companies to plant the trees on their land (GEXI 2008; Mkok and Shanahan, 2005).

Several small-to-medium sized projects with a total current acreage of 4,500 ha have been identified. They are predominantly privately owned and commercial outgrower schemes - sometimes in combination with plantations. Cultivation is reported to be low maintenance with no irrigation and little fertilisation. As of 2008, the largest project identified (2,000 ha) is operated by Bio Energy Resources Ltd. near Salina and in the Nkhotakota area. The organisation C3 has set up an outgrower scheme and nurseries near Salina.

There is little information available on Jatropha cultivation in Malawi, making potential land-use dynamics difficult to assess.

Yield-gap and available land for cultivation of rainfed crops

According to the Deininger et al (2011), Malawi's yield gap for rainfed crops is about 85%. Therefore, by improving agricultural practices and/or intensifying cultivation, Malawi has a theoretical potential to increase the total production of rainfed crops with about 85%, without having to expand onto new land. Being a densely populated country, Malawi is already cultivating most of the land that is suitable for rainfed cultivation. Therefore, closing yield-gaps is essential for achieving significant increases in rainfed crop production in Malawi.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane and jatropha in Malawi are summarised in Table 31.

Table 31: Production system characteristics for sugarcane and jatropha in Malawi

System component	Sugarcane	Jatropha
Large scale	Dominating	
Small scale	Outgrower schemes	
Mechanized farming system		
Manual farming system	Dominating	
Tillage		
Reduced and no tillage		Perennial crop
Irrigated	Dominating	
Rain fed		
Mono-cropping		
Multi-cropping		
Crop rotation		Perennial crop
Mineral fertilizer used		
Chemical pesticides used		
GMO seeds for sowing		
Land preparation with fire		
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field	Mosquito repellent from seed cake

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Frenken, 2005; J.H. Pratt &L.B. Satali, 2001; Mkoka and Shanahan, 2005; WWF, 2005).

Observed local environmental impacts from sugarcane and jatropha production in Malawi are summarised in Table 32.

Table 32: Observed local environmental impacts from sugarcane and jatropha production in Malawi

Environmental impact	Sugarcane	Jatropha
Deforestation		
Loss of agro-biodiversity		
Loss of biodiversity		
Air pollution		
Water pollution		
GMO contamination		
Eutrophication		
Soil fertility decline		
Erosion		

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Frenken, 2005; J.H. Pratt &L.B. Satali, 2001; Mkoka and Shanahan, 2005; WWF, 2005).

Local environmental impacts allocated to domestic biofuel production

The share of the total sugarcane area that was harvested for domestic biofuel production was 9.5% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (9.5%).

Since no production of domestic biofuels from jatropha has been identified for 2008; no local environmental impacts from cultivation of jatropha can be allocated to domestic biofuel production in Malawi.

Local environmental impacts allocated to EU biofuel demands

Since no feedstock for EU biofuels in 2008 has been traced to sugarcane or jatropha produced in Malawi; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Brittaine, R. and Lutaladio, N., 2010. *Jatropha: A Smallholder Bioenergy Crop. The Potential for Pro-Poor Development*. Rome: Food and Agriculture Organization of the United Nations (FAO) and International Fund for Agricultural Development (IFAD) (Integrated Crop Management Vol. 8–2010).

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

FAO, 2006. *Country Pasture/Forage Resource Profiles – Malawi.* Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO, 2008. *Nutrition Country Profile – Republic of Malawi*. Rome: FAO.

FAO, 2011. *FAO country profile: Malawi. Map - Land cover*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO/WFP, 2005. *Special Report: FAO/WFP Crop and Food Supply Assessment Mission to Malawi - 20 June 2005*. FAO/WFP.

Frenken, K., 2005. *Irrigation in Africa in figures, AQUASTAT Survey – 2005*. Rome: FAO.

GEXI, 2008. *Global Market Study on Jatropha Project Inventory: Africa*. The Global Exchange for Social Investment. Available at: http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Jatropha-Project-Inventory_AFRICA.pdf Accessed on May 12, 2011.

Malawian government, 2005. *Support to NEPAD–CAADP implementation. Volume II of V. Bankable investment project profile – Commercialization of High-Value Crop*. NEPAD/FAO.

Pratt, J. H. and Satali, L. B., 2001. *MAFE Marketing & Enterprise Program (MEP)*

Mkoka, C. and Shanahan, M., 2005. *The bumpy road to clean, green fuel*. Available at: http://www.scidev.net/en/features/the-bumpy-road-to-clean-green-fuel.html Accessed on 25 May, 2011.

WWF, 2005. Sugar and the Environment: Encouraging Better Management Practices in sugar production. Zeist: WWF Global Freshwater Programme.

Mozambique

Selected biofuel crops for Mozambique include sugarcane and jatropha. As seen in Table 27, domestic biofuel production has not been possible to identify or estimate, for neither of the crops. No biofuels for the EU market in 2008 have been traced to Mozambique.

Table 33: Area used for production of Mozambique's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	180	-	-	-	-
Jatropha	8	-	-	-	-

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

As seen in Figure 32, pastures constitute the largest share of the total agricultural area in Mozambique. Permanent crops are uncommon compared to annual crops, which are dominating the cultivated land. Jatropha plantings in 2008 were rather insignificant while sugarcane cultivations constituted about 4% of the total land under annual crops in 2008.

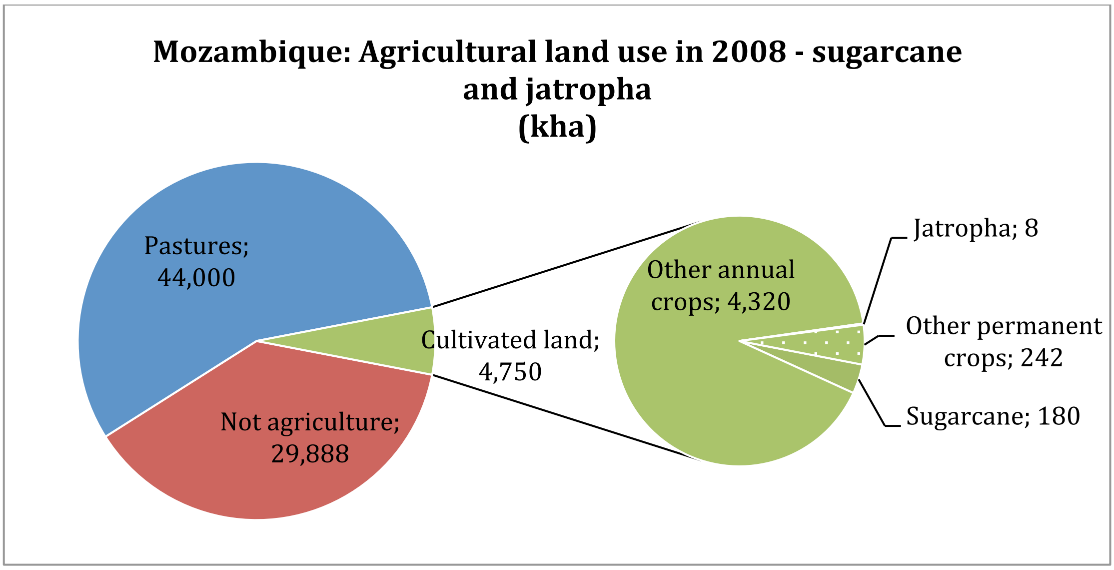


Figure 32: Agricultural land use in Mozambique in 2008, focused on sugarcane and jatropha production

Sugarcane

Historical developments

Between 1990 and 2008, sugarcane production in Mozambique increased by 639%. As seen in Figure 33, the increase has been made possible almost entirely by an increased harvested area, while yields have remained rather unchanged during the period. Most of the production increase and expansion occurred after 2000.

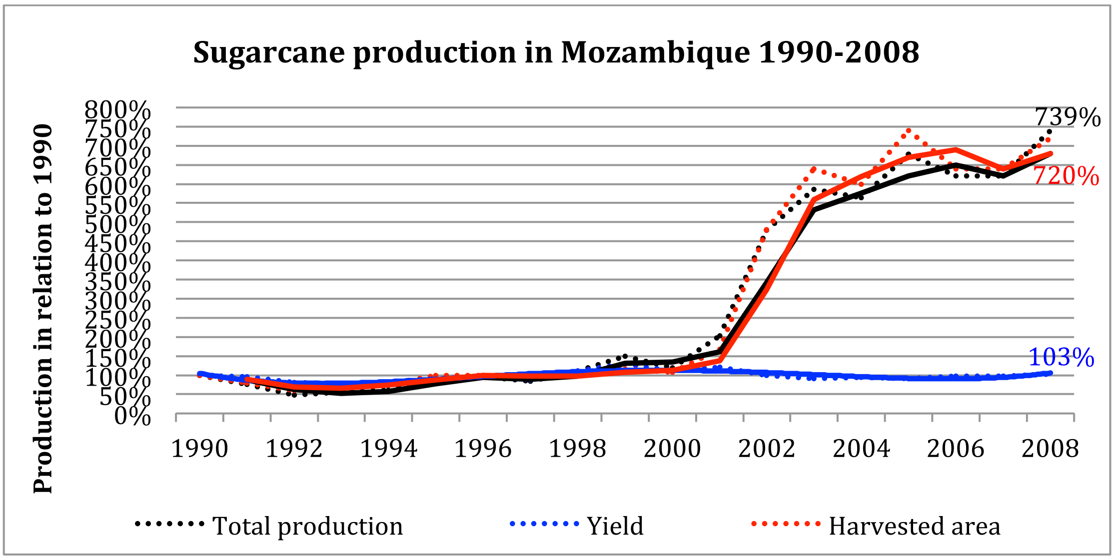


Figure 33: Change in sugarcane production, yields and harvested area in Mozambique, 1990-2008

Several sugarcane plantations are located in areas with easy access to water for irrigation, around rivers and dams (Nhantombo & Salamão, 2010). Popular areas for sugarcane production are the areas around the Incomati river, in Maputo in the southern part of Mozambique, the areas around the Buzi and Zambezi rivers in Sofala in central Mozambique as well as around Lurio and other rivers in in Cabo Delgado in the northern part of Mozambique.

Land-use dynamics from future production increases

By the end of 2008, Mozambique had formally received 17 investment proposals for biofuel projects (Schut et al., 2010). Five of these proposals were focused on ethanol production, mainly from sugarcane. As of 2010, three out of these five had been approved. The projects are located in Sofala (15 000 ha mainly sugarcane), Manica in the central parts (18 000 ha sugarcane) and Gaza in the northern parts of the country (30 000 ha sugarcane). There are also planned or suggested sugarcane projects in the areas of Cabo Delgado (Nhantombo & Salamão, 2010) and in Maputo (Nhantombo & Salamão, 2010; Schut et al., 2010).

The five regions identified as suitable for sugarcane production are all covered with savannah and some woodland (FAO, 2011a), making it likely that these types of vegetation can be converted in case of a sugarcane expansion. This is supported by Atanassov (2011), who reports that savannahs and forestland are likely to be converted in case of a sugarcane expansion in Mozambique.

Cropland for other types of production are established in all five regions identified as suitable for sugarcane production (FAO, 2011a). Atanassov (2011) believes that an expansion on existing cropland is very likely, but is not likely to replace any specific crops.

Most parts of Mozambique have low densities of livestock (FAO, 2011b), which makes it less likely that a potential expansion of sugarcane would occur on pastures.

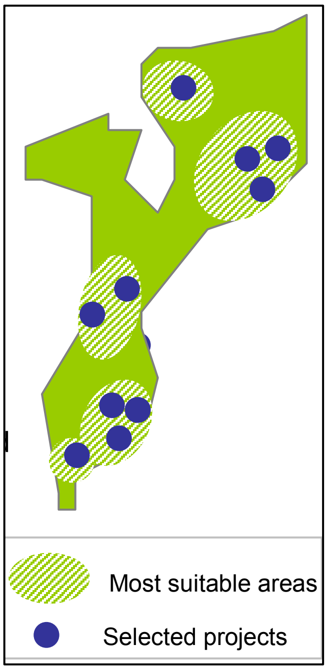
This is also supported by Atanassov (2011). The Maputo area, in the northern part of Mozambique, has a higher density of livestock than the other areas, but still relatively few animals per square meter.

According to Schut et al. (2010) the average yields of the officially proposed sugarcane projects are expected to be around 50% higher than the highest yields achieved by industries in Mozambique during the past five years (113,3 ton per hectare compared to 72 ton per hectare). A technology transfer from these projects to domestic sugarcane production might therefore result in an increased average yield and consequently help to decrease the immediate demand for land, that otherwise would be likely in the event of an increased demand for sugarcane.

Jatropha

The climatic and political situation in Mozambique is in general considered favourable for commercial Jatropha cultivation. Local experts suggest a significant increase in Jatropha cultivation to 170,000 ha by 2015. Project owners as well state optimistic plans for growth – especially for commercial plantations (GEXI 2008).

Prior to 2006, only small quantities of oilseed were produced in Mozambique, for domestic use, and no biodiesel was produced from jatropha (Schut et al., 2010). Out of the 17 formally proposed biofuel projects in Mozambique, 12 are biodiesel projects mainly focused on jatropha (Schut et al., 2010). By 2010, only one has formally been approved; a Jatropha plantation on 18 920 ha located in Sofala in the central parts of Mozambique. The other formal proposals are distributed in all but one of the provinces in Mozambique (Tete, in the northwest part). However, the proposed projects are mainly located in the central parts of Mozambique (Manica, Sofala and Zambézia) and along the cost of Inhambane in the southern parts of the country. Even though only one jatropha project has been formally approved according to Schut et al. (2010), five projects had started cultivating jatropha in 2008 and another 7 projects were initiating operations (GEXI 2008). The vast majority of Jatropha projects are found in the southern provinces Inhambane and Gaza, the central provinces Sofala and Manica as well as in the Northern Provinces of Nampula (see figure). Climatic features in these regions are reported advantageous for Jatropha cultivation, especially the sandy soils of Inhambane and Gaza (see figure). Some local experts reported a lower growth rate for Jatropha on sites in the central-western area, which may be related to soil characteristics.



Source: (GEXI 2008)

According to Atanassov (2011), jatropha production is very likely to occur on natural vegetation such as savannah, forestland and costal vegetation. This is partly supported by available information about the proposed projects, as reported by GEXI (2008) and Schut et al. (2010). Several of the most important provinces in regard to existing and proposed projects are located in the southern areas near the coast and in addition to coastal vegetation; they contain both forestland and savannahs (FAO, 2011b).

Large areas of cropland exist in most provinces that have been targeted by jatropha projects (FAO, 2011a), indicating that cropland might be converted in case of an increased jatropha expansion. Atanassov (2011) supports this by claiming that an expansion of jatropha on cropland is likely to occur, although not likely to replace any specific crops. As previously mentioned, the livestock density is low in Mozambique (FAO, 2011b), indicating that an expansion of jatropha on pastures is less likely. Atanassov (2011) supports this by claiming that a potential expansion of jatropha is unlikely to occur on pastures.

Yield-gap and available land for cultivation of rainfed crops

According to the Deininger et al (2011), Mozambique's yield gap for rainfed crops is about 90%. Therefore, by improving agricultural practices and/or intensifying cultivation, Mozambique has a theoretical potential to increase the total production of rainfed crops with about 90%, without having to expand onto new land. However, since unused land suitable for production of rainfed crops is rather abundant (only 25% is currently under cultivation) (Deininger et al 2011), incentives to increase yields in Mozambique may be lower compared to countries with lower land availability, such as Malawi.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane and jatropha in Mozambique are summarised in Table 34.

Table 34: Production system characteristics for sugarcane and jatropha in Mozambique

System component	Sugarcane	Jatropha
Large scale	Outgrowers	Industrial
Small scale	Outgrowers	Experimental
Mechanized farming system		
Manual farming system	Dominant	
Tillage		
Reduced and no tillage		Perennial crop
Irrigated	Limited scale	Manual and industrial irrigation in south, partial manual irrigation in the beginning of the plantation/propagation process, central areas
Rain fed		
Mono-cropping		
Multi-cropping		Small scale – not recommended with cassava as they are from same family
Crop rotation		Perennial crop
Mineral fertilizer used		
Chemical pesticides used		
GMO seeds for sowing		
Land preparation with fire		
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field	

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Friends of the Earth, 2010; Jelsma et al., 2010; WorldBank, 2008).

97% of the cultivated land in Mozambique is comprised of 3 million family-based small-scale farms, with a average farm size of about 1.24 hectares and very rarely exceeding 5 hectares. Nevertheless, small farmers produce about 95% of the country's agricultural GDP. The small-scale production system is characterised by manual work, use of simple cultivation techniques, rainfed farming systems without use of chemicals, while the large-scale plantation system is characterised by mechanisation, large-scale irrigation and chemical input usage. Jatropha, has largely, until recently, been planted as hedge or a living fence. Now jatropha is also grown as cash crop and produced industrially making use of chemical based fertilizers and pesticides.

Observed local environmental impacts from sugarcane and jatropha production in Mozambique are summarised in Table 35.

Table 35: Observed local environmental impacts from sugarcane and jatropha production in Mozambique

Environmental impact	Sugarcane	Jatropha
Deforestation		
Loss of agro-biodiversity		
Loss of biodiversity		Can be invasive to native species and agroforestry systems
Air pollution		
Water pollution		
GMO contamination		
Eutrophication		
Soil fertility decline		
Erosion		

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Friends of the Earth, 2010; Jelsma et al., 2010; WorldBank, 2008).

Local environmental impacts allocated to domestic biofuel production

Since no production of domestic biofuels from sugarcane or jatropha has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in Mozambique.

Local environmental impacts allocated to EU biofuel demands

Since no feedstock for EU biofuels in 2008 has been traced to sugarcane or jatropha produced in Mozambique; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Atanassov, B., 2011. *Expert consultation*. Boris Atanassov, Director GreenLight Ltd.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

FAO, 2011a. *FAO country profile: Mozambique. Map - Land cover*. Available: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO, 2011b. *FAO country profile: Mozambique. Map – Livestock Bovine*. Available: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

Friends of the Earth. 2010. *The Jatropha trap? The realities of farming Jatropha in Mozambique*. Amsterdam: Friends of the Earth. (May 2010, Issue 118).

GEXI, 2008. *Global Market Study on Jatropha Project Inventory: Africa*. The Global Exchange for Social Investment. Available at: http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Jatropha-Project-Inventory_AFRICA.pdf Accessed on May 12, 2011.

Jelsma, I., Bolding, A. and Slingerland, M., 2010. *Smallholder Sugarcane Production Systems in Xinavane, Mozambique: Report from the Field*. Wageningen: Wageningen University, Plant Science Group, Plant Production Systems.

Nhantombo, I. and Salamão, A., 2010. *Biofuels, land access and rural livelihoods in Mozambique*. London: IIED.

Schut, M., Slingerland, M. and Locke, A., 2010. Biofuel developments in Mozambique. Update and analysis of policy, potential and reality. *Energy Policy,* 38(9), pp.5151-5165.

World Bank, 2008. *Mozambique Biofuels Assessment*. Maputo: World Bank.

Nigeria

Selected biofuel crops for Nigeria include oil palm, soybean and cassava. As seen in Table 36, domestic biofuel production has not been possible to identify or estimate, for neither of the crops. No biofuels for the EU market in 2008 have been traced to Nigeria.

Table 36: Area used for production of Nigeria's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Oil palm	3,200	0	0%	0	0%
Soybean	609	0	0%	0	0%
Cassava	3,778	-	-	0	0%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Oil Palm

Historical developments

Between 1990 and 2008, Oil Palm production in Nigeria increased by 37%. As seen in Figure 34, the increase has been made possible entirely by an increased harvested area, while yields have remained rather unchanged during the period.

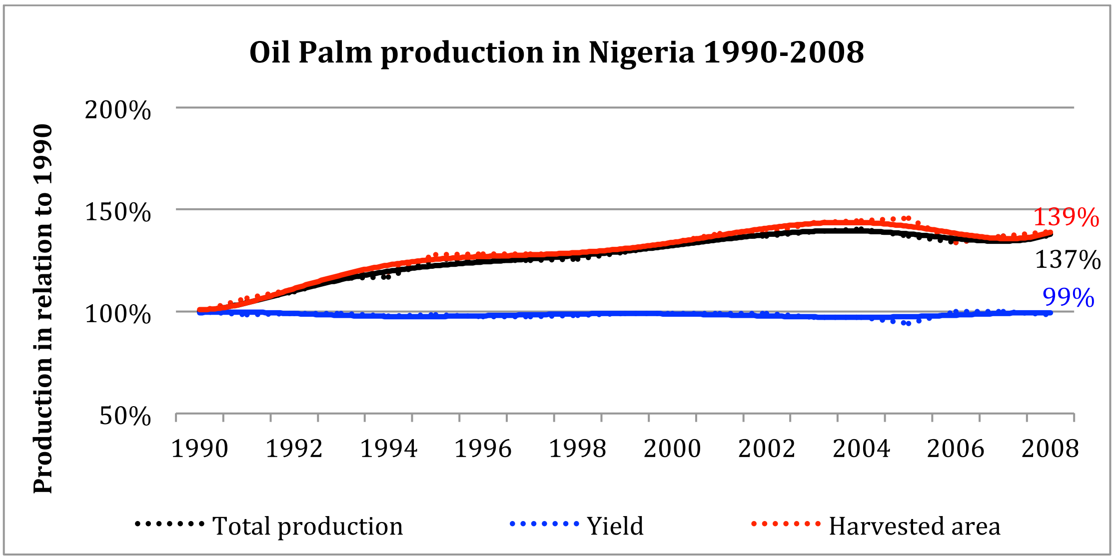


Figure 34: Change in oil palm production, yields and harvested area in Nigeria, 1990-2008

Oil palm is grown in the southern, more humid parts of Nigeria and in the tropical high forest zones (FAO, 2006). It is likely that forests have been cleared for establishing the plantations. Most of the oil palm plantations in the eastern and western parts on Nigeria are old and have low productivity (Abila, 2010).

Land-use dynamics from future production increases

Abila (2011) argues that if cultural practices and plantations maintenance were intensified, the production of oil palm would probably increase in Nigeria. Considering that the oil palm plantations in the eastern and western parts are old with low yields (Abila, 2010), there is a potential to improve the production in these areas.

If the production of oil palm would increase in Nigeria, expansion would most likely occur on existing farmland, according to Abila (2011). Farmers would likely shift to producing oil palm for increasing income. It is however difficult to say if there are any particular types of crops that would be replaced by oil palm production.

A potential expansion is not likely to occur on pastures or natural vegetation, according to Abili (2011), but rather on abandoned, unused or underutilized arable land. Especially arable land not under aided fallow or undertaken by invasive species is likely to be used. It is also likely that old plantations that were used for production of cash crops, but have been rendered unproductive due to fires or neglect, could be used.

Soybean

Historical developments

Between 1990 and 2008, Soybean production in Nigeria increased by 171%. As seen in Figure 35, the increase has been made possible entirely by continuously increasing yields, while the harvested area seems to have decreased by 16% since 1990.

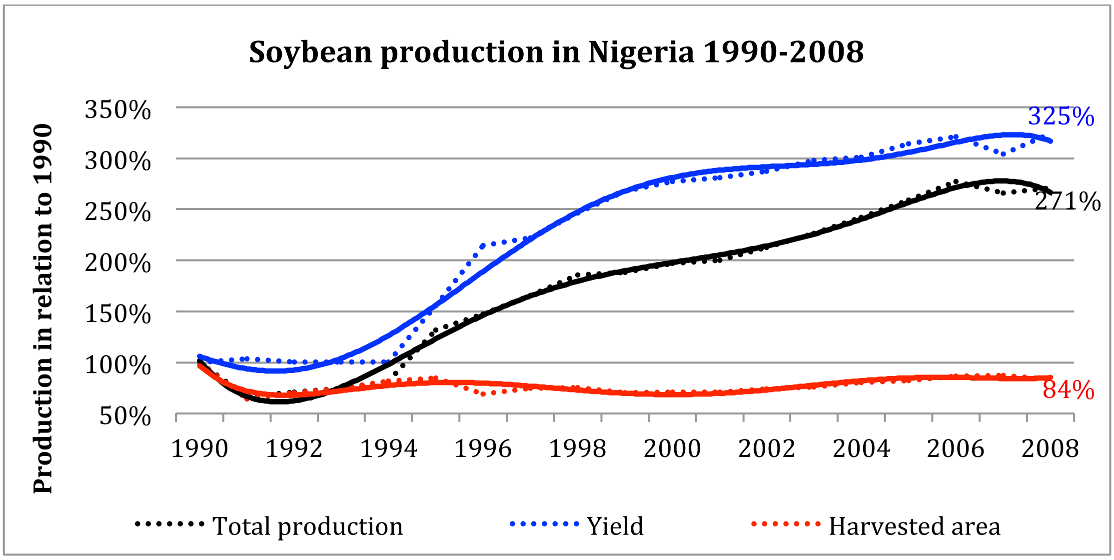


Figure 35: Change in soybean production, yields and harvested area in Nigeria, 1990-2008

Land-use dynamics from future production increases

According to Abila (2011), increased production of soybean in Nigeria is very likely to occur on existing arable farmland, where it is likely to replace crops growing during the same season as soybean, such as maize, sesame or other beans. Most food crops are produced in the central and western parts of Nigeria (FAO, 2006). It is not likely that soybean production would occur on pastures or on natural vegetation, according to Abili (2011).

As also seen in Figure 35, Abila (2011) reports that farmland devoted to production of soybean has not increased the past decades. Instead yields have increased significantly during the past decades as a result of better practices and better seeds. With an increased demand for soybean, these practices are likely to be implemented more widely. This could help to keep the demand for land low, even though the demand for soybean increases.

Studies have also shown that soybean can be intercropped with cassava, for example in the southeastern parts of Nigeria (Umeh & Mbah, 2008). Soybean, being a nitrogen-fixating crop, acts as a soil improver by increasing the nitrogen concentration in the soil. Rotating these biofuel crops can thus be a potentially beneficial strategy for Nigeria.

Cassava

Nigeria is the world's largest cassava producer (Truman et al. 2004). Over the last decade, cassava has evolved in Nigeria from a mere food security crop to a cash and industrial crop (IITA 2011) . Cassava is one of the most important food crops for both urban and rural consumers in Nigeria (FAO 2005). The cassava roots are processed into granules, pastes, flours, chips etc., or consumed freshly boiled or raw, also the leaves are also consumed as a green vegetable (providing protein and vitamins A and B) (IITA, 2011). Cassava has many qualities as a crop which makes it appreciated by farmers; the ability to grow on marginal lands where cereals and other crops do not grow well; it can tolerate drought and can grow in low-nutrient soils, cassava roots can be stored in the ground for up to 24-36 months (depending on variety), harvest may be delayed until market, processing, or other conditions are favourable (IITA, 2011). Research is on-going into genetically modified forms of cassava financed by the Nigerian government and Shell (Friends of the Earth, 2010).

Historical developments

Between 1990 and 2008, cassava production in Nigeria increased by 134%. As seen in Figure 36, the increase has been made possible entirely by an increased harvested area, while yields have remained rather unchanged during the period.

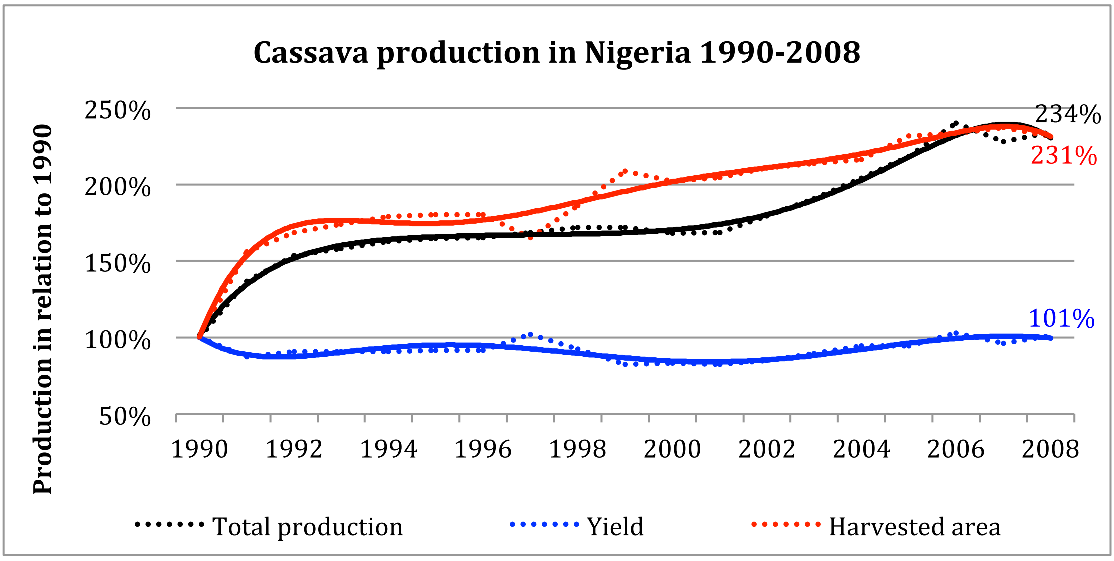


Figure 36: Change in cassava production, yields and harvested area in Nigeria, 1990-2008

Most food crops, including cassava, are grown in the central and western parts of Nigeria (FAO 2006).

Land-use dynamics from future production increases

Abila (2011) refers to cassava as a "crop of the poor". Increased population in Nigeria has caused unemployment and inflation and since the price of cassava has remained relatively stable, the production of cassava has increased with population.

Although Nigeria has large oil reserves, the country is still a large importer of refined oil products such as gasoline (Ohimain, 2010). Lately, Nigeria has shown interest in ethanol and has imported large quantities from Brazil. There are several emerging bioethanol projects in Nigeria, although mainly focused on domestic consumption. Out of twenty projects, half are focused on ethanol production from cassava. Most of the projects are planned to be located in the southern/southwest parts of Nigeria, in which forest is the main land cover (FAO, 2011). According to Abali (2011), it is likely that cassava expansion would occur on natural vegetation, mainly forests recovering from agricultural overuse. It is not likely that pastures would be used for cassava (Abila 2011).

Abila (2011) reports that cassava production is most likely to occur on already existing farmland, and likely to replace other tubers such as yams. Yams require more input and takes a longer time to mature. According to Ohimain (2010) an increased interest in crop production for ethanol purposes, e.g. sugarcane, sweet sorghum and cassava, is likely to shift cultivation from maize, rice and yams.

Yield-gap and available land for cultivation of rainfed crops

According to the Deininger et al (2011), Nigeria's yield gap for rainfed crops is about 80%. Therefore, by improving agricultural practices and/or intensifying cultivation, Nigeria has a theoretical potential to increase the total production of rainfed crops with about 80%, without having to expand onto new land. Since unused land suitable for production of rainfed crops is scarce (more than 90% is already under cultivation)

(Deininger et al 2011), incentives to increase yields in Nigeria may be higher compared to countries with higher land availability, such as Mozambique. This supports Abali's (2011) statements on soybean production.

Production system characteristics and local environmental impacts

Production system characteristics for oil palm, soybean and cassava in Nigeria are summarised in Table 37.

Table 37: Production system characteristics for oil palm, soybean and in Nigeria

System component	Oil Palm	Soybean	Cassava
Large scale	370 000 ha[12] out of some intercropped with cassava		
Small scale	80-90%		
Mechanized farming system			
Manual farming system	Dominating	Dominating	
Tillage			
Reduced and no tillage	Perennial crop		
Irrigated			
Rain fed			
Mono-cropping			
Multi-cropping	Dominant		E.g. vegetables, plantation crops (such as coconut, oil palm, and coffee), yams, sweet potato, melon, maize, rice, groundnut, or other legumes
Crop rotation	Perennial crop		
Mineral fertilizer used			Although in limited scale
Chemical pesticides used	Some are banned in the EU	Observe that "Paraquat" is recommended	Although in limited scale
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)			

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information

Sources: (Dugje et al., 2009; Waters-Bayer, 1988).

---

[12] Source: *Oil World Monthly*, april 2006; *Oil Annual* 2005.

Observed local environmental impacts from oil palm, soybean and cassava production in Nigeria are summarised in Table 38.

Oil palm is a native species in many West African countries. Nigeria has set a national target for using up to 10% domestically produced agrofuel in transport fuel by 2020. Roads constructed for the oil palm plantations and mills increase the access to previously remote areas, facilitating logging and hunting. Nigeria’s forests are only some 10% of the size they were just two decades ago, but they still provide an incredibly rich and diverse habitat. Poisoned fishponds from pesticide use in oil palm plantations have been observed. In Nigeria, farmers use pesticides banned in Europe. There is also evidence on altered hydrology. Oil palm plantations have led to compaction of soils, as well as soil and water mining. Oil palm is a native species in many West African countries. Nigeria has set a national target for using up to 10% domestically produced agrofuel in transport fuel by 2020.

Soybean production in Nigeria is mainly small holder non-mechanised for domestic food market, and industrial use (FAO 2004). Nigeria is the largest producer of soybeans for food in West and Central Africa. (Waters-Bayer 1988).

Table 38: Observed local environmental impacts from oil palm, soybean and cassava production in Nigeria

Environmental impact	Oil Palm	Soybean	Cassava
Deforestation			
Loss of agro-biodiversity			
Loss of biodiversity			
Air pollution			
Water pollution			
GMO contamination			
Eutrophication			
Soil fertility decline			
Erosion			

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Dugje et al., 2009; Waters-Bayer, 1988).

Local environmental impacts allocated to domestic biofuel production

Since no production of domestic biofuels from oil palm, soybean or cassava has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in Nigeria.

Local environmental impacts allocated to EU biofuel demands

Since no feedstock for EU biofuels in 2008 has been traced to oil palm, soybean or cassava produced in Nigeria; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Abila, N., 2010. Biofuels adoption in Nigeria: A preliminary review of feedstock and fuel production potentials. *Management of Environmental Quality*, 21(6), pp.785-795.

Abila, N., 2011. *Expert consultation: Nelson Abila, Business Development Consultant at Millennium Village Project.*

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

Dugje, I.Y., Omoigui, L.O., Ekeleme, F., Bandyopadhyay, R., Lava Kumar, P. and Kamar, A.Y., 2009. *Farmers' Guide to Soybean Production in Northern Nigeria*. Ibadan: International Institute of Tropical Agriculture (IITA).

FAO, 2004. *The role of soybean in fighting world hunger*. Rome: FAO Commodities and Trade Division, Basic Foodstuffs Service.

FAO, 2005. *A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin*. Rome: Food and Agriculture Organisation of the United Nations.

FAO, 2006. *Country Pasture/Forage Resource Profiles – Nigeria.* Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO, 2011. *FAO country profile: Nigeria. Map - Land cover*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

Friends of the Earth, 2010. *Africa: up for Grabs – The scale and impact of land grabbing for agrofuels*. Brussels: Friends of the Earth Europe.

IITA, 2011. Available at http://www.iita.org/ Accessed on May 30, 2011.

Ohimain, E.I., 2010. Emerging bio-ethanol projects in Nigeria: Their opportunities and challenges. *Energy Policy* 38(11), pp.7161-7168.

Truman, P.P., Taylor, D.S., Sanni, L., and Akoroda, M.O., 2004. *A Cassava Industrial Revolution in Nigeria: The Potential for a New Industrial Crop*. Rome: Food and Agriculture Organisation of the United Nations.

Umeh, S.I. & Mbah, B.N., 2010. Intercrop performance of different varieties of soybean (Glycine Max. (L) Merril) in a cassava (Manihot esculenta Crantz) based cropping system within the derived savannah zone. *African Journal of Biotechnology*, 9(50), pp.8636-8642.

Waters-Bayer, A., 1988. Soybean Daddawa: an innovation by Nigerian Women. *ILEIA Newsletter*, 4(3), October 1988.

Sudan

Selected biofuel crops for Nigeria include sugarcane, soybean and millet. As seen in Table 36, domestic biofuel production has not been possible to identify or estimate, for neither of the crops. No biofuels for the EU market in 2008 have been traced to Sudan.

Table 39: Area used for production of Sudan's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	69	-	-	-	-
Sorghum	6,619	-	-	-	-
Millet	2,333	-	-	-	-

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

Historical developments

Between 1990 and 2008, sugarcane production in Sudan increased by 77%. As seen in Figure 37, the increase has been made possible mostly by continuously increasing yields, while the harvested area increased by 6% since 1990.

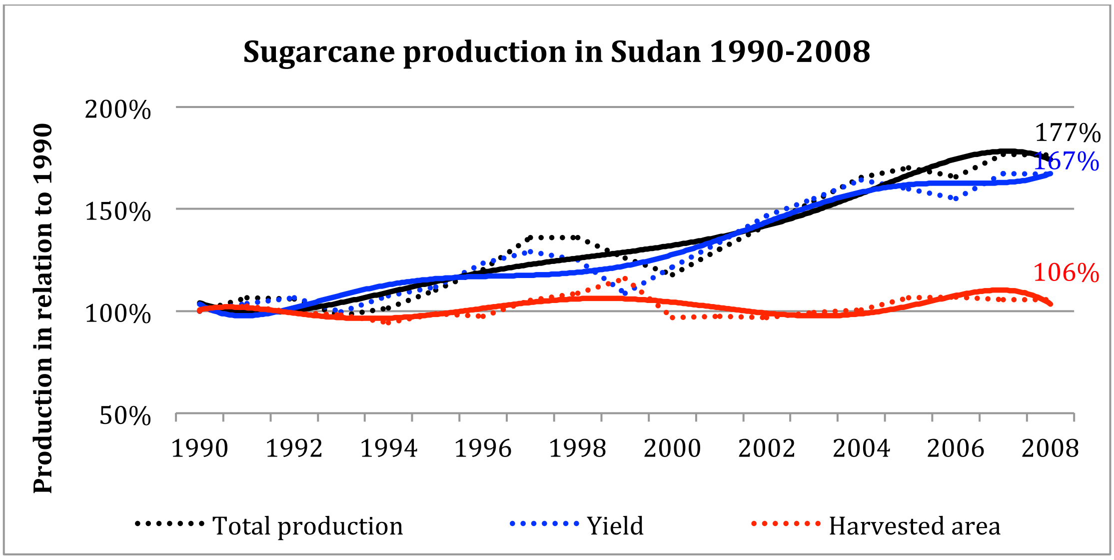


Figure 37: Change in sugarcane production, yields and harvested area in Sudan, 1990-2008

Large parts of northern Sudan are covered with barren desert land (FAO, 2006). Most of the large-scale cultivation initiatives in Sudan are located in the low rainfall savannah zone south of the desert. The zone stretches along the central parts of Sudan and along parts of the river Nile. There are three large-scale sugarcane plantations located in the central/east parts in the irrigated area near the river Nile.

Land-use dynamics from future production increases

Large parts of the savannah are cultivated with rainfed crops and have limited possibilities for irrigation (FAO, 2006). If sugarcane production expands in Sudan it is likely to occur in areas close to where it is currently cultivated, along the upper parts of the river Nile. Few other areas in Sudan have possibilities for irrigation. According to Gaiballa (2011), natural vegetation is likely to be converted in case of sugarcane expansion. Natural vegetation surrounding existing sugarcane plantations is primarily savannah, making it likely that savannah can be converted to sugarcane production in case of an increased demand for sugarcane.

Gaiballa (2011) reports that sugarcane production is not likely to occur on existing cropland. Since there are several large-scale agricultural initiatives in the irrigated areas around the river Nile (FAO, 2006), irrigation has a potential to be extended to new sugarcane initiatives in the near vicinity.

According to Gaiballa (2011), pastures on the rangelands in central Sudan are likely to be used for an expansion of sugarcane production. According to FAO (2006), free grazing on these rangelands is the most common type of managing livestock. Areas in these rangelands with possibilities for irrigation can therefore be suitable for sugarcane production, supporting Gaiballa’s (2011) statement.

Sorghum

Historical developments

Between 1990 and 2008, sorghum production in Nigeria increased by 228%. As seen in Figure 38, the increase has been made possible mostly by an increased harvested area. Yields increased with 37% during the period. There have been significant fluctuations in production and harvested area during the period. Yields have also been fluctuating, although to a smaller extent. Reasons for the fluctuations are unknown.

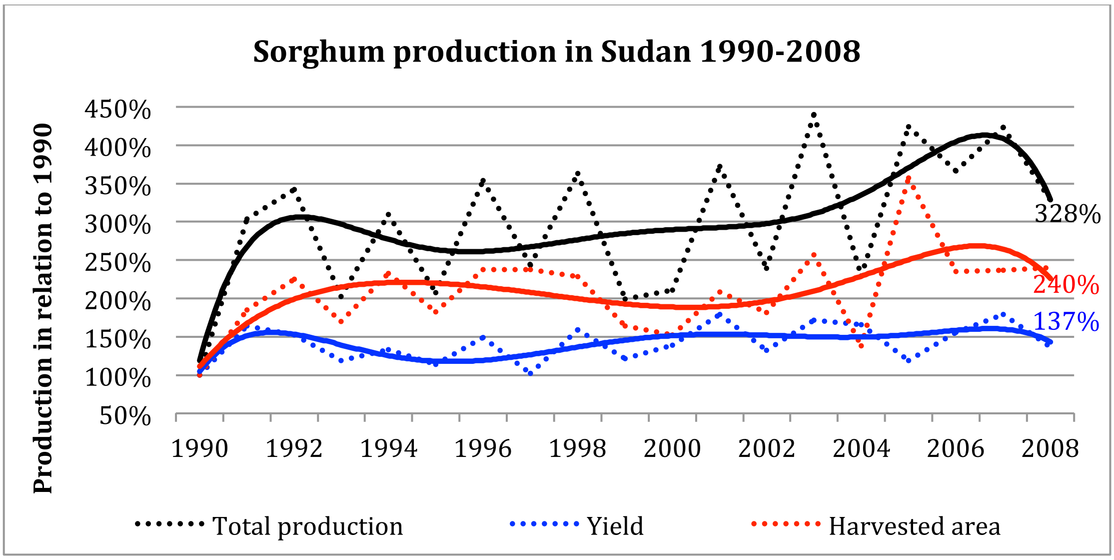


Figure 38: Change in sorghum production, yields and harvested area in Sudan, 1990-2008

Sorghum is the most commonly cultivated cereal crop in Sudan and is cultivated both in the northern semi-desert zones, on soils with high clay content, as well as in the flood plains in the southern part of Sudan (GIEWS, 2011). Most of the cultivation is rainfed (FAO, 2006).

Land-use dynamics from future production increases

Sorghum does not require irrigation in the same was as sugarcane and could therefore be cultivated on land where it is not possible to irrigate, such as central parts of Sudan with longer distance to the river Nile. According to Gaiballa (2011), a potential expansion of sorghum is not likely to occur on existing farmland. Instead he states that such an expansion is most likely to occur on natural vegetation. Since Sudan is mostly covered by savannah and only has small areas of other grassland, forest and shrubland, it is likely that savannah will be converted to sorghum production if the demand increases.

Gaiballa (2011) argues that sorghum and pastures are unlikely to compete for land in case of a sorghum expansion.

Millet

Historical developments

Between 1990 and 2008, millet production in Nigeria increased by 748%. As seen in Figure 39, the increase has been made possible both by an increased harvested area (+253%) and increased yields (+141%).

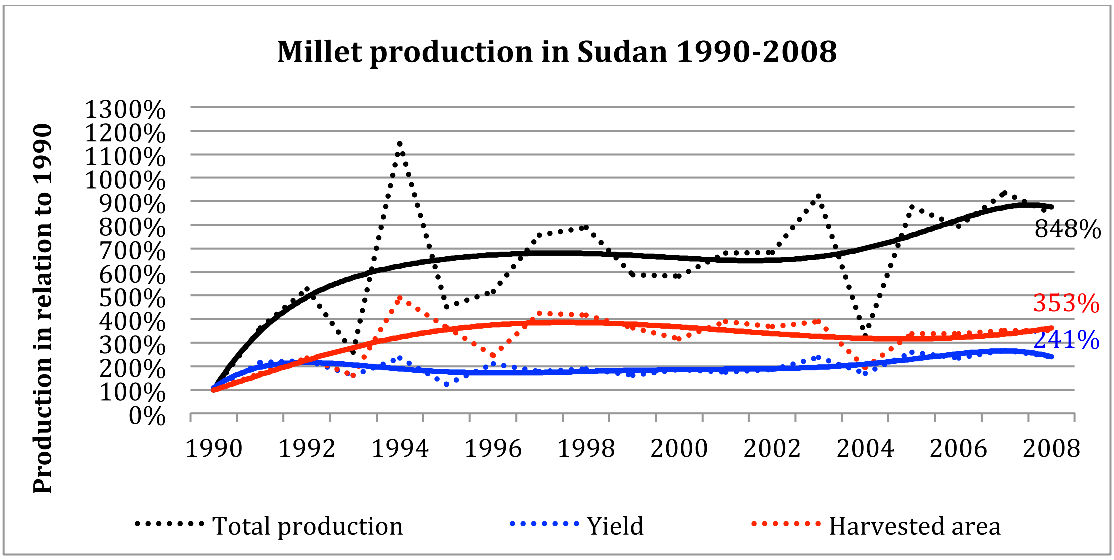


Figure 39: Change in millet production, yields and harvested area in Sudan, 1990-2008

Millet is primarily cultivated in the western parts of the country (Gaiballa 2011). However, it is also grown both in the semi-desert zones in the north and in the low rainfall savannah zones in central Sudan, although on sandy soils in contrary to sorghum which is grown on clay soils (FAO, 2006). According to Gaiballa (2011), most of the production is for local consumption.

Land-use dynamics from future production increases

Gaiballa (2011) does not expect millet production to increase and, consequently, does not believe that an expansion on arable land, pastures or natural vegetation is likely to happen. However, considering past trends, it seems unreasonable to rule out further production increases in such a way. Potential external demand for biofuel feedstock may also increase the demand for millet. However, little information regarding the potential of future millet expansion for biofuel purposes has been found, so the above discussion should be regarded as conjecture.

Yield-gap and available land for cultivation of rainfed crops

According to the Deininger et al (2011), Sudan's yield gap for rainfed crops is more than 90%. Therefore, by improving agricultural practices and/or intensifying cultivation, Sudan has a theoretical potential to increase the total production of rainfed crops with more than 90%, without having to expand onto new land. Since unused land suitable for production of rainfed crops is rather abundant (less than 30% is under cultivation) (Deininger et al 2011), there are no apparent incentives to increase yields. Therefore, past trends of both expansion and increased yields are likely to continue.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, sorghum and millet in Sudan are summarised in Table 40.

Table 40: Production system characteristics for sugarcane, sorghum and millet in Sudan

System component	Sugarcane	Sorghum	Millet
Large scale	The company 'Kenana Sugar', transformed 40 000 ha a long the White Nile into one of the world's largest sugarcane plantations in 2007. The Sudanese government want to expand the current 200 000 ha into 1.4 million hectares.		
Small scale		Traditional farming for subsistence dominant	Traditional farming for subsistence dominant
Mechanized farming system		Mainly land preparation and sowing	
Manual farming system			
Tillage			
Reduced and no tillage			
Irrigated		In 2000/2001, irrigated sorghum accounted for 35% of total production, however, this was proposed by the government to cater for the "food gap".	
Rain fed			
Mono-cropping			
Multi-cropping			
Crop rotation			
Mineral fertilizer used		Limited scale	
Chemical pesticides used		Limited scale	
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field		

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (AchaNoticias, 2007; Cheesman, 2004; El Moghraby, 2002; Elnagheeb and Bromley, 1994; Sudan Tribune, 2007; UNEP, 2007; World Resource Institute, 2003)

Observed local environmental impacts from sugarcane, sorghum and millet production in Sudan are summarised in Table 41.

Sorghum and millet are currently promoted as water saving bio-energy crops on account of their superior drought tolerance in comparison to e.g. maize. However, at the same time sorghum and millet are two of the main staple foods in and play a vital role in food security for smallholder farmers in dryland areas such as Sudan. Sudan is the third largest sugar cane producer in Africa (Hassan, 2008).

Table 41: Observed local environmental impacts from sugarcane, sorghum and millet production in Sudan

Environmental impact	Sugarcane	Sorghum	Millet
Deforestation			
Loss of agro-biodiversity			
Loss of biodiversity			
Air pollution			
Water pollution			
GMO contamination			
Eutrophication			
Soil fertility decline			
Erosion			

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (AchaNoticias, 2007; Cheesman, 2004; El Moghraby, 2002; Elnagheeb and Bromley, 1994; Sudan Tribune, 2007; UNEP, 2007; World Resource Institute, 2003)

Local environmental impacts allocated to domestic biofuel production

Since no production of domestic biofuels from sugarcane, sorghum or millet has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in Sudan.

Local environmental impacts allocated to EU biofuel demands

Since no feedstock for EU biofuels in 2008 has been traced to sugarcane, sorghum or millet produced in Sudan; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

AchaNoticias, 2007. *Sugar factory in Sudan to double production*. Available at www.achanoticias.com.br/noticia_pdf.kmf?noticia=7443399 Acccessed on May 30, 2011.

Cheesman, O., 2004. *The environmental impacts of sugar production*. Trowbridge: CABI Publishing and WWF.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

El Moghraby, A.I., 2002. State of the environment in Sudan. In B. Sadler and M. McCabe, eds. *Environmental Impact Assessment Training Resource Manual.* Geneva: UNEP.

Elnagheeb, A.H., and Bromley, D.W., 1994. Extensification of agriculture and deforestation: empirical evidence from Sudan. *Agicultural Economics*, 10(2), pp.193-200.

FAO, 2006 *Country Pasture/Forage Resource Profiles – Sudan.* Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

Gaiballa, A., 2011. *Expert consultation: Abdelaziz Gaiballa, Associate Prof., Sudan University of Science & Technology.*

GIEWS, 2011. *GIEWS Country Brief: Sudan*. GIEWS/FAO.

Hassan, S.F., 2008. Development of sugar industry in Africa. *Sugar Tech*, 10(3), pp.197-203.

Sudan Tribune, 2008. Sudan announces ambitious plan for sugar production. *Sudan Tribune*. 6 March.

UNEP, 2007. *Sudan Post-Conflict Environmental Assessment*. Nairobi: United Nations Environment Programme.

World Resource Institute, 2003. *Earth Trends Country Profiles, Agriculture and Food: Sudan*. Available at: http://earthtrends.wri.org Accessed on February 23, 2011.

Tanzania

Selected biofuel crops for Tanzania include sugarcane, oil palm and jatropha. As seen in Table 42, domestic biofuel production has not been possible to identify or estimate, for neither of the crops. No biofuels for the EU market in 2008 have been traced to Tanzania.

Table 42: Area used for production of Tanzania's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	23	-	-	-	-
Oil palm	5	-	-	-	-
Jatropha	18	-	-	-	-

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

As seen in Figure 40, pastures constitute the largest share of the total agricultural area in Tanzania. Permanent crops are less common than annual crops, which are dominating the cultivated land. Sugarcane, oil palm and jatropha plantings were rather insignificant in 2008.

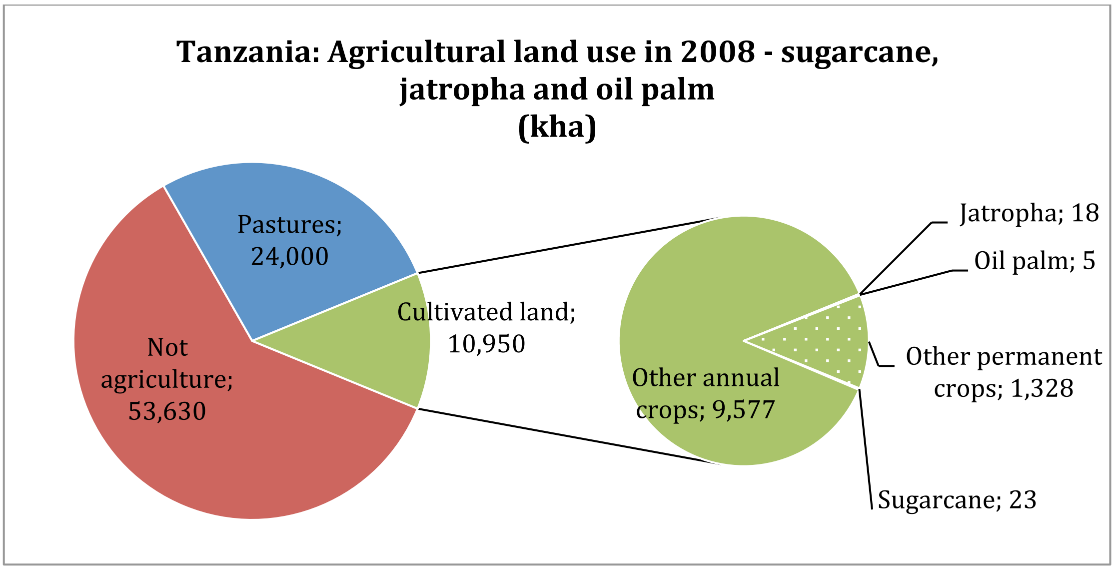


Figure 40: Agricultural land use in Tanzania in 2008, focused on sugarcane, oil palm and jatropha production

Sugarcane

Historical developments

Between 1990 and 2008, sugarcane production in Tanzania increased by 80%. As seen in Figure 41, the increase has been made possible mainly by an increased harvested area (+50%), but also by increasing yields (+20%).

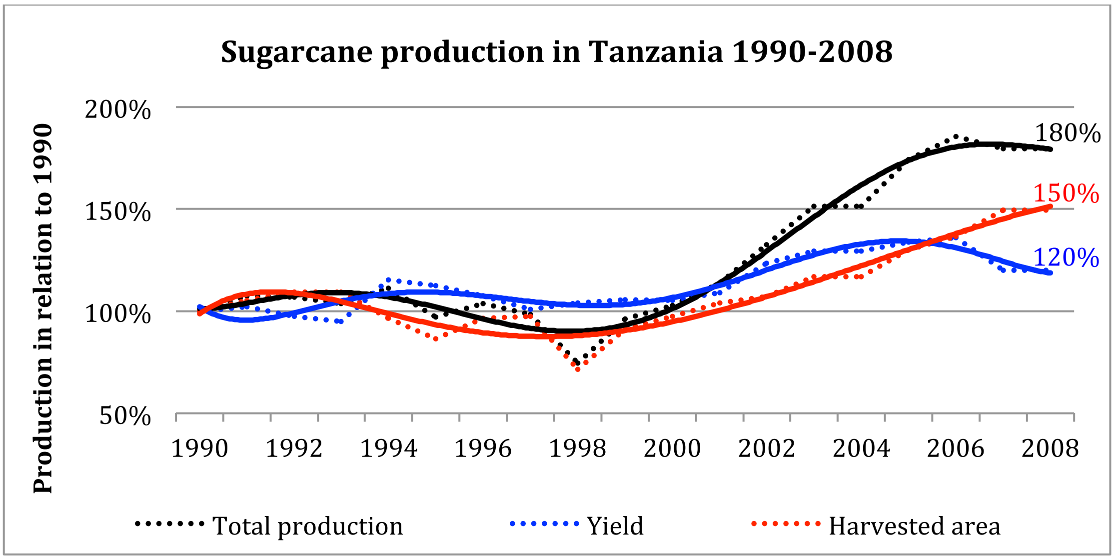


Figure 41: Change in sugarcane production, yields and harvested area in Tanzania, 1990-2008

Most sugarcane is produced in large-scale irrigated projects, although small-scale rainfed production also exists to a smaller extent (Sulle and Nelson, 2009). Much of the current large-scale cultivation is taking place in the Kilombero valley, in central/southern Tanzania.

Land-use dynamics from future production increases

According to Hella (2011), sugarcane expansion in Tanzania is not likely to occur on existing farmland. However, if that would happen, it would likely replace production of rice, maize and coconut, as well as small-scale sugarcane production for local purposes. Most likely expansion would take place on pastures and natural vegetation.

Most sugarcane production in Tanzania aims at producing sugar, not ethanol. However, there are currently a few large-scale projects planned where sugarcane will be produced for ethanol purposes (Sulle and Nelson, 2009). These projects are planned mainly along the coast in Bagamoyo and Rufiji. These areas are surrounded by forest areas and savannah (FAO, 2011a) and have a relatively high density of livestock, making it possible that the expansion will occur on pastureland, as well as forest areas and savannah.

Irrigation needed for an increased sugarcane production will, according to Hella (2011), be expensive. In addition, expansion in the Rufiji region is likely to substantially effect the Rufiji delta, both biologically and ecologically.

Oil Palm

Historical developments

Between 1990 and 2008, oil palm production in Tanzania increased by 30%. As seen in Figure 42, the increase has been made possible mainly by an increased harvested area (+21%), but to a smaller extent also by increasing yields (+7%).

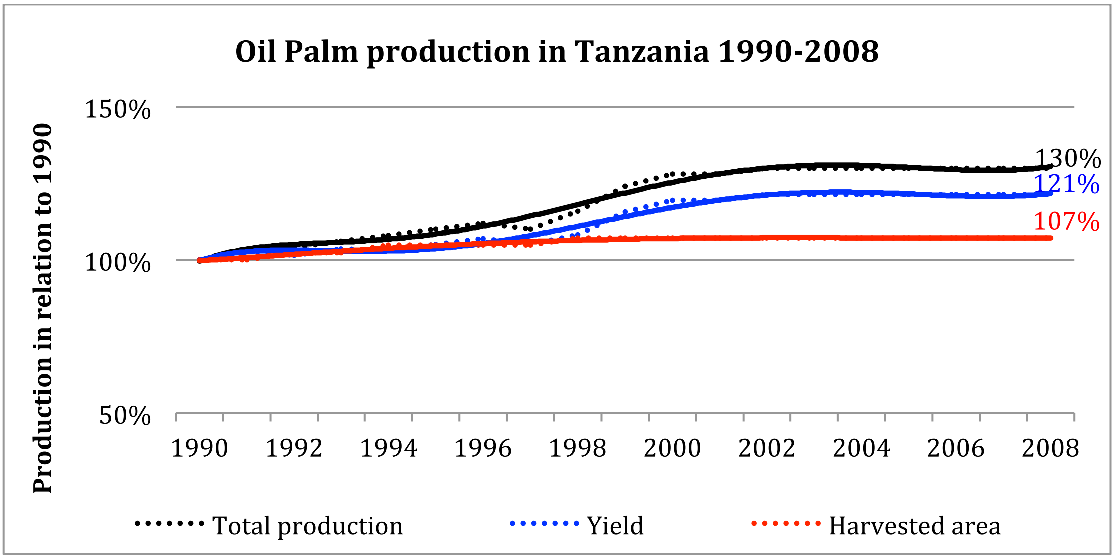


Figure 42: Change in oil palm production, yields and harvested area in Tanzania, 1990-2008

Oil palm has been cultivated in Tanzania for a long time. The Kigoma district in west Tanzania, near Lake Tangayika, has cultivated oil palm since 1920. The western parts of Tanzania are mainly covered by forest (FAO, 2011a), which was likely cleared when oil palm plantations were established.

The current production of oil palm in Tanzania is performed by smallholder farmers in the Kigoma region, the Mbeya region in southwestern Tanzania and to a smaller extent in the Tanga region on the east coast of Tanzania (Sulle and Nelson, 2009). All these areas are surrounded by forests (FAO, 2011a).

Land-use dynamics from future production increases

Oil palm production is very likely to replace farmland, but it is difficult to say if any particular crops would be replaced, according to Hella (2011). As for jatropha, smallholder systems are likely to be established, where smallholders plant oil palms where it fits into their farming system and then sell the oil palm fruit to a core company.

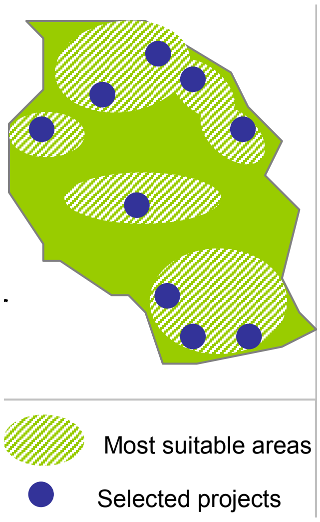
Hella (2011) argues that natural vegetation, such as woodlands and grasslands, would likely be used for expanding oil palm production. There are currently a few oil palm projects planned in the Kigoma region in the west and the Rufiji and Kilombero districts on the east coast (Sulle and Nelson, 2009). All areas are surrounded by forests and the two districts on the east coast are also surrounded by some savannah. This supports Hella's (2011) statement, although indicating that expansion may also occur on forests.

According to Hella (2011), pastures are not likely to be used for a potential palm oil expansion. Low livestock densities in the areas where oil palm production is planned supports this statement (FAO, 2011b).

Jatropha

Jatropha is widely cultivated in Tanzania; both on small and large scale and mainly on marginal lands (Sulle and Nelson, 2009). Almost all regions in Tanzania feature a climate that is well suited for Jatropha cultivation (see figure). Projects were mainly identified in the northern and southern part of the country (GEXI 2008).

Jatropha has become increasingly popular and several new projects are planned (Sulle and Nelson, 2009). Most of these are located on the eastern and northeastern parts of Tanzania, close to forests (FAO, 2011a). There are also a few planned projects in the northern parts, south of Lake Victoria. These areas are mostly covered with savannah, other grasslands and some forests, but have little existing cropland. Hella (2011) reports that an expansion on natural vegetation is likely, particularly on woodlands.



Source: GEXI 2008

Even though jatropha can grow on marginal lands, it thrives on fertile soil (Sulle and Nelson, 2009). A few of the planned projects are planned in fertile areas in the Mbeya region in the southwestern parts of Tanzania and in the Mpanda district and the Rukwa region in the western parts. These regions are important areas for food production, especially the Rukwa region where maize is produced. It is therefore likely that jatropha can replace production of food crops, such as maize, in these areas.

Hella (2011) reports that jatropha expansion is likely to occur on existing farmland, replacing maize, sorghum as well as coconut and pineapple production along the coast, and is very likely to occur on pastures. Expansion on degraded pastures may be beneficial, since jatropha can grow on such marginal lands.

Yield-gap and available land for cultivation of rainfed crops

According to the Deininger et al (2011), Tanzania's yield gap for rainfed crops is almost 85%. Therefore, by improving agricultural practices and/or intensifying cultivation, Tanzania has a theoretical potential to increase the total production of rainfed crops with almost 85%, without having to expand onto new land. Since unused land suitable for production of rainfed crops is still rather abundant (about 50% is under cultivation) (Deininger et al, 2011), there are no apparent incentives to increase yields. However, if expansion of cropland continues to increase, incentives to improve cropping practices will grow stronger.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, oil palm and jatropha in Tanzania are summarised in Table 43.

Table 43: Production system characteristics for sugarcane, oil palm and jatropha in Tanzania

System component	Sugarcane	Oil Palm	Jatropha
Large scale	Dominating	Mostly at planning stage, large scale production combined with out grower schemes (with possible intercropping) 50-50 in area, in Kigoma 10 000 hectares and another 50-60 000 hectares suggested	
Small scale	Outgrowers	Dominant	Widely cultivated under out grower schemes
Mechanized farming system			
Manual farming system		Dominant	x
Tillage			
Reduced and no tillage		Perennial crop	Perennial crop
Irrigated	Dominating, large scale estates		
Rain fed			
Mono-cropping			
Multi-cropping			
Crop rotation		Perennial crop	Perennial crop
Mineral fertilizer used			
Chemical pesticides used			
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field		Poor quality wood and fruits (as fertilizer

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (African Biodiversity Network, 2007; Cleaver, 2009; Henning, 2005; Kikula et al., 2003; Longschaap, 2007; Mkindi, 2007; Mkindi, 2008; Songela and Maclean, 2008; Sulle and Nelson, 2009; Tarimo and Takamura, 1998; UNEP, 2009).

Deforestation was observed in e.g. in Maligarasi area, during expansion of oil palm plantations (African Biodiversity Network, 2007). However, in areas like Kigoma, where expansion is taking place, large areas of forest have already been cleared due to the use of fuel wood for refugee camps. There are concerns about diverted water sources from food production if oil palm production is largely expanded. In order to attract more investors, the government of Tanzania have analysed many fertile regions of Tanzania. These regions are the ones with the best access to water, and are therefore usually the areas where farmers are already growing food.

Jatropha is the biofuel crop currently responsible for some of the largest land allocations to foreign-driven plantation schemes in Tanzania (Sulle and Nelson, 2009). The jatropha oil is produced both for domestic and export markets. The Dutch investor Bioshape has been accused of converting valuable land (Mkindi, 2008), resulting in loss, fragmentation and degradation of e.g. grasslands, miombo forests, wetlands and extensive agricultural areas, as well as blockage of wildlife migration routes around the Selous Game Reserve. In other areas, land has been acquired by jatropha investors, which was providing the surrounding community with access to fuel wood collections, medicinal plants, wild animal catching etc. A number of large-scale investors have acquired land for jatropha cultivation in relatively fertile areas. Examples include the Kapunga Rice Project replacing rice farms, and jatropha production in Rukwa Region - a significant producer of maize, the main staple food crop in Tanzania (Sulle and Nelson, 2009). Jatropha can grow in dry areas, however, like most crops, fertile and irrigated soils are more attractive for commercial production. A report from UNEP states that jatropha has a high global average water footprint (UNEP, 2009). On the other hand, jatropha can be used against erosion, thereby reducing siltation of rivers and lakes (Henning, 2005).

Observed local environmental impacts from sugarcane, oil palm and jatropha production in Tanzania are summarised in Table 44.

Table 44: Observed local environmental impacts from sugarcane, oil palm and jatropha production in Tanzania

Environmental impact	Sugarcane	Oil Palm	Jatropha
Deforestation	[red]	[red]	[red]
Loss of agro-biodiversity	[white]	[red]	[red]
Loss of biodiversity	[red]	[red]	[red] Can be invasive to native species and agroforestry systems
Air pollution	[red]	[white]	[white]
Water pollution	[red]	[red]	[red]
GMO contamination	[green]	[white]	[white]
Eutrophication	[white]	[white]	[white]
Soil fertility decline	[red]	[white]	[white]
Erosion	[red]	[white]	[green]

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (African Biodiversity Network, 2007; Cleaver, 2009; Henning, 2005; Kikula et al., 2003; Longschaap, 2007; Mkindi, 2007; Mkindi, 2008; Songela and Maclean, 2008; Sulle and Nelson, 2009; Tarimo and Takamura, 1998; UNEP, 2009).

Local environmental impacts allocated to domestic biofuel production

Since no production of domestic biofuels from sugarcane, oil palm or jatropha has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in Tanzania.

Local environmental impacts allocated to EU biofuel demands

Since no feedstock for EU biofuels in 2008 has been traced to sugarcane, oil palm or jatropha produced in Tanzania; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

African Biodiversity Network, 2007. *Agrofuels in Africa – The impacts on land, food and forests. Case Studies from Benin, Tanzania, Uganda and Zambia*. African Biodiversity Network.

Cleaver, J., Schram, R. and Wanga, G., 2009. *Bioenergy in Tanzania - The Country Context*. Rome: FAO.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

FAO, 2011a. *FAO country profile: Tanzania. Map - Land cover*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO, 2011b. *FAO country profile: Tanzania. Map – Livestock Bovine*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

GEXI, 2008. *Global Market Study on Jatropha Project Inventory: Africa*. The Global Exchange for Social Investment. Available at: http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Jatropha-Project-Inventory_AFRICA.pdf Accessed on May 12, 2011.

Hella, J., 2011. *Expert consultation: Joseph Hella, Mwalimu at Sokoine University of Agriculture.*

Henning, K. R., 2005. *Jatropha Curcas L. in Africa - Assessment of the impact of the dissemination of "the Jatropha System" on the ecology of the rural area and the social and economic situation of the rural population (target group) in selected countries in Africa*. Weissensberg: Global Facilitation Unit for underutilized species.

Kikula, I.S., Mnzava, E.Z. and Mung'ong'o, C., 2003. *Shortcomings of Linkages between Environmental Conservation Initiatives and Poverty Alleviation in Tanzania*. Dar es Salaam: Research on Poverty Alleviation (REPOA).

Longschaap, R.E.E., Corré, W.J., Bindraban, P.S and Brandenburg, W.A., 2007. *Claims and facts about Jatropha curcas L -Global Jatropha Curcas* *evaluation, breeding and propagation programme*. Wageningen: Plant Research International B.V.

Mkindi, A., 2007. *The socio-economic and environmental impacts of a biofuel industry in Tanzania*. London.

Mkindi, A., 2008. *Impact on Jatropha Trade in Tanzania*. Dar es Salaam: Envirocare.

Songela, F., and Maclean, A., 2008. *Scooping Exercise (Situation Analysis) on the Biofuels Industry Within and Outside Tanzania*. Dar es Salaam: WWF.

Sulle, E. and Nelson, F., 2009. *Biofuels, land access and rural livelihoods in Tanzania*. London: IIED.

Tarimo, A.J.P. and Takamura, Y.T., 1998. Sugarcane Production, Processing and Marketing in Tanzania. *African Study Monographs*, 19(1), pp.1-11.

UNEP, 2009. *Water and Bioenergy*. Paris: UNEP. Available at: http://www.uneptie.org/energy/bioenergy/issues/pdf/Issue%20Paper%20No.2_FINAL.pdf Accessed on May 30, 2011.

Uganda

Selected biofuel crops for Uganda include sugarcane, oil palm and jatropha. As seen in Table 45, domestic biofuel production has not been possible to identify or estimate, for neither of the crops. No biofuels for the EU market in 2008 have been traced to Uganda.

Table 45: Area used for production of Uganda's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	35	-	-	0	0%
Sorghum	321	-	-	0	0%
Jatropha	0 [1)]	-	-	-	-

1) Projects initiating

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Sugarcane

Historical developments

Between 1990 and 2008, sugarcane production in Uganda increased by 285%. As seen in Figure 43, the increase has been made possible mainly by increasing yields (+175%), but to a smaller extent also by increasing the harvested area (+40%).

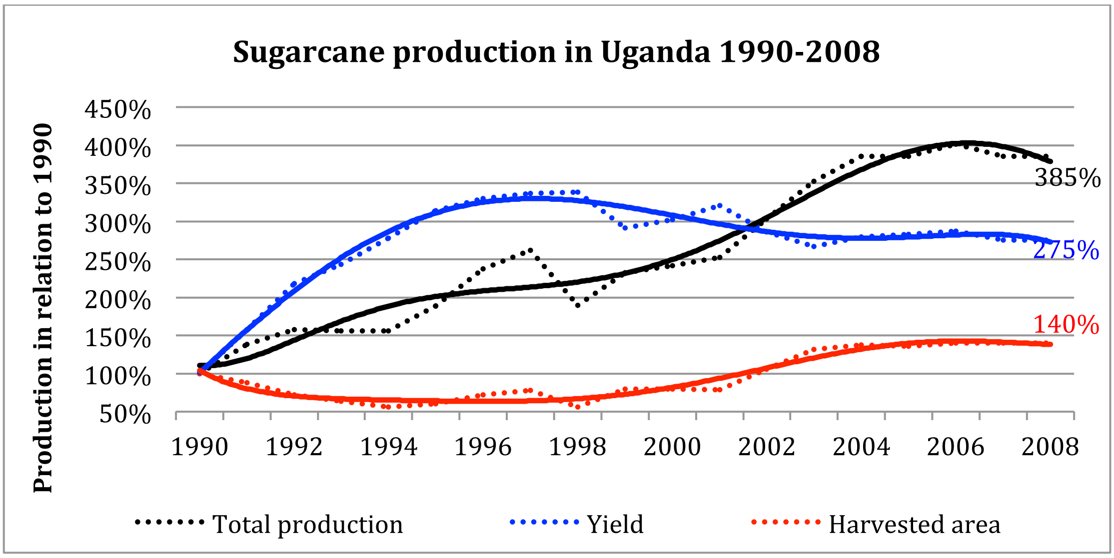


Figure 43: Change in sugarcane production, yields and harvested area in Uganda, 1990-2008

According to Uganda Sugar Cane Technologists' Association (USCTA) (2011), the main sugar producing companies in Uganda are located in Kakia near Lake Victoria in the southeastern part of Uganda, Masindi in the central/west part on Uganda near lake Lac Albert, Lugazi in Central Uganda near Lake Victoria and Rakai in southern Uganda, west of Lake Victoria. Most of these areas are located near woodland or shrubland (FAO, 2011a). It is therefore likely that such ecosystems have been cleared to establish existing plantations.

Land-use dynamics from future production increases

According to Kajubi (2011) it is likely that a potential sugarcane expansion could occur on existing farmland. If sugarcane is promoted as a biofuel crop, outgrowers would likely switch to produce it as a cash crop, instead of producing seasonal food crops such as cassava, maize, potatoes and beans. The area where sugarcane is produced today contains large areas of farmland (FAO, 2011a), which in case of an increased demand for sugarcane could be converted to sugarcane production.

All areas where sugarcane is currently being cultivated have irrigation capacities. Therefore, they can be subject to further expansion.

Kajubi (2011) reports that pastures are of high value for communities holding livestock. Pastures are therefore not likely to be converted to sugarcane production. The southern parts of Uganda have the highest densities of livestock (FAO, 2011b), while free grazing is more common in the northern parts (FAO, 2006a). It is common that farmers have mixed farming systems, where livestock and crop production is combined (FAO, 2006a), indicating that pastures are unlikely to be targeted for sugarcane expansion.

It is further likely that natural vegetation, such as shrubland, would be converted in case of a sugarcane expansion. Natural forests may also be subject for conversion, unless sufficiently monitored by local authorities (Kajubui 2011). Since existing cropland is located in areas with these types of vegetation (FAO, 2011a), that assumption seem to be plausible.

Sorghum

Sorghum is the third most important staple cereal food crop in Uganda after maize and millet, occupying 321,000 ha of arable land in 2008. It is mainly used for food and brewing.

Historical developments

Between 1990 and 2008, sorghum production in Uganda increased by 33%. As seen in Figure 44, the increase has been made possible by increasing the harvested area, while yields have remained rather unchanged.

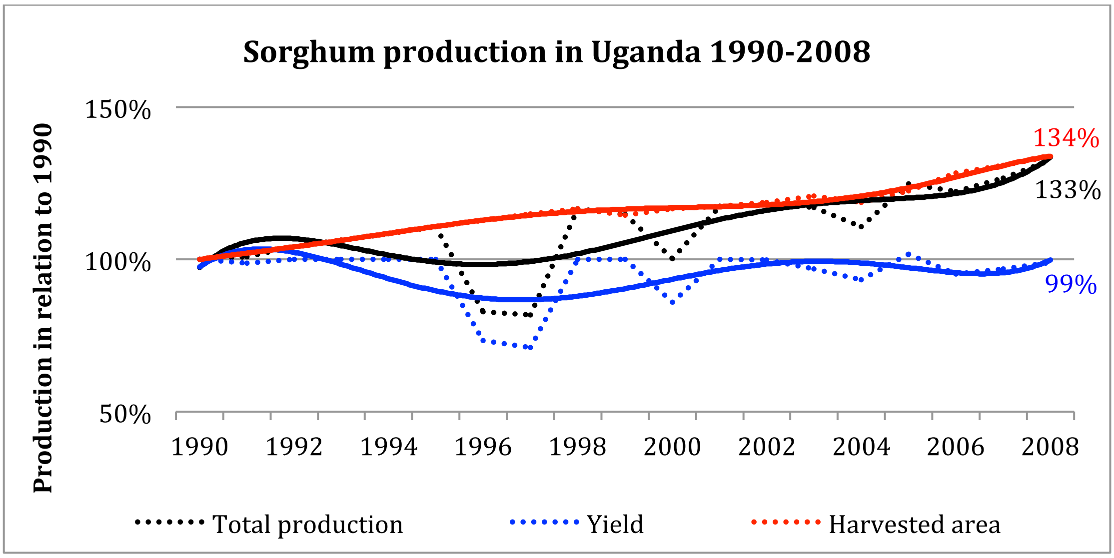


Figure 44: Change in sorghum production, yields and harvested area in Uganda, 1990-2008

Maize is the most commonly produced food crop in Uganda (GIEWS, 2011), while sorghum is cultivated primarily in the central and northern parts of the country (FAO, 2006d). According to Kajubi (2011), shrubland and forests have historically been cleared for cropland expansion, including sorghum.

Land-use dynamics from future production increases

There is little information available regarding sorghum as a potential biofuel crop in Uganda.

Kajubi (2011) reports that a potential expansion of sorghum is very likely to occur on existing farmland, replacing seasonal food crops such as maize, beans, potatoes and cassava. Livestock is uncommon in areas with this type of food crop production, making it unlikely that pastures would be targeted for sorghum production.

Natural vegetation is likely to be cleared in case of a sorghum expansion, particularly shrubland and forests (Kajubi (2011). The northern parts, where Sorghum is currently being cultivated (FAO, 2006d), contain large areas of savannah, indicating that savannah may be targeted for sorghum production.

Jatropha

Mainly two oil seed crops have historically been produced in Uganda; sesame and sunflower (FAO/WFP, 2008). Jatropha has been grown mainly as a support tree in small-holder vanilla farms. The oil production of the locally grown variety/cultivar of jatropha is not known. Its local name is Ekiroowa and farmers are "cursing the resilience of the plant that it is difficult to destroy as it will germinate almost anywhere". The variety/cultivar of jatropha grown locally is not known and therefore there is no information on its seed yield potential (Kyamuhangire 2008). In Uganda, the government is responsible for facilitating the development of biofuels sector through policies and regulations, the provision of incentives, extension advice, information and market infrastructure, however information on the results is not easily accessible. Nexus Biodiel LTD has planted over 400 hectares of jatropha, Nexus alone boasts of more than 2,000 registered outgrowers.

Current trends in Uganda are to use less productive land for jatropha production, indicating that farmland is unlikely to be targeted. However, if jatropha would be expanded onto existing farmland, it would likely replace maize, bulrush millet and sorghum, but also likely minor crops like peas and potatoes (Kajubi 2011).

Jatropha has been promoted in the northern part of Uganda, mainly in Karamoja (Kajubi 2011). Grasslands in the northern parts are used for grazing and are important pastures for semi-nomadic herders (FAO, 2006d). According to Kajubi (2011), cattle keepers in these areas are too fond of their livestock to start cultivating jatropha on their pastures, making an expansion of smallholder production on pastures unlikely. However, large-scale projects by international investors may still be approved unless land-rights are sufficiently respected by the decision-makers.

It is most likely that jatropha expansion would occur in the northern parts, where it is currently promoted. Nearly all land in the northern parts of Uganda is covered with Savannah, with small areas of shrubland in the northeastern part and some small forest patches (FAO, 2011i). Since it is unlikely that existing farmland or pastures will be used for an expansion, the most likely scenario is that natural vegetation will be targeted, most likely savannah. In other parts of the country, shrubland and forests are more likely to be targeted.

Yield-gap and available land for cultivation of rainfed crops

According to the World Bank (2011), Uganda's yield gap for rainfed crops is about 75%, which is the lowest yield-gap among the assessed African countries. Therefore, by improving agricultural practices and/or intensifying cultivation, Uganda has a theoretical potential to increase the total production of rainfed crops with about 75%, without having to expand onto new land. Since unused land suitable for production of rainfed crops is rather scarce (about 90% is under cultivation) (World Bank 2011), incentives to increase yields should be strong.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, sorghum and jatropha in Uganda are summarised in Table 46.

Table 46: Production system characteristics for sugarcane, sorghum and jatropha in Uganda

System component	Sugarcane	Sorghum	Jatropha
Large scale			
Small scale	Outgrowers		Outgrowers
Mechanized farming system	Some practices e.g. land preparation and transport	Very limited	
Manual farming system	Dominant, e.g. weeding		
Tillage			
Reduced and no tillage			Perennial crop
Irrigated	Limited scale, only by large scale estates		
Rain fed			
Mono-cropping			
Multi-cropping		E.g. cowpeas, pumpkins, groundnuts, sesame	Not commonly intercropped although possible for first 3 years, intercropped with vanilla
Crop rotation			Perennial crop
Mineral fertilizer used		Very limited	
Chemical pesticides used		Very limited	
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)	Tops and leaves from mechanical harvesting are left on the field		

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Cotula et al., 2008; FAO, 2006b; Howden, 2007; Johnston et al., 2007; Plant Genetic Resources Centre and NARO, 2010; Thomas and Kwong, 2001; William Kyamuhangire, 2008)

In Uganda, allocation of national forest reserves in Bugala and Mabira to foreign plantation companies for establishment of oil palm and sugarcane plantations elicited demonstrations in Kampala, court cases led by non-governmental organizations, a sugar boycott, petitions and a mobile-phone messaging campaign. The Ugandan Government subsequently withdrew plans to convert the Bugala forest reserve to sugarcane (Cotula et al., 2008), although so far not the plans for the Mabira forest reserve.

Observed local environmental impacts from sugarcane, sorghum and jatropha production in Uganda are summarised in Table 47.

Table 47: Observed local environmental impacts from sugarcane, sorghum and jatropha production in Uganda

Environmental impact	Sugarcane	Sorghum	Jatropha
Deforestation	[red]	[red]	[red]
Loss of agro-biodiversity	[white]	[white]	[white]
Loss of biodiversity	[red]	[red]	[red]
Air pollution	[red]	[white]	[white]
Water pollution	[red]	[white]	[white]
GMO contamination	[green]	[green]	[white]
Eutrophication	[red]	[white]	[white]
Soil fertility decline	[red]	[red]	[green]
Erosion	[red]	[red]	[white]

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Cotula et al., 2008; FAO, 2006b; Howden, 2007; Johnston et al., 2007; Plant Genetic Resources Centre and NARO, 2010; Thomas and Kwong, 2001; William Kyamuhangire, 2008)

Local environmental impacts allocated to domestic biofuel production

Since no production of domestic biofuels from sugarcane, sorghum or jatropha has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in Uganda.

Local environmental impacts allocated to EU biofuel demands

Since no feedstock for EU biofuels in 2008 has been traced to sugarcane, sorghum or jatropha produced in Uganda; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Cotula, L., Dyer, N. and Vermeulen, S., 2008. *Fuelling exclusion? The biofuels boom and poor people's access to land*. Rome: FAO and IIED.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

FAO/WFP, 2008. *Special report: FAO/WFP assessment of the impact of 2007 flood on food and agriculture in eastern and northern Uganda*. FAO/WFP.

FAO, 2006a *Country Pasture/Forage Resource Profiles – Uganda.* Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO, 2006b. *AQUASTAT- FAO's Information System on Water and Agriculture: Uganda*. Available at: http://www.fao.org/nr/water/aquastat/countries/uganda/index.stm Accessed on February 21, 2011.

FAO, 2011a *FAO country profile: Uganda. Map - Land cover*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

FAO, 2011b. *FAO country profile: Uganda. Map – Livestock Bovine*. Available at: http://www.fao.org/countryprofiles/ Accessed on April 4, 2011.

GIEWS, 2011. *GIEWS Country Brief: Sudan*. GIEWS/FAO.

GEXI, 2008. *Global Market Study on Jatropha Project Inventory: Africa*. The Global Exchange for Social Investment. Available at: http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Jatropha-Project-Inventory_AFRICA.pdf Accessed on May 12, 2011.

Howden, D., 2007. African forest under threat from sugar cane plantation. *The Independent*, 10 July. Available at: http://www.independent.co.uk/environment/african-forest-under-threat-from-sugar-cane-plantation-456601.html Accessed on May 27, 2011.

Johnston, C., Meyer, R. and Curtis, A., 2007. *Value Chain Governance and Access to Finance Maize, Sugarcane and Sunflower oil in Uganda*. USAID.

Kajubi, L., 2011. *Expert consultation: Lammeck Kabuji. President/CEO: www.awe-engineers.com; www.pce-engineers.com, Registered Professional Engineer (PE), ERB/570, NEMA-Registered EIA Practitioner, NEMA-Registered Environmental Auditor, Certified Carbon Auditor (UK)*

Plant Genetic Resources Centre and NARO, 2010. *Country Report on the State of Plant Genetic Resources For Food and Agriculture – Uganda*. Entebbe: Plant Genetic Resources Centre – NARO.

Thomas, V. and Kwong. A., 2001. Ethanol as a lead replacement: phasing out leaded gasoline in Africa. *Energy Policy*, 29(13), pp.1133–1143.

William Kyamuhangire, P. 2008. *Perspective of Bioenergy and Jatropha in Uganda*. Rome: International Consultation on Pro-poor Jatropha Development.

USCTA, 2011. *Uganda Sugar Cane Technologists' Association (USCTA)*. Available at: http://test.imaginet.co.ug/usta/index.php Accessed on April 4, 2011.

COUNTRY PROFILES – ASIA/UKRAINE

This section includes country profiles for Indonesia, Malaysia, India, Pakistan and Ukraine.

Regional conclusions

The most important crops for biofuel production in this region include oil palm, sugarcane, maize, jatropha, neem, rapeseed and sugarbeet.

The countries included in the study can be grouped into three groups, *Southeast Asia* (including Indonesia and Malaysia), *Pacific Asia* (including India and Pakistan) and *Europe* (including only Ukraine). Making general conclusions or a join summary would be unjust.

Southeast Asia

Both Indonesia and Malaysia contain high percentages of natural forest. Expansion of either oil palm or sugarcane may risk conversion of natural forest, in many cases highly carbon rich forest such as primary rainforest and forests on peatlands. The expansion is supported by the government as a mean for increasing exports of both feedstock and biofuels, although concerns about GHG emissions from deforestation are increasing. With an increased international demand for biofuels, oil palm production is likely to increase and, since the yield is already very high, the most likely outcome would be an expansion in planted area, at the expense of forests.

Pacific Asia

India has a strict no-deforestation policy, which has helped to halt deforestation and even resulted in some reforestation. Pakistan has very little forestland. India has vast areas of agricultural land while Pakistan is highly constrained when it comes to agricultural land, water availability being the primary limiting factor. As a result of an increased international demand for biofuels, domestic biofuel production in India and Pakistan might increase but most likely not on the expense of natural vegetation. An expansion on agricultural land would be an option, but that would require an increased irrigation and a price on either the feedstock or the end product – ethanol or biodiesel, which is higher than the price on the current crop. In India, and potentially also Pakistan, the government supports an expansion of biofuel feedstock production on wastelands, where the production would not compete with food production or negatively affect carbon balance.

Ukraine

About 70% of Ukraine's total land area is already used for agriculture, mostly for cultivation of annual crops (56% of total land area). Forest and forest-covered areas constitute some 17% and built-up areas about 4%. Farmers employ a variety of crop-rotation schemes and increased production of biofuel crops will likely be achieved mainly by adjustments in crop rotations to increase the total area sown with such crops, reducing the area used for other crops such as barley and wheat and also reducing the fallow area. There is substantial scope for increasing yields in Ukrainian agriculture and intensification may allow for increasing the production of both biofuel crops and other crops without expanding the total agricultural area significantly.

India

Selected biofuel crops for India include sugarcane, jatropha and neem. As seen in Table 48, more than 7% of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production, although only very small amounts were exported to the EU. Domestic biofuel production from jatropha and neem has not been possible to identify or estimate.

Table 48: Area used for production of India's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Sugarcane	5,055	373	7.4%	0	0%
Jatropha	407	-	-	-	-
Neem	-	-	-	-	-

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

As India's service sector has grown, agriculture's share of the GDP has dropped from 57% in 1950 to 22% in 2002. However, the agricultural sector provides income and employment to 233 million people, or almost 60% of the rural labour force. Farmers are mainly marginal farmers and smallholders cultivating land constituting less than one third of the country's total cultivated area (IFAD 2011). About two thirds of India's total area is under cultivation (FAO 2007), covering 180 Mha of which sugarcane is harvested on about 5 Mha. Irrigation is most common in the southern districts while the districts in the north are arid and holds little agriculture (FAO 2011).

Sugarcane

Historical developments

Between 1990 and 2008, sugarcane production in India increased by 54%. As seen in Figure 45, the increase has been made possible mostly by an increased harvested area, while yields have increased by 5% since 1990. The largest increase, both in harvested area and yields, has occurred since 2005.

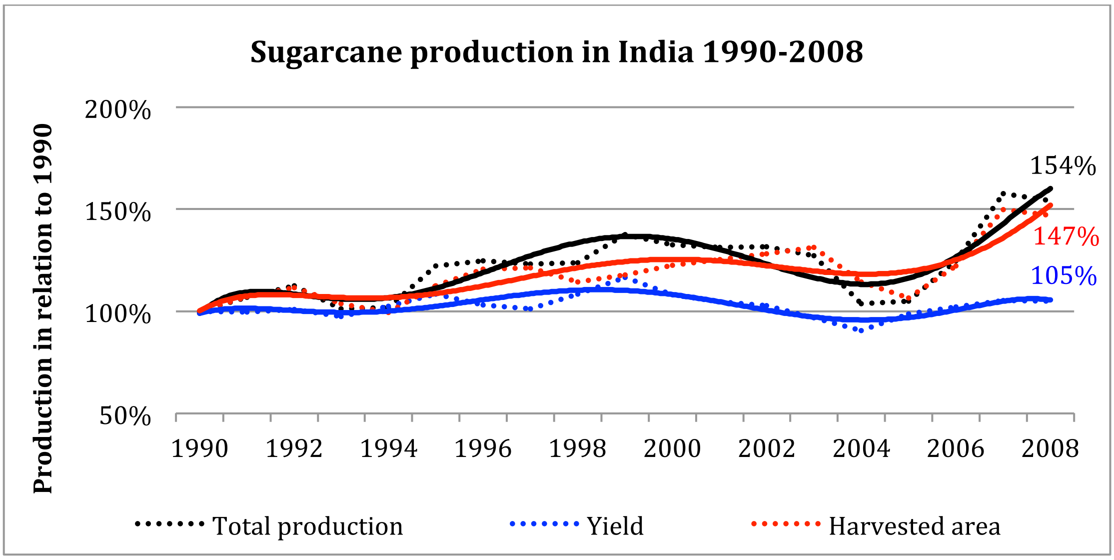


Figure 45: Change in sugarcane production, yields and harvested area in India, 1990-2008

In 2007/08 and 2008/09, Indian sugar production was on the downward side of the country's persistent cyclical fluctuations in production. Despite decreased harvested areas in 2009/10, sugar production increased by 7.3% because of higher yields. Sugar consumption fell by almost 3% in 2009/10. However, consumption is 6.2 MT higher than production, which resulted in an increase in net imports from 2.6 MT in 2008/09 to 6.0 MT in 2009/10 (FAPRI 2010).

Land-use dynamics from future production increases

In India, ethanol is produced mainly from molasses, a co-product in sugar production from sugarcane. India's ethanol production decreased 32.6%, from 1677 ML in 2008 to 1128 ML in 2009. However, production soon regained and is projected to increase by 113 % until 2019/20, resulting in a total production of 2403 ML (FAPRI 2010). According to FAPRI's (2010) projections, sugar production and consumption is projected to increase with 75.5% and 26.4%, respectively, by 2019/20. With the projected recovery in 2010/11, India becomes a net exporter, with net exports increasing and then declining over the projection period (FAPRI 2010).

Indian domestic ethanol consumption was 1790 ML in 2009/10 and is projected to increase with 48.3% to a total of 2658 ML in 2019/20. Currently, India is a net importer of ethanol with an import of 201 ML and is predicted to increase its import to 288 ML within the next 10 years (FAPRI 2010). This projection would require an increased production either from an expansion onto other areas or increased sugarcane yields. According to the Deininger et al (2011) there is in practice no land available for expansion. Any increase in production would thus come from increased yields rather than expansion onto non-agricultural land. Potential expansion on agricultural land might be possible, although not likely in areas with little potential for irrigation. Compared to other countries, India seems to have a rather good potential for increasing yields, although water availability might be constraining this. A potential expansion on natural vegetation is not likely.

Oilseed – Jatropha and Neem

Historical developments

India has a long history of producing oilseeds for various reasons, including medicine, fuel and food. Neem is a native species naturally appearing in forests, while Jatropha is a relatively new alien species originating from Latin America. Neem has been grown for a long time while the interest for Jatropha has emerged during the last 20 years.

Jatropha and Neem have become two of the most important crops for biofuel production in India and planting them in commercial plantations for biofuel purposes is a rather new concept, gaining more and more interest. Jatropha oil can be used directly after extraction (i.e. without refining) in diesel generators and engines. The production of Jatropha oil for biodiesel delivers economic benefits to India on the macroeconomic or national level as it reduces the nation's fossil fuel imports for diesel production, which is the main transportation fuel used in the country. One of the reasons for the large political and moral acceptance of Jatropha is the lack of dependence on agricultural land for expansion, unlike corn or sugarcane ethanol.

Land-use dynamics from future production increases

Due to the strict forest protection policy, which prohibits expansion of agriculture on natural forests, any expansion of biofuel crops in natural forest is unlikely. Other possibilities include an expansion onto agricultural or pasture land. Another possibility, which has been highlighted by the government, is the expansion of biofuel crops, especially Jatropha, onto degraded lands, in India called wasteland. Both Neem and Jatropha are hardy species that are resistant to drought and can survive on poor soils, which would make them suitable to be planted on wastelands (ICRAF 2009). However, yields are likely to be affected by the biophysical conditions and production would not be maximized. On the other hand, a study by Abou Kheira and Atta (2009) concludes that Jatropha can survive and produce full yields with high quality seeds on otherwise unproductive agricultural land and under minimum water requirements, without any significant effect of the oil composition. Foidl et al (1996) supports this theory and concludes that Jatropha is a wild species that doesn't need irrigation to grow. Resent research show that Jatropha production on wastelands might even increase water availability downstream (see separate project report on *Water*).

In recent years, the Indian central Government as well as some State Governments has expressed their support for bringing wastelands, which cannot be used for food production, under cultivation for biofuel purposes (Kishwan et al. 2009). In 2003, the Indian Government announced the National Mission on Biofuel, which anticipated that 4 Mha of wasteland across the country would be converted to bioenergy crop, such as Jatropha and sweet sorghum, plantations by 2008-09. However, in 2008 the program was aborted due to a fear of land-grabbing by large energy companies. Another policy was established shortly after where the government introduced a general biofuel target aiming for a 20 % blend of biofuels, either ethanol or biodiesel in all petrol and diesel sold by the year 2017. The government stipulated that 11 Mha of plantations will be established nationwide to be able to cope with this target. Even though the policy is supposed to target wasteland, low Jatropha yields on wastelands has raised concerns that agricultural land can be used for the expansion instead (The Bioenergy Site 2010) altering the main argument for establishing Jatropha.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, jatropha and neem in India are summarised in Table 49.

Table 49: Production system characteristics for sugarcane, jatropha and neem in India

System component	Sugarcane	Jatropha	Neem
Large scale			
Small scale			
Mechanized farming system			
Manual farming system			E.g. harvesting
Tillage			
Reduced and no tillage		Perennial	Perennial
Irrigated	Dominating		
Rain fed			
Mono-cropping	Dominating		
Multi-cropping	In some cases intercropping with crops like wheat, potato, cowpea, French bean, Chickpea, water melon, brinjal etc. in the initial state	E.g. ground nuts, pigeon pea. Research ongoing on suitable intercrops	
Crop rotation		Perennial crop	Perennial crop
Mineral fertilizer used			
Chemical pesticides used			
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)	Sugarcane tops can be used for feeding for animals when climate is relatively dry and sometimes also as fuel	Branches, leaves fruit shell and cake used for briquettes for heat or for biogas	

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Brittaine and Lutaladio, 2010; Cheesman, 2004; de Fraiture et al., 2008; FAO, 2005; Gonsalves, 2006; ICRISAT-WWF, 2009; Ministry of Agriculture)

Under marginal conditions jatropha does not reliably produce crop yields of commercial scale. The advantages that jatropha has on the small scale do not necessarily translate to plantation-scale cultivation. However, it is nitrogen-fixing and benefits from symbiosis with a fungus that can be inoculated so that the yield can be improved with about 15%. Most of the jatropha currently grown is toxic which renders the seedcake unsuitable for use as livestock feed unless detoxified and potentially a human safety hazard.

Observed local environmental impacts from sugarcane, jatropha and neem production in India are summarised in Table 50.

Table 50: Observed local environmental impacts from sugarcane, jatropha and neem production in India

Environmental impact	Sugarcane	Jatropha	Neem
Deforestation	White	Red	Green
Loss of agro-biodiversity	White	White	Green
Loss of biodiversity	White	Red	Green
Air pollution	Red	White	Green
Water pollution	Red	White	Green
GMO contamination	Green	White	Green
Eutrophication	Red	White	Green
Soil fertility decline	Red	White	Green
Erosion	Red	Red	Green

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Brittaine and Lutaladio, 2010; Cheesman, 2004; de Fraiture et al., 2008; FAO, 2005b; Gonsalves, 2006; ICRISAT-WWF, 2009; Ministry of Agriculture; Uppal, 2008).

Local environmental impacts allocated to domestic biofuel production

The share of the total sugarcane area that was harvested for domestic biofuel production was 7.4% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (7.4%).

Since no production of domestic biofuels from jatropha or neem has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in India. However, it is likely that biodiesel is being produced from both jatropha and neem in India, although to an unknown extent.

Local environmental impacts allocated to EU biofuel demands

Since no feedstock for EU biofuels in 2008 has been traced to jatropha or neem produced in India, and only small fractions of Indian sugarcane; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Abou Kheira, A.A. and Atta, N.M.M., 2009. Response of Jatropha Curcas L. to water deficit: yield, water use efficiency and oilseed characteristics. *Biomass and bioenergy*, 33(10), pp.1343-1350.

Bioenergy Site, the, 2010. Available at: http://www.thebioenergysite.com/news/5430/is-indias-miracle-biofuel-crop-too-good-to-be-true Accessed on January 27, 2010.

Brittaine, R. and Lutaladio, N., 2010. *Jatropha: A Smallholder Bioenergy Crop. The Potential for Pro-Poor Development*. Rome: Food and Agriculture Organization of the United Nations (FAO) and International Fund for Agricultural Development (IFAD) (Integrated Crop Management Vol. 8–2010).

Cheesman, O., 2004. *The environmental impacts of sugar production*. Trowbridge: CABI Publishing and WWF.

de Fraiture, C., Giordano, M., and Liao, Y., 2008. Biofuels and implications for agricultural water use: blue impacts of green energy. *Water Policy*, 10 Supplement 1, pp.67–81.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

FAO. 2005. *Fertilizer use by crop in India*. Rome: FAO - Land and Plant Nutrition Management Service Land and Water Development Division.

FAO, 2007. *FAO Country Profiles – India.* Available at: http://www.fao.org/countryprofiles/index.asp?lang=en&ISO3=IND Accessed on April 8, 2011.

FAO, 2011. *FAO country profile: India*. Available at: http://www.fao.org/countryprofiles/index.asp?lang=en&iso3=IND Accessed on May 30, 2011.

FAPRI, 2010. *FAPRI 2010 U.S. and World Agricultural Outlook*. Ames: Food and Agricultural Policy Research Institute, Iowa State University and University of Missouri-Columbia.

Foidl N., Foidl, G., Sanchez, M., Mittelbach, M. and Hackel, S., 1996. Jatropha curcas L. as a source for the production of biofuel in Nicaragua. *Bioresource Technology*, 58(1), pp.77-82.

Gonsalves, J.B., 2006. *An assessment of the biofuels industry in India*. United Nations Conference on Trade and Development. (UNCTAD/DITC/TED/2006/6).

ICRAF, 2009. *Agroforestree Database*. World Agroforestry Center. Available at: http://www.worldagroforestrycentre.org/sites/treedbs/aft.asp Accessed on October 1, 2009.

ICRISAT-WWF, 2009. *Sustainable Sugarcane Initiative (SSI) - Improving Sugarcane Cultivation in India - Training Manual*. Andhra Pradesh: ICRISAT - WWF Project.

IFAD, 2011. *Rural Poverty Portal*. Available at: http://www.ruralpovertyportal.org/web/guest/country/geography/tags/india Accessed on April 6, 2011.

Kishwan, J., Pandey, R and Dadhwal, V.K., 2009. *India's forest and tree cover: Contribution as a carbon sink*. Dehradun: The Indian Council of Forestry research and Education. (Technical paper No 130).

Ministry of Agriculture. *Neem -a versatile tree*. http://www.keralaagriculture.gov.in/htmle/bankableagriprojects/fw/neem.htm Accessed on February 27, 2011.

Indonesia

Selected biofuel crops for Indonesia include oil palm and sugarcane. As seen in Table 51, a rather small share (about 3%) of the total area under oil palm production in 2008 was used for domestic biodiesel production. However, about 4% of the total area was used for production of biodiesel and –feedstock for the EU market. The reason for this is that most (about 76%) of the EU palm oil biodiesel that originated from Indonesia in 2008 was processed outside Indonesia. It should be noted that some co-products are likely to have been produced on the same areas as biodiesel feedstock. About 10% of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production, although none was exported to the EU.

Table 51: Area used for production of Indonesia's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Oil palm	5,000	142	2.8%	190	3.8%
Sugarcane	416	40	9.6%	0	0%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Oil Palm

As seen in Figure 46, cultivated land constitutes a much larger share of the total agricultural land than pastures. Permanent crops are widespread, although slightly more land is used for the cultivation of annual crops. Oil palm production constitutes about one third of the total area under permanent crops, making it a very important crop in Indonesia's agriculture. Not much oil palm is used for domestic production of biodiesel, although significant amounts of Indonesian palm oil might be used for biodiesel production in other countries.

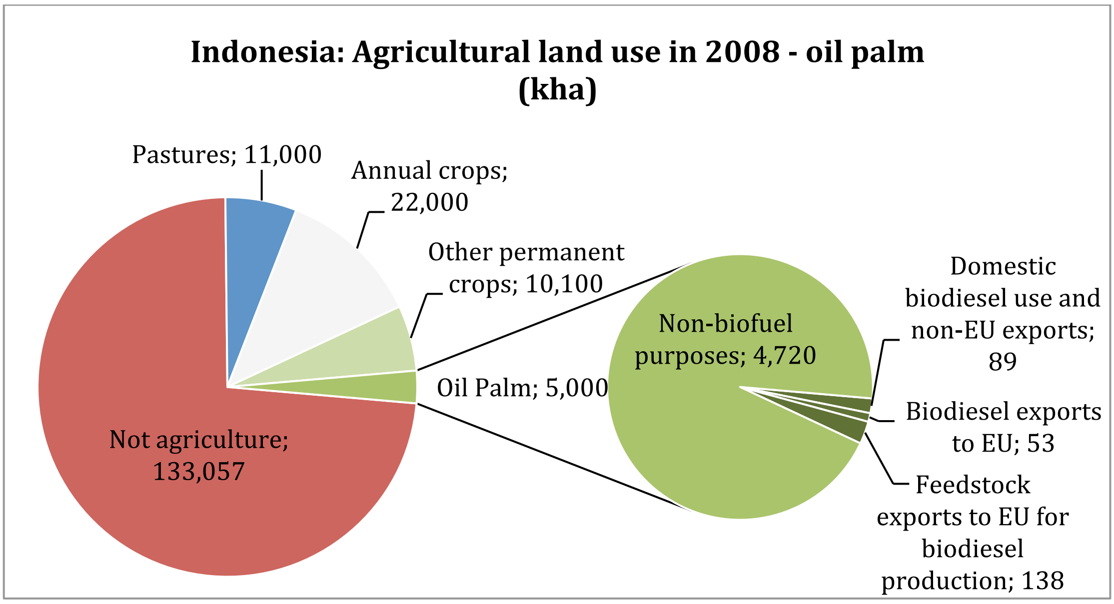


Figure 46: Agricultural land use in Indonesia in 2008, focused on oil palm production

Historical developments

Between 1990 and 2008, oil palm production in Indonesia increased more than 6.5 times. The increase was rather constant during 1990-1998 and then continued to be constant, but with a higher rate, between 1999-2008. As can be seen in Figure 47, yields have remained rather unchanged during the period, while acreage have increased in direct relation to production volumes. Therefore, oil palm production increases in Indonesia have been made possible due to a continuous expansion of oil palm plantations.

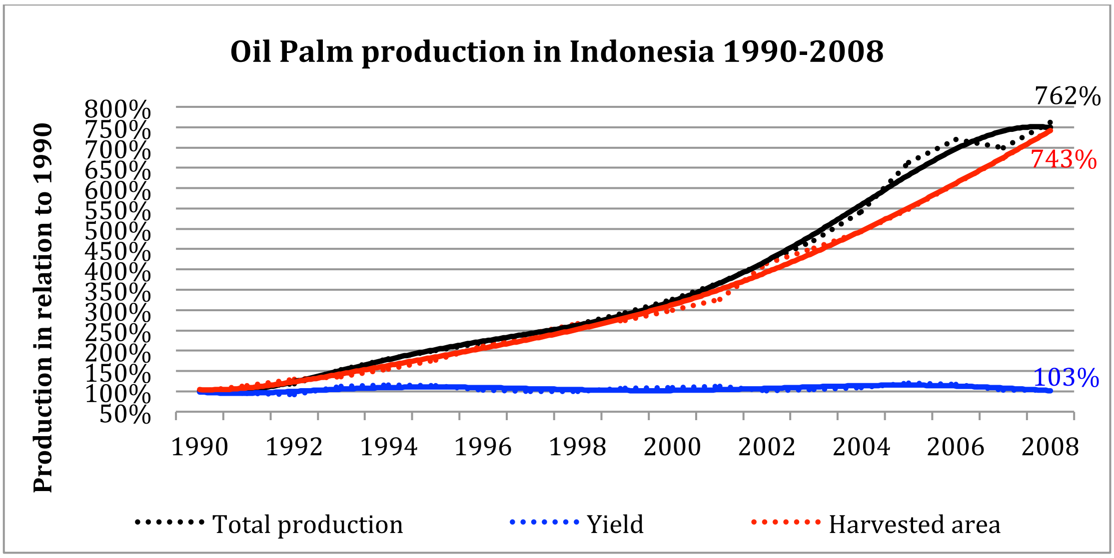


Figure 47: Change in oil palm production, yields and harvested area in Indonesia, 1990-2008

Historically, commercial oil palm cultivation started in Sumatra in 1911 while the expansion to other parts of Indonesia did not occur until the 1980s. Traditionally, oil palm plantations often have replaced forests previously degraded by fire and logging, although illegal oil palm developments have been reported inside protected areas.

Between 1990 and 2005 the area under oil palm production increased by 4.4 million ha to 6.1 million ha (MoA 2011), while total forest loss was 28.1 million ha. Hence, conversion to oil palm could account for at most 16% of recent deforestation. It has been estimated that 1.7–3.0 million ha of forest were lost to oil palm during this period (Fitzherbert et al 2008). However, Koh and Wilcove's (2008) analysis of land-cover data compiled by the FAO suggests that during the period 1990–2005 at least 56% of the oil palm expansion in Indonesia occurred at the expense of forests. It is clear that the uncertainties regarding these estimates are high and, as they exclude changes in unproductive land area and include only mature oil palm area, they could be over- or underestimates (FAO 2011).

The forest areas classified as conversion forest are allocated for utilization to non-forest uses. This mean that deforestation in these areas are planned losses within Indonesia's forest management framework. These planned losses constitute 25% of overall deforestation on state owned land. Areas of conversion forest are used for agriculture and plantation crops, and a high proportion is converted to timber (pulp) and oil palm plantations (the World Bank 2009). Some of this converted forest is swampland on peat soil, which represents only 5-8 Mha, but are likely among the most intensive sources of greenhouse gas emissions per hectare. Estimations show that approximately 25% of the historical oil palm establishments have been on peatlands. Because of high carbon concentrations in peat soil, smaller areas may lead to higher greenhouse gas emissions than deforestation on mineral soil, or "dry land". Developments of oil palm on peatlands cause irreversible damage to vulnerable ecosystems and require high levels of management to be sustainable (the World Bank 2009).

Land-use dynamics from future production increases

Even though the extent to which oil palm has been a direct cause of past deforestation is difficult to quantify, its potential as a future agent of deforestation is large (Fitzherbert et al. 2008). The demand for palm oil is predicted to continue increasing, and globally, most of the remaining areas suitable for planting are forested or under other land uses. Presently, relatively little oil palm is grown outside Southeast Asia, although, 410–570 million ha of currently forested land across Southeast Asia, Latin America and Central Africa are potentially suitable for oil palm cultivation and might be increasingly utilised as demand rises and agronomic advances are made (Fitzherbert et al. 2008).

According to projections made by FAPRI (2010) palm oil production is projected to increase by 35.7% from 21 Mt in 2009/10 to 28.5 Mt in 2019/20 (FAPRI 2010). Indonesia will continue to be a strong player in the international export of palm oil with a projected increase in export from 15.7 Mt during 2009/10 to 22.8 Mt in 2019/20, an increase of 45.2% (FAPRI 2010).

The biodiesel in Indonesia is produced mainly from palm oil. The amount produced feedstock for the biodiesel, in this case palm oil, was 84 kt in 2009/10 and is projected ton increase by 158,33% to 217 kt by 2019/20. (FAPRI 2010)

Indonesia's National Biofuel Development Committee has suggested that the government makes it mandatory for biofuels to constitute 2 to 2.5% of the nation's total fuel consumption (the World Bank 2009). This would result in an increase in the consumption of biofuel to 5.3 million kiloliters by 2010 and 9.8 million kiloliters by 2015. As in other countries, economic incentives and quotas are being suggested in Indonesia as means to stimulate the sector. This would equal 1.2 million to 1.5 million kiloliters (kl) per year. Tax exemptions for diesel fuel with biofuel added have been suggested by the industry at the same time as the Indonesian Biofuel Producers Association (APROBI) demanded the government to make biofuel use mandatory at 1% of the country's total fuel consumption as a way to help develop the industry.

The predicted domestic consumption of biodiesel in Indonesia was estimated by FAPRI (2010) at 11.4 ML in 2009/10 and is projected to increase 66,67%, to 19.0 ML, in 2019/20. At the same time Indonesia's net exports predicted to increase from 79.5 ML in 2009/10 to 219.5 ML in 2019/20.

Indonesia is actively promoting biofuel developments and oil palm expansion is often supported by the government (the World Bank 2009). As means to increase the production, forested and non-forested land has been provided at low rates within a legal framework, which in many cases have lacked attention to local land rights (Barr et al. 2010). The idea was that timber sales were expected to finance the establishment of oil palm plantations. However, in many cases palm oil schemes have been used to obtain logging licenses without ever establishing oil palm estates, resulting only in deforestation without replanting of oil palm. Some estimates predict that up to 12 million ha have been allocated to oil palm and deforested but not planted (Fargione et al. 2008).

As a way to avoid future deforestation from oil palm expansion, there have been suggestions to convert Imperata grasslands, which is usually portrayed as unproductive wasteland, into oil palm production (Deininger et al, 2011). According to Fairhurst and McLaughlin (2009), there are more than 20 million ha of Imperata grassland available for such developments. This would be more than enough to cover the estimated 10–20 million ha needed to meet oil palm demand for the next decade and beyond. Costs of establishing oil palm on these lands are much lower than on secondary forests, and yields are estimated to be similar to those on forestland. However, the current usage of these lands needs to be taken into account since they might be important to local communities. Bringing Imperata grasslands into oil palm production will thus require that land rights are recognised and negotiated and that benefits are shared with local communities. The World Resources Institute is currently conducting community mapping to identify degraded land of interest for oil palm developments, which could replace planned expansion in forest areas (Deininger et al, 2011).

Regarding potential expansion into other land uses FAPRI have projected that biofuel production in Indonesia is unlikely to expand onto existing agricultural land. According to FAO data from 2007, there is no decline in land areas harvested for other purposes; the area of oil palm is rapidly increasing, rice is increasing, rubber is increasing slightly while other production is more or less constant.

Sugarcane

Historical developments

Between 1990 and 2008, the total production of sugarcane in Indonesia fluctuated with an overall negative trend resulting in a decrease of 7% in 2008 compared to 1990. Yields have followed the same pattern although with less fluctuations and an overall decrease of 33%. As can be seen in Figure 48, the harvested area increased between 1990 and 1994 when it started to slowly decrease until 2003. Since then, the harvested area has increased to a total increase of 20% in 2008 compared to 1990. The small decrease in total production can be explained by the increase in harvested area at the same time as yields decreased.

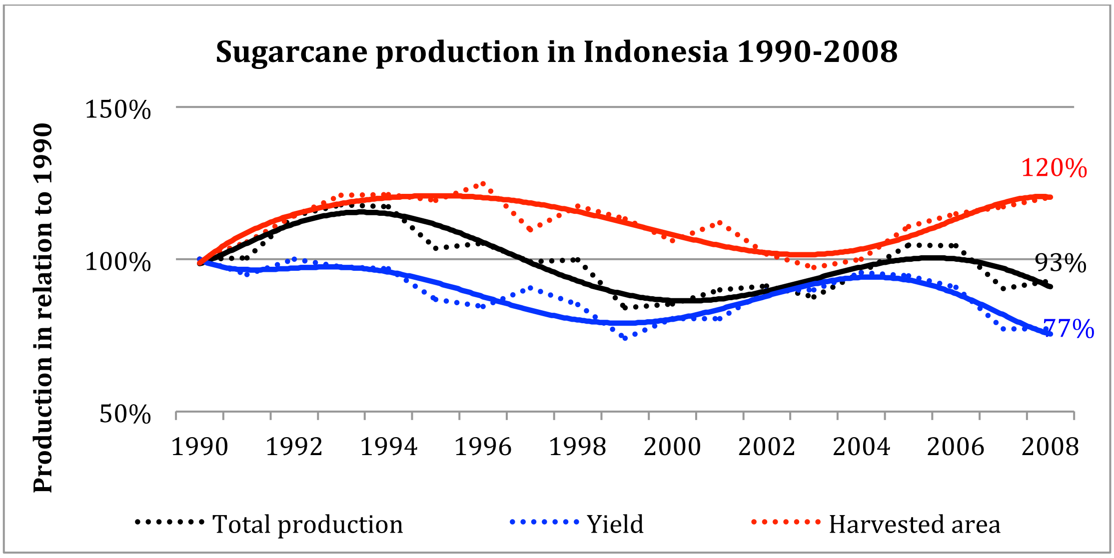


Figure 48: Change in sugarcane production, yields and harvested area in Indonesia, 1990-2008

Historically, sugarcane has had to compete with other crops, especially rice. Relatively less attractive returns as compared to other crops have continued to discourage some farmers from growing cane (FAO 1997). Competition for land, particularly irrigated areas, not only from other crops and livestock production, but also increasingly from urbanization in densely populated areas of Java, has resulted in a shift in the cultivation of sugarcane to non-irrigated areas and to poorer lands (FAO 1997). Thus, unless yields can be sufficiently increased to enhance the economic viability of crop, possibilities for growth will continue to be limited.

Land-use dynamics from future production increases

According to FAPRI (2010), areas under sugarcane cultivation are not predicted to increase during the next ten years, remaining at a steady 350 000 ha. However, slightly increasing yields (+2.75%) and total production (+3.17%) are expected. The domestic consumption, however, is projected to increase with 23.07 % by 19/20, a demand likely to be met primarily by increasing imports. Indonesia is one of the main net importers of sugar, following only EU, Russia and the US. In addition, imports are projected to increase from 1.5 Mt to 2.3 Mt in 10 years (FAPRI 2010). As a region, Asia is the largest importer of sugar, with China, Indonesia, Japan, Malaysia and South Korea projected to account for 19% of world trade by 2019/20.

Since Indonesia is a large importer of sugar and is unavailable to meet domestic demands, it is unlikely that Indonesia will produce significant amounts of sugarcane ethanol for the EU-RED market.

Production system characteristics and local environmental impacts

Production system characteristics for oil palm and sugarcane in Indonesia are summarised in Table 52.

Table 52: Production system characteristics for oil palm and sugarcane in Indonesia

System component	Oil Palm	Sugarcane
Large scale	Dominant	
Small scale	Outgrower schemes, 35-40 % of area planted	70% of the sugarcane areas are cultivated by farmers, mostly on small to medium sized holdings
Mechanized farming system	Land preparation	
Manual farming system	Harvesting	
Tillage		
Reduced and no tillage	Perennial crop	
Irrigated		
Rain fed		
Mono-cropping	Dominant	
Multi-cropping		
Crop rotation	Perennial crop	
Mineral fertilizer used		
Chemical pesticides used	E.g. "Paraquat"	
GMO seeds for sowing	Very little	
Land preparation with fire		
By-products (from harvesting)		

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (German et al, 2010; FAO, 1997; Fitzherbert, 2008; Hooijer A, 2006; ICN, 2010; Koh and Wilcove, 2008; Movement, 2008; Oosterkamp, 2007; Pramudya and Pertiwi, 1998; Tauli-Corpuz, 2007; Vermeulen, 2006).

Deforestation and loss of biodiversity and ecosystem services is the most serious impact of oil palm plantations in Indonesia, including loss of habitat for endangered species. A report published in 2007 by UNEP (the United Nations Environment Programme) acknowledges that oil palm plantations are now the leading cause of rainforest destruction in Indonesia and Malaysia. Indonesia lost 1.7-3.0 million hectares of forest to oil palm plantations between 1990 and 2005 (Fitzherbert, 2008). Conversion of either primary or secondary (logged) forests to oil palm results in habitat fragmentation, soil erosion, landslides, haze, drought and floods, as well as significant biodiversity losses, whereas conversion of pre-existing cropland (rubber) to oil palm results in fewer biodiversity losses (Koh and Wilcove, 2008). It has been estimated that 80-100% of the species in a rainforest do not survive in the plantations (Movement, 2008). Data on indirect deforestation are largely qualitative. A CIFOR study found that oil palm plantations cause degradation in adjacent forest areas by displacing timber extraction activities and concentrating these activities in remaining forests (German et al, 2010). Conversion of peat swamp forest to oil palm is the land use change of greatest concern to global climate change mitigation (German et al, 2010). The burning of the country's peat land areas alone accounts for 4% of global greenhouse gas emissions (Hooijer A, 2006). Estimates for the time required to return to levels of carbon in the original ecosystem (the so-called 'carbon payback time') for these forests range from 423 to 692 years (Fitzherbert et al. 2008; Fargione et al. 2008 in (German et al, 2010).

Air pollution results from using fire for land preparation, as well as annual fires from drained peat and deforested lands. In 1998, millions of people in the region were affected by the widespread fires, which have been related to the oil palm industry.

Water pollution results from increased erosion and siltation, use of pesticides and fertilizers and from the increased incidence of flooding resulting from the destruction of natural drainage in peatlands (German et al, 2010). Integrated pest management practices is used to an unclear but increasing extent both among smallholders and in plantations (FAO 2004).

By-products are palm kernel oil (pressed from the kernels of the oil palm fruit) and palm kernel meal (produced by grinding the kernels from which oil is pressed). Most of the palm kernel oil is used in e.g. soap, detergents and cosmetic industries. A recent trend is to use this as energy source for electricity plants and for biofuel (Oosterkamp, 2007).

Observed local environmental impacts from oil palm and sugarcane production in Indonesia are summarised in Table 53.

Table 53: Observed local environmental impacts from oil palm and sugarcane production in Indonesia

Environmental impact	Oil Palm	Sugarcane
Deforestation		
Loss of agro-biodiversity		
Loss of biodiversity		
Air pollution		
Water pollution		
GMO contamination		
Eutrophication		
Soil fertility decline		
Erosion		

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (German et al, 2010; FAO, 1997; Fitzherbert, 2008; Hooijer A, 2006; ICN, 2010; Koh and Wilcove, 2008; Movement, 2008; Oosterkamp, 2007; Pramudya and Pertiwi, 1998; Tauli-Corpuz, 2007; Vermeulen, 2006).

Local environmental impacts allocated to domestic biofuel production

The share of the total oil palm area that was harvested for domestic biofuel production was 2.8% in 2008. However, the net area requirement is lower since oil palm biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 2.6% of the total oil palm area in 2008. Since oil palm cultivation for domestic biofuels has the same characteristics as oil palm cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total oil palm area used for production of domestic biofuels (2.6%). It should be noted though that a much larger share of the total oil palm was likely used for production of palm oil, processed into biofuels in other countries.

The share of the total sugarcane area that was harvested for domestic biofuel production was 9.6% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (9.6%).

Local environmental impacts allocated to EU biofuel demands

The share of the total oil palm area that was harvested for EU biofuel production was 3.8% in 2008. However, the net area requirement is lower since oil palm biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 3.5% of the total oil palm area in 2008. Since oil palm cultivation for EU biofuels has the same characteristics as oil palm cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total oil palm area used for EU biofuel production (3.5%).

Since no feedstock for EU biofuels in 2008 has been traced to sugarcane produced in Indonesia; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Barr, C., Dermawan, A., Purnomo, H. and others. 2010, *Financial Governance and Indonesia's Reforestation Fund during the Socharto and Post-Socharto Periods 1989–2009*. Bogor: Center for International Forestry Research. Occasional Paper 52.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

Fairhurst, T. and McLaughlin, D., 2009. *Sustainable Oil Palm Development on Degraded Land in Kalimantan*. Washington DC: World Wildlife Fund (WWF).

FAO, 1997 *Proceedings of the Fiji/FAO 1997 Asia Pacific Sugar Conference*. Available at: http://www.fao.org/docrep/005/x0513e/x0513e21.htm Accessed on March 13, 2011.

FAO, 2004. *Fertilizer use by crop in Malaysia*. Available at: http://www.fao.org/docrep/007/y5797e/y5797e00.htm Accessed on June 1, 2011.

FAO, 2011. *FAO country profile: Indonesia*. Available at: http://www.fao.org/countryprofiles/index.asp?lang=en&iso3=IDN Accessed on May 30, 2011.

FAPRI, 2010. *FAPRI 2010 U.S. and World Agricultural Outlook*. Ames: Food and Agricultural Policy Research Institute, Iowa State University and University of Missouri-Columbia.

Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P., 2008. Land clearing and the biofuel carbon debt. *Science*, 319(5867), pp.1235–1238.

Fitzherbert, E.B., Struebig, M.J., Morel, A., Danielsen, F., Brühl, C.A., Donald, P.F. and Phalan, B., 2008. How will oil palm expansion affect biodiversity?. *Trends in Ecology & Evolution*, 23(10), pp.538-545.

German, L., Schoneveld, G., Skutsch, M., Andriani, R., Obidzinski, K., Pacheco, P., Komarudin, H., Andrianto, A., Lima, M. and Dayang Norwana, A.A.B., 2010. *The local social and environmental impacts of biofuel feedstock expansion - A synthesis of case studies from Asia, Africa and Latin America*. Bogor: Center for International Forestry Research (CIFOR).

Hooijer, A., Silvius, M., Wösten, H. and Page, S., 2006. *PEAT-CO_2, Assessment of CO_2 emissions from drained peatlands in SE Asia*. Delft Hydraulics Report Q3943.

ICN, 2010. *Development of sugar plantations toward sugar self sufficiency*. Indonesian Commercial Newsletter (ICN). Available at: http://www.datacon.co.id/Agri-2010Sugar.html Accessed on May 27, 2011.

Koh, P.L. and Wilcove, S.D., 2008. Is oil palm agriculture really destroying tropical biodiversity?. *Conservation Letters*, 1(2), pp.60–64.

MoA, 2011. *Ministry of Agriculture, Indonesia*. Available at: http://www.deptan.go.id Accessed on April 2, 2011.

Movement, W.R. 2008. *Regional perspectives on plantations - Oil palm and rubber plantations in Western and Central Africa: An Overview*. WRM Briefing.

Oosterkamp, J.W., 2007. *Oil Palm: comparing Chocó (Colombia) with West Kalimantan (Indonesia)*. Bogota: Cordaid.

Pramudya, B. and Pertiwi, S., 1998. *Sugar-cane Cropping and Operation Scheduler for Selective Mechanized Plantation*. Bogor: Agricultural Information Technology in Asia and Oceania.

Tauli-Corpuz, V. and Tamang, P., 2007. *Oil Palm and Other Commercial Tree Plantations, Monocropping: Impacts on Indigenous Peoples' Land Tenure and Resource Management Systems and Livelihoods*. New York City: UN Permanent Forum on Indigenous Peoples, Sixth Session.

Vermeulen, S. and Goad, N., 2006. *Towards better practice in smallholder palm oil production*. London: Institute for Environment and Development.

World Bank, the, 2009. Investing in a more sustainable Indonesia, Country environmental Analysis. Jakarta: the World Bank Group.

Malaysia

Selected biofuel crops for Malaysia include oil palm only. As seen in Table 54, a very small share (about 1%) of the total area under oil palm production in 2008 was used for domestic biodiesel production. However, 2.5% of the total oil palm area was used for production of biodiesel and –feedstock for the EU market. The reason for this is that most (about 96%) of the EU palm oil biodiesel that originated from Malaysia in 2008 was processed outside Malaysia. It should be noted that some co-products are likely to have been produced on the same areas as biodiesel feedstock.

Table 54: Area used for production of Malaysia's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Oil palm	3,900	43	1.1%	98	2.5%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Oil Palm

As seen in Figure 49, most of the agricultural land in Malaysia is cultivated and pastures are uncommon. Permanent crops are widespread and constitute about 76% of the total cultivated land. Oil palm is being produced on about two thirds of the land under permanent crops, making it the most important crop in Malaysia's agriculture. Not much oil palm is used for domestic production of biodiesel, although significant amounts of Indonesian palm oil might be used for biodiesel production in other countries.

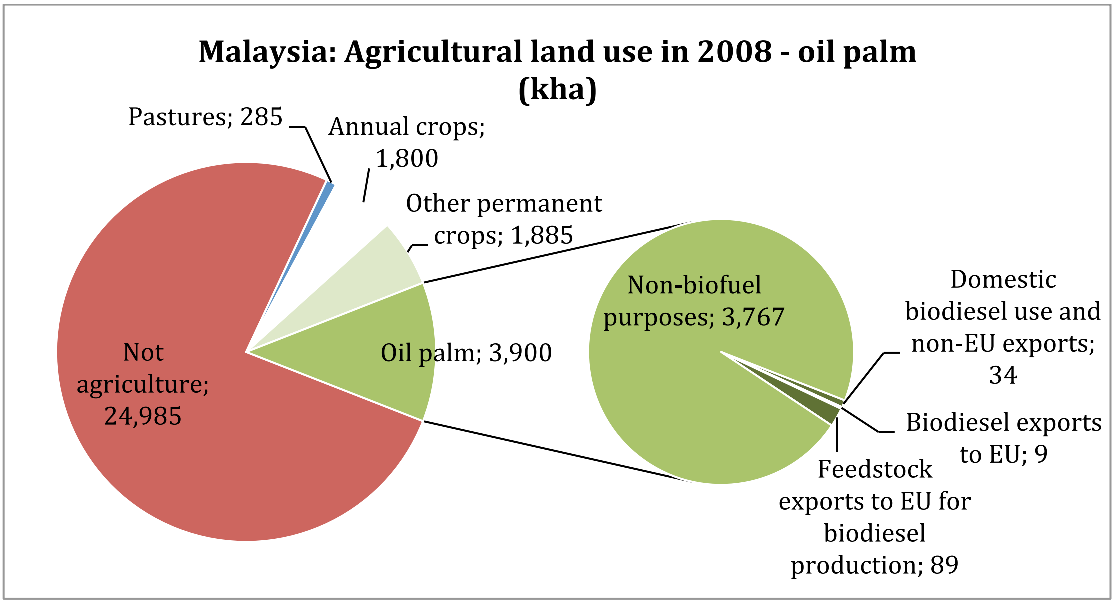


Figure 49: Agricultural land use in Malaysia in 2008, focused on oil palm production

Oil palm was first planted commercially in Peninsular Malaysia in 1917, where it historically has replaced both rubber plantations and forest. Large-scale expansion commenced during the 1960s, mainly in response to the government's diversification policy, which aimed to reduce the dependence of the national economy on natural rubber. Rubber prices were continuing to decline, there was mounting competition from synthetic rubber, and the demand for edible oils was expanding (UNDP 2007). As land became scarce, expansion of oil palm shifted to other areas, most commonly Sabah and Sarawak. Expansion often occurred in association with logging, which was facilitated by the reclassification of some state forest reserves to allow for conversion into plantations (Fitzherbert et al. 2008).

Historical developments

Malaysia has experienced a steady increase in palm oil production during 1990-2008 resulting in a total production increase of 168 %. As seen in Figure 50, the increase has been made possible mainly due to an increased harvested area (+123%). Yields remained rather unchanged until 2002, but have since then increased with 20%.

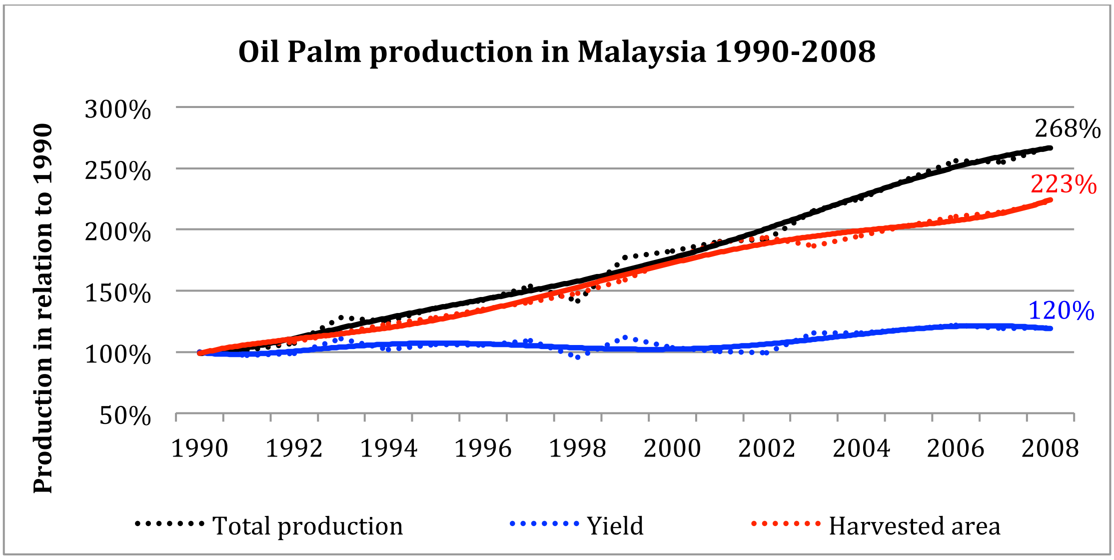


Figure 50: Change in oil palm production, yields and harvested area in Malaysia, 1990-2008

Agriculture in Malaysia is mainly taking place in the Peninsular Malaysia while northern Borneo is mostly covered with dense natural forest, although with smaller areas under intensive cultivation (FAO 2011). Even though oil palm production occurs in all states in Malaysia, four states; Sabah, Johor, Pahang and Sarawak constitute 75% of the total planted area. Each of these states has over half a million hectares under oil palm production (UNDP 2007).

Historical developments

Between 1990 and 2005 the area of oil palm in Malaysia increased by 1.8 Mha to 4.2 Mha, while at the same time 1.1 million ha of forest were lost (MPOB 2011). However, this estimate neither considers conversion of forests into unproductive land, nor whether oil palm caused or simply followed deforestation (Fitzherbert et al. 2008). According to Koh and Wilcove's (2008) analysis of land-cover data compiled by the FAO, 55%–59% of oil palm expansion in Malaysia during 1990–2005 occurred at the expense of forests. Besides expansion on forests, oil palm expansion has historically partly taken place on abandoned rubber plantations in Malaysia, as previously discussed.

Land-use dynamics from future production increases

Malaysia and Indonesia constitute 85 % of the global palm oil production. Palm oil is used for a variety of products, one of them being biodiesel. If demand for biodiesel would increase, demand for palm oil is likely to follow.

Palm oil production is projected to increase with 26.5 %, from 18.5 Mt in 2009/10 to 23.4 Mt in 2019/20 (FAPRI 2010). Malaysia will also continue to be a large exporter of palm oil with a projected 24.5% increase in export, from 15.1 Mt in 2009/10 to 18.8 Mt in 2019/20 (FAPRI 2010). Production of palm oil fruit is projected to increase with 57,36%, from 265 kt in 2009 to 417 kt in 2019/20.

Production of biodiesel in Malaysia is predicted to increase with 56,58%, from 288 ML in 2009/10 to 450 ML in 2019/20. Domestic consumption in 2009/10 was 68 ML and is projected to increase by 11,11%, to 76 ML in 2019/20. Malaysia's net export of biodiesel is predicted to increase from 220 ML in 2009/10 to 375 ML in 2019/20 (FAPRI 2010)

The predicted increase in both oil palm and biodiesel production will demand either increasing yields, as projected by Chan (2011), expansion onto new land, or both. Considering that Malaysia has the world's highest oil palm yields (21.3 t/ha) (the Deininger et al, 2011), increasing yields seems insufficient for meeting the projected production increases. Therefore, expansion onto new land is likely.

According to the Deininger et al (2011), available land for oil palm expansion in Malaysia adds up to 145 000 ha. However, most of the available areas have a population density of more than 25 people per ha and are located more than 6 hours from the closest market, which is likely to obstruct a potential expansion.

According to Chan (2011), a part of the expansion is very likely to occur on agricultural land, although not likely on pastures. Relations between oil palm expansion and agricultural land area can be seen in FAO statistics. As the oil palm area is rapidly increasing, areas planted with other crops are slightly declining (e.g. rubber) or remaining constant (e.g. rice). However, FAO (2011) reports that the risk of oil palm plantations expanding onto agricultural land is small. Therefore, it can be assumed that future expansion of oil palm production will occur either on degraded or abandoned rubber plantations, as projected by FAPRI (2010) or on natural vegetation. Areas of relevance would be coastal swamp areas, logged over secondary forest/degraded forest, and most likely primary rainforest. Fargione et al. (2008) estimates that accelerating demand for palm oil is contributing to 1.5% annual deforestation of tropical rainforests in Malaysia and Indonesia.

Production system characteristics and local environmental impacts

Production system characteristics for oil palm Malaysia are summarised in Table 55.

Table 55: Production system characteristics for oil palm in Malaysia

System component	Oil Palm
Large scale	62 %
Small scale	600 000 hectares of land settlement schemes, 11 % of oil palm plantations are independent small holder production
Mechanized farming system	E.g. land preparation
Manual farming system	E.g. harvesting
Tillage	
Reduced and no tillage	Perennial crop
Irrigated	
Rain fed	
Mono-cropping	Dominating
Multi-cropping	
Crop rotation	Perennial crop
Mineral fertilizer used	
Chemical pesticides used	
GMO seeds for sowing	
Land preparation with fire	
By-products (from harvesting)	

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (German et al, 2010; Jelsma et al, 2009; Rahman, 2008; Tauli-Corpuz, 2007)

A report published in 2007 by UNEP acknowledges that oil palm plantations are the leading cause of rainforest destruction in Indonesia and Malaysia (WWF 200-). In Malaysia, 86% of deforestation from 1995-2000 was for oil palm plantations, which has led to a significant reduction in biological diversity (of 80% for plants and 80-90% for mammals, birds, and reptiles). Clearing land for oil palm production in slopes also causes erosion and landslides.

Air pollution results from using fire for land preparation, as well as annual fires from drained peat and deforested lands. In 1998, millions of people in the region were affected by the widespread fires, which have been related to the oil palm industry.

Water pollution and eutrophication results from fertilizers, and pesticides. In Malaysia, e.g. the poisonous chemical compounds paraquat and round-up are used by smallholders (Rahman, 2008). Water pollution also results from erosion, landslides and the destruction of natural drainage in peatlands (German et al, 2010). There is documentation of low water tables, as well as flooding and water logging (due to e.g.

peat swamp drainage and removal of forests natural water retention services), which can lead to increased frequency of malaria and yellow fever (German et al, 2010).

Observed local environmental impacts from oil palm production in Malaysia are summarised in Table 56.

Table 56: Observed local environmental impacts from oil palm production in Malaysia

Environmental impact	Oil Palm
Deforestation	Major issue
Loss of agro-biodiversity	
Loss of biodiversity	Major issue
Air pollution	Major issue
Water pollution	
GMO contamination	
Eutrophication	
Soil fertility decline	
Erosion	

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (German et al, 2010; Jelsma et al, 2009; Rahman, 2008; Tauli-Corpuz, 2007)

Local environmental impacts allocated to domestic biofuel production

The share of the total oil palm area that was harvested for domestic biofuel production was 1.1% in 2008. However, the net area requirement is lower since oil palm biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 1% of the total oil palm area in 2008. Since oil palm cultivation for domestic biofuels has the same characteristics as oil palm cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total oil palm area used for production of domestic biofuels (1%). It should be noted though that a much larger share of the total oil palm was likely used for production of palm oil, processed into biofuels in other countries.

Local environmental impacts allocated to EU biofuel demands

The share of the total oil palm area that was harvested for EU biofuel production was 2.5% in 2008. However, the net area requirement is lower since oil palm biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 2.3% of the total oil palm area in 2008. Since oil palm cultivation for EU biofuels has the same characteristics as oil palm cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total oil palm area used for EU biofuel production (2.3%).

References

Chan, J. H., 2011. *Expert consultation: Carlos Duarte, consultant for Winrock International for the EU Biofuel Baseline project*.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

FAO, 2011. *FAO country profile: Malaysia*. Available at: http://www.fao.org/countryprofiles/index.asp?lang=en&iso3=MYS Accessed on April 5, 2011.

FAPRI, 2010. *FAPRI 2010 U.S. and World Agricultural Outlook*. Ames: Food and Agricultural Policy Research Institute, Iowa State University and University of Missouri-Columbia.

Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P., 2008. Land clearing and the biofuel carbon debt. *Science*, 319(5867), pp.1235–1238.

Fitzherbert, E.B., Struebig, M.J., Morel, A., Danielsen, F., Brühl, C.A., Donald, P.F. and Phalan, B., 2008. How will oil palm expansion affect biodiversity?. *Trends in Ecology & Evolution*, 23(10), pp.538-545.

German, L., Schoneveld, G., Skutsch, M., Andriani, R., Obidzinski, K., Pacheco, P., Komarudin, H., Andrianto, A., Lima, M. and Dayang Norwana, A.A.B., 2010. *The local social and environmental impacts of biofuel feedstock expansion - A synthesis of case studies from Asia, Africa and Latin America*. Bogor: Center for International Forestry Research (CIFOR).

Jelsma, I., Giller, K. and Fairhurst, T., 2009. *Smallholder Oil Palm Production Systems in Indonesia: Lessons from the NESP Ophir Project*. Wageningen: Wageningen University, Plant Science Group, Plant Production Systems.

Koh, P.L. and Wilcove, S.D., 2008. Is oil palm agriculture really destroying tropical biodiversity?. *Conservation Letters*, 1(2), pp.60–64.

MPOB, 2011. *Malaysian Palm Oil Board*. Available at: http://www.mpob.gov.my Accessed on April 5, 2011.

Rahman, A.K.A., Abdullah, R., Shariff, F.M. and Simeh, M.A., 2008. The Malaysian Palm Oil Supply Chain: The Role of the Independant Smallholders. *Oil palm industry economic journal*, 8(2), pp.17-27.

Tauli-Corpuz, V. and Tamang, P., 2007. *Oil Palm and Other Commercial Tree Plantations, Monocropping: Impacts on Indigenous Peoples' Land Tenure and Resource Management Systems and Livelihoods*. New York City: UN Permanent Forum on Indigenous Peoples, Sixth Session.

UNDP, 2007. *Malaysia Generating Renewable Energy From Palm Oil Wastes*. Kuala Lumpur: The United Nations Development Programme (UNDP).

WWF, 200-. *WWF website: Palm oil & forest conversion*. Available at: http://wwf.panda.org/what_we_do/footprint/agriculture/palm_oil/environmental_impacts/forest_conversion/ Accessed on June 1, 2011.

Pakistan

Selected biofuel crops for Pakistan include sugarcane, rapeseed and maize. As seen in Table 57, about 8% of the total area under sugarcane cultivation in 2008 was used for domestic ethanol production and about 1% of the total area was used for production of fuel ethanol for the EU market. Domestic biofuel production from rapeseed or maize has not been possible to identify or estimate.

Table 57: Area used for production of Pakistan's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	**Total harvested area in 2008** (kha)	**Cropland used for domestic biofuel production in 2008**		**Cropland used for production of feedstock for EU biofuels in 2008**	
		kha	% of total	kha	% of total
Sugarcane	1,241	98	7.9%	16	1.3%
Rapeseed	396	0	0%	0	0%
Maize	1,052	-	-	0	0%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Pakistan, which consumes about 3 million tons of vegetable oils, buys palm oil from Malaysia and Indonesia, and rapeseed from Canada, Australia and Europe. Cotton and sunflower seeds are the main sources of the nation's local cooking oil supplies" (Abraham, 2010).

Pakistan, which used to qualify for reduced tariffs under the original General System of Preference (GSP), is no longer a beneficiary since total EU imports of Pakistani ethanol are larger than 1% and thereby, subject to Full most Favoured Nations (MFN) imports. Resulting from the revocation from the GSP status, two of the seven operating distilleries in Pakistan shut down while, due to uncertain markets, another five new distilleries are likely to cancel their plans to start operation (FAO, 2007).

Agriculture accounts for more than one fifth of Pakistan's GDP. Large parts of the land area are arid, semi-arid or rugged, and not easily cultivated. The dry cropland and pastures as well as irrigated cropland are located along the major rivers in the central and southern areas of the country (FAO 2011). Most of the cropland in the country is used for rice and wheat production. Water resources are scarce throughout most of the country, and there are difficulties in providing remote rural communities with a reliable water supply (IFAD 2009). Agriculture is at the heart of the rural economy and most rural people rely on agriculture for their livelihood. Nearly two thirds of the population and 80% of the country's poor live in rural parts of the country (IFAD 2009). Large numbers of rural people are poor because of unequal land distribution; a few large landholders own a disproportionate amount of land. More than 4 million family farms have plots of less than 5 hectares each, and 25% of all farms have less than one hectare of land (IFAD 2009).

Sugarcane

As seen in Figure 51, most of the agricultural land in Pakistan is cultivated, primarily with annual crops. Sugarcane constitutes about 6% of the total land under annual crop cultivation, making it a rather important crop in Pakistan's agriculture. Since about 9% of the total sugarcane area in Pakistan is being used for domestic ethanol production, ethanol can be regarded as a rather important application for sugarcane. However, it should be noted that ethanol is primarily being produced from molasses, from sugar production.

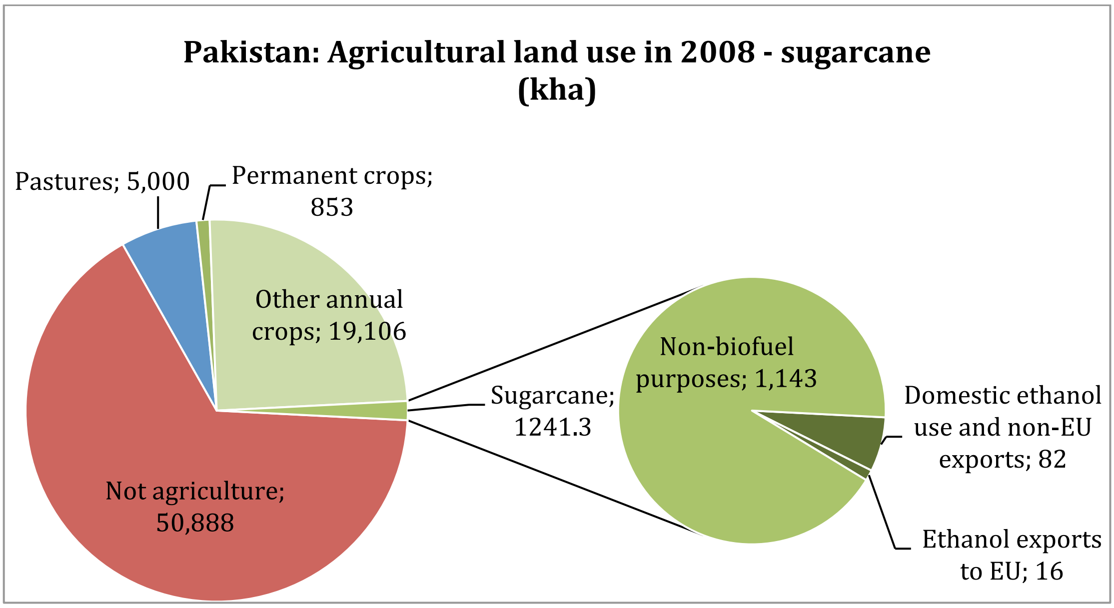


Figure 51: Agricultural land use in Pakistan in 2008, focused on sugarcane production

Historical developments

Between 1990 and 2008, sugarcane production in Pakistan increased with 80%. As seen in Figure 52, the increase has been made possible mainly by an increased harvested area (+45%), but also by increasing yields (+24%). Much of the increase in production and harvested area has happened since 2006.

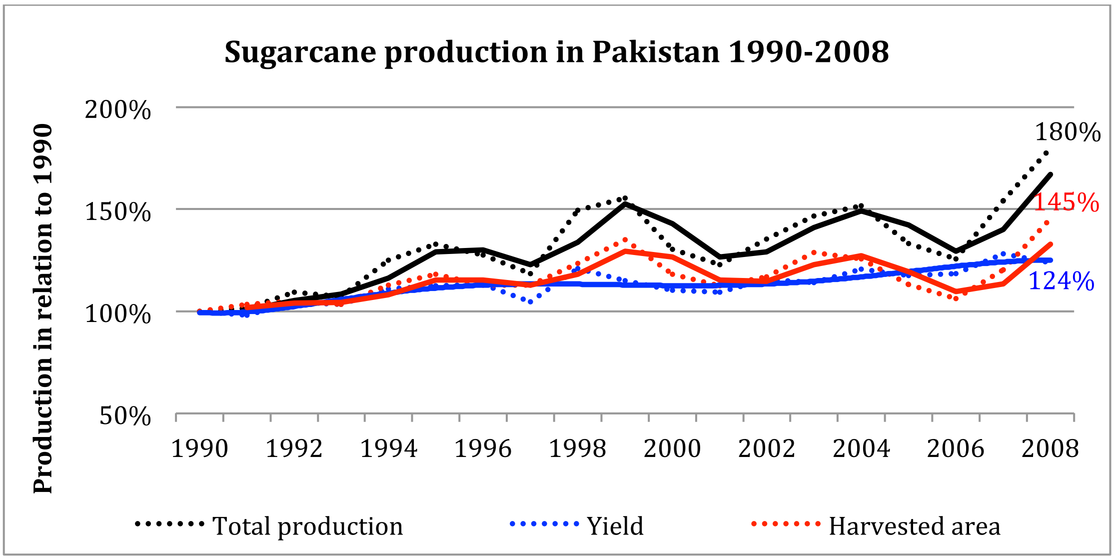


Figure 52: Change in sugarcane production, yields and harvested area in Pakistan, 1990-2008

The expansion during the last few years has mainly been at the expense of wheat production (Zaidi 2011).

Land-use dynamics from future production increases

According to Zaid (2011), a potential expansion of sugarcane is not likely to happen on agricultural land. However, if that would happen it would likely affect the production of wheat and maize during the fall and the production of cotton and rice during the spring. Sugarcane could also potentially expand on pastures, but only in areas with potential for irrigation. Any expansion onto natural vegetation is not likely due to water constraints. Rather than expanding onto new land, production should be increased by increasing yields or sucrose content, which currently is low. New and better varieties to increase sucrose content in cane are currently being investigated (Zaid 2011). This is supported by a World Bank report stating that the current area under sugarcane production is 1.2 Mha and that no land is available for expansion (Deininger et al, 2011). FAPRI (2010) also supports this, claiming that the area under sugar cane cultivation is projected to remain stable while yields, and thus production, are projected to slightly increase until 2020.

Pakistan is projected by FAPRI (2010) to be a net importer of sugar (including both beet and cane sugar) in the future and thus unlikely to produce additional sugarcane for bioethanol production. However, Pakistan's large sugar production provides for substantial amounts of ethanol being produced from molasses.

Rapeseed

Historical developments

Between 1990 and 2008, rapeseed production in Pakistan increased with 67%. As seen in Figure 53, both increasing yields (+29%) and an increased harvested area (+30%) has made the production increase possible.

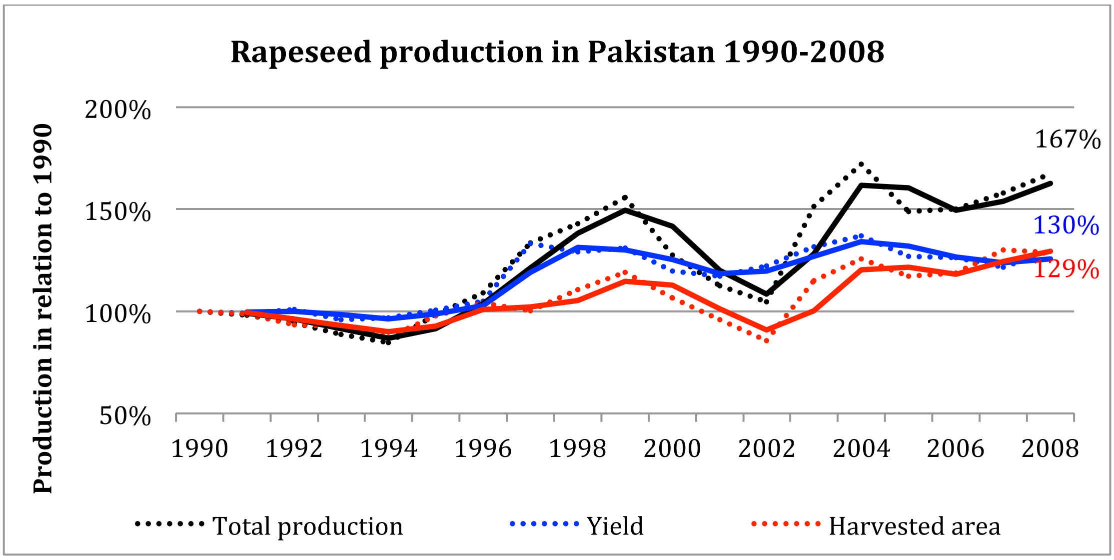


Figure 53: Change in rapeseed production, yields and harvested area in Pakistan, 1990-2008

Land-use dynamics from future production increases

A major challenge in Pakistan is the deficit of edible oils, with an indigenous production well below national consumption levels. Presently, oilseed production only meets about 25% of the demand. Rapeseed-mustard is the second most important crop, following cotton, constituting more than 17% of Pakistan's total oilseed production (PARC 2011).

According to Zaidi (2011), a potential expansion of rapeseed on existing farmland or pastures is not likely. If a potential expansion would still take place on existing cropland, it would most likely replace sugarcane and wheat production. However, the production of rapeseed already competes with wheat production for the limited water supplies and since farmers prefer to grow wheat, as it is not only a staple food but have higher economic returns, as confirmed by Zaidi (2011), such a replacement is not likely to happen. An expansion onto natural vegetation is not likely, mainly due to the limited water resources and the lack of financial capacity to invest. According to Ahmad (2010), the yield-gap for oilseeds in Pakistan is 54-85%. Therefore, by improving agricultural practices and/or intensifying cultivation, Pakistan has a theoretical potential to increase the total production of rapeseed with 54-85%, without having to expand onto new land. It should be noted though that Pakistan's limited water resources might make the yield-gap difficult to close.

Maize

Historical developments

Between 1990 and 2008, maize production in Pakistan increased with 203%. Most of the increase occurred after 2002. As seen in Figure 54, the increase was made possible mainly by increasing yields (+144%), but to a smaller extent also by an increased harvested area (+24%).

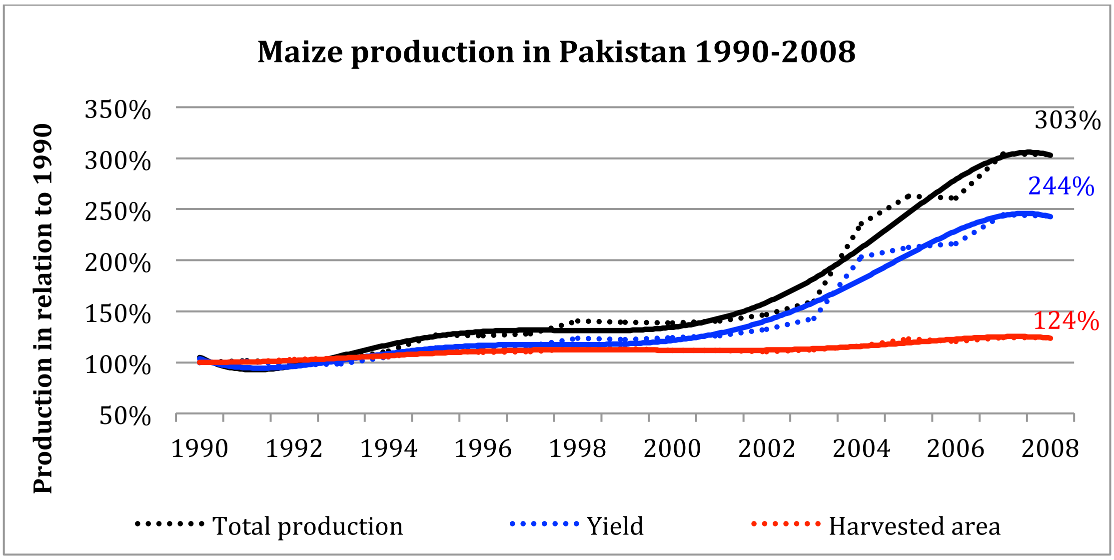


Figure 54: Change in maize production, yields and harvested area in Pakistan, 1990-2008

Land-use dynamics from future production increases

Pakistan is a net importer of maize with a projected continued steady import of 10 kt/y until 2019/20 (FAPRI 2010). A slight increase in harvested area is projected until 2019/20, from 1.05 Mha in 2009/10 to 1.07 Mha. Yields are projected to slightly increase during the same period from 2.86 t/ha in 2009/10 to 3.03 t/ha in 2019/20. According to Deininger et al (2011), there is no land available for maize expansion, which will make the country even more dependent on imports and make incentives to increase yields larger. This is supported by Zaidi (2011), who reports that a potential increase in maize production would demand investments in better yielding varieties.

Considering the high poverty levels and biophysical constraints, such as lack of water and land suitable for cultivation, most small-scale farmers are unlikely to have sufficient financial capacity for making large-scale investments. Most of the land available for expansion will require (expensive) intensive irrigation, making expansion difficult for others than financially strong large-scale landowners. However, the limited land availability might pose such a big constraint that expansion of any type of cultivation could be unprofitable, regardless of the financial capacity of the developer.

Production system characteristics and local environmental impacts

Production system characteristics for sugarcane, rapeseed and maize in Pakistan are summarised in Table 58.

Table 58: Production system characteristics for sugarcane, rapeseed and maize in Pakistan

System component	Sugarcane	Rapeseed	Maize
Large scale			
Small scale	Dominating		
Mechanized farming system			
Manual farming system	Dominating		
Tillage			
Reduced and no tillage			
Irrigated	Dominating		Dominating
Rain fed			
Mono-cropping			
Multi-cropping			
Crop rotation			
Mineral fertilizer used			
Chemical pesticides used			
GMO seeds for sowing			
Land preparation with fire			
By-products (from harvesting)	Limited use of sugarcane tops as animal feed		Green maize and dry stalks used for animal feed

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: Akbar and Khwaja, 2006; Cheesman, 2004; Dufey and Grieg-Gran, 2010; FAO, 1990; Majid et al, 2003; Muhammad D; Muhammad D., 1998; Pakissan.com 2011a; Pakissan.com 2011b; USDA 2009.

Observed local environmental impacts from sugarcane, rapeseed and maize production in Pakistan are summarised in Table 59.

Table 59: Observed local environmental impacts from sugarcane, rapeseed and maize production in Pakistan

Environmental impact	Sugarcane	Rapeseed	Maize
Deforestation			
Loss of agro-biodiversity			
Loss of biodiversity			
Air pollution			
Water pollution			
GMO contamination			
Eutrophication			
Soil fertility decline			
Erosion			

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: Akbar and Khwaja, 2006; Cheesman, 2004; Dufey and Grieg-Gran, 2010; FAO, 1990; Majid et al, 2003; Muhammad D; Muhammad D., 1998; Pakissan.com 2011a; Pakissan.com 2011b; USDA 2009.

Local environmental impacts allocated to domestic biofuel production

The share of the total sugarcane area that was harvested for domestic biofuel production was 7.9% in 2008. Since sugarcane cultivation for domestic biofuels has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarcane area used for production of domestic biofuels (7.9%).

Since no production of domestic biofuels from rapeseed or maize has been identified for 2008; no local environmental impacts from cultivation of these crops can be allocated to domestic biofuel production in Pakistan.

Local environmental impacts allocated to EU biofuel demands

The share of the total sugarcane area that was harvested for EU biofuel production was 1.3% in 2008. Since sugarcane cultivation for EU biofuel production has the same characteristics as sugarcane cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total sugarcane area used for EU biofuel production (1.3%).

Since no feedstock for EU biofuels in 2008 has been traced to rapeseed or maize produced in Pakistan; no local environmental impacts from cultivation of these crops can be allocated to EU biofuel demands.

References

Abraham, T.K., 2010. Pakistan to Buy More Palm Oil, Rapeseed to Meet Ramadan Demand, Group Says. *Bloomberg*, 5 August.

Ahmad, S., 2010. *Oilseed crops for Spate irrigated farming in Pakistan, Practical Notes #4*. Spate Irrigation Network Pakistan. Available at:

http://www.spate-irrigation.org/pakistan_network/documents/4_oil_seeds_spate_note_LQ.pdf Accessed on May 27, 2011.

Akbar, N.M. and Khwaja, M.A., 2006. *Study on Effluents from Selected Sugar Mills in Pakistan: Potential Environmental, Health, and Economic Consequences of an Excessive Pollution Load*. Islamabad: Sustainable Development Policy Institute (SDPI).

Cheesman, O., 2004. *The environmental impacts of sugar production*. Trowbridge: CABI Publishing and WWF.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. and Stickler, M., 2011. *Rising global interest in farmland - can it yield sustainable and equitable benefits?* Washington DC: The International Bank for Reconstruction and Development/The World Bank.

Dufey, A. and Grieg-Gran, M., eds., 2010. *Biofuels production, trade and sustainable development*. London: International Institute for Environment and Development.

FAO, 2007. *A review of the current state of Bioenergy development in G8 + 5 countries*. Rome: GBEP Secretariat.

FAO, 2011. *FAO country profile: Pakistan*. Available at: http://www.fao.org/countryprofiles/index.asp?lang=en&iso3=PAK Accessed on May 30, 2011.

FAPRI, 2010. *FAPRI 2010 U.S. and World Agricultural Outlook*. Ames: Food and Agricultural Policy Research Institute, Iowa State University and University of Missouri-Columbia.

FAO, 1990. *Pakistan Agricultural Census 1990 – Main Results*. Available at: http://www.fao.org/fileadmin/templates/ess/documents/world_census_of_agriculture/main_results_by_country/Pakistan_1990.pdf Accessed on February 20, 2011.

IFAD, 2009. *Enabling poor rural people to overcome poverty in Pakistan*. International Fund for Agricultural Development.

Majid, A., Nawaz, N., Hazara, R., Yousaf, M. and Baig, D., 2003. Weed dynamics, growth and yield of rapeseed canola in response to trifluralin efficacy under rainfed conditions. *Pakistan Journal of Arid Agriculture*, 6(2), pp.53-63.

Muhammad, D. *Fodder production for peri-urban dairies in Pakistan*. Available at: http://www.fao.org/ag/AGP/AGPC/doc/pasture/dost/fodderdost.htm Accessed on February 25, 2011.

Muhammad, D. 1998. *Pakistan Country Pasture/Forage resource profiles*. Available at: http://www.fao.org/ag/AGP/AGPC/doc/counprof/pakistan.htm Accessed on February 25, 2011. Last updated November 2002.

Pakissan.com, 2011a. *Rape seed mustard production in Pakistan*. Available at: http://www.pakissan.com/english/allabout/crop/rapeseed.shtml Accessed on March 1, 2010.

Pakissan.com, 2011b. *Maize production in Pakistan*. Available at: http://www.pakissan.com/english/allabout/crop/maize.shtml Accessed on March 1, 2010.

PARC, 2011. *National Coordinated Research Program*. Pakistan Agricultural Research Council. Available at: http://www.parc.gov.pk/1SubDivisions/NARCCSI/CSI/oil.html Accessed on May 27, 2011.

USDA, 2009. *Production levels different commodities*. Available at: http://www.indexmundi.com/agriculture/?country=pk&commodity=rapeseed-oilseed&graph=area-harvested Accessed on February 25, 2011.

Zaidi, M.S., 2011. Expert opinion, Muhammad Shifaat Zaidi, Islamabad, Pakistan, Advisor, Quality Control Molasses; ED&F Man Molasses, The Netherlands / United (Tate & Lyle) Molasses, UK Vice Chairman, Standing Committees on 1- Banking Credit & Finance 2- Environment, The federation of Pakistan Chambers of Commerce & Industry. Former President, Pakistan Society of Sugar Technologists.

Ukraine

Selected biofuel crops for Ukraine include rapeseed and sugarbeet. As seen in Table 60, no domestic rapeseed biodiesel production has been identified. However, 26.5% of the total area under rapeseed cultivation was used for production of biodiesel feedstock for the EU market. About 5% of the total area under sugarbeet cultivation was used for domestic ethanol production in 2008, although only small amounts were exported to the EU.

Table 60: Area used for production of Ukraine's selected biofuel crops, including areas used for domestic biofuel production and feedstock for biofuels on the EU market in 2008

Crop	Total harvested area in 2008 (kha)	Cropland used for domestic biofuel production in 2008		Cropland used for production of feedstock for EU biofuels in 2008	
		kha	% of total	kha	% of total
Rapeseed	1,380	0	0%	366	26.5%
Sugarbeet	377	19	5.1%	0.3	0.1%

Source: FAOSTAT (land data); Agra CEAS and Ecofys (biofuel production and trade data).

Rapeseed

As seen in Figure 55, most of the agricultural land in Ukraine is cultivated, almost entirely with annual crops. Actually, most of the total land area in Ukraine is under annual crop cultivation. Rapeseed constitutes about 4% of the total land under annual crop cultivation. Biodiesel production is not yet an application for rapeseed in Ukraine, although about 27% of the total land under rapeseed cultivation is used for production of feedstock for EU biodiesel.

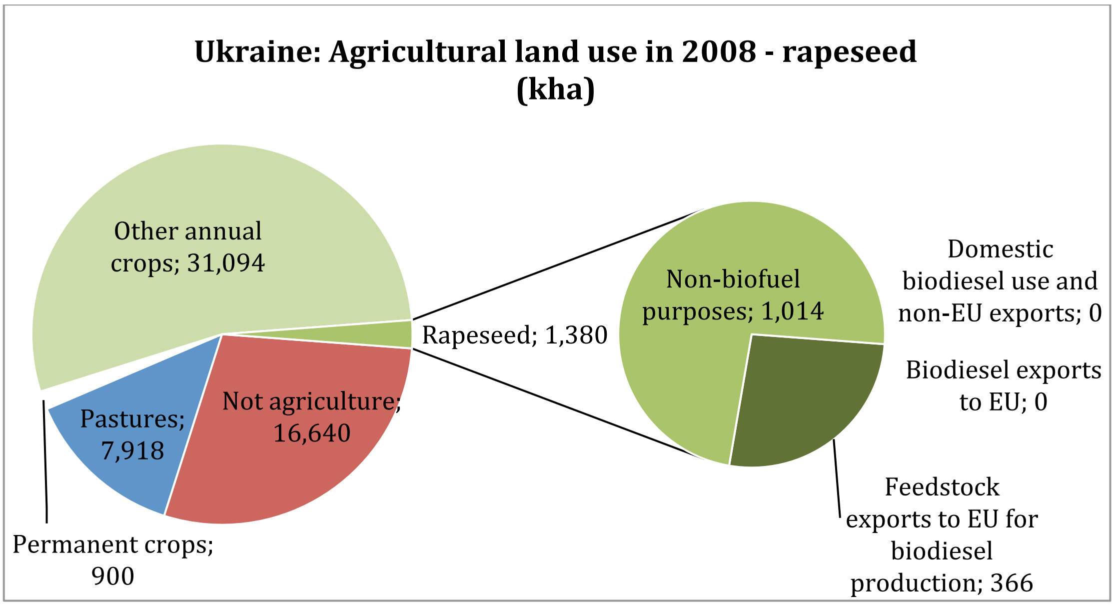


Figure 55: Agricultural land use in Ukraine in 2008, focused on rapeseed production

Ukraine is the largest exporter of rapeseed to the EU and the second largest exporter globally, trailing Canada (FAPRI 2010; MVO 2008). Regarding rapeseed oil, Ukraine is an important exporter but contributes less to the global trade due to lack of domestic crushing capacity (MVO 2008).

Historical developments

Since 1992, rapeseed production in Ukraine has increased with 2512%, which is a remarkable increase. As seen in Figure 56, the production increase has been made possible almost entirely from an increased harvested area (+2302%) while yields have remained rather unchanged during the period (+9%). Most of the increase has occurred since 1994.

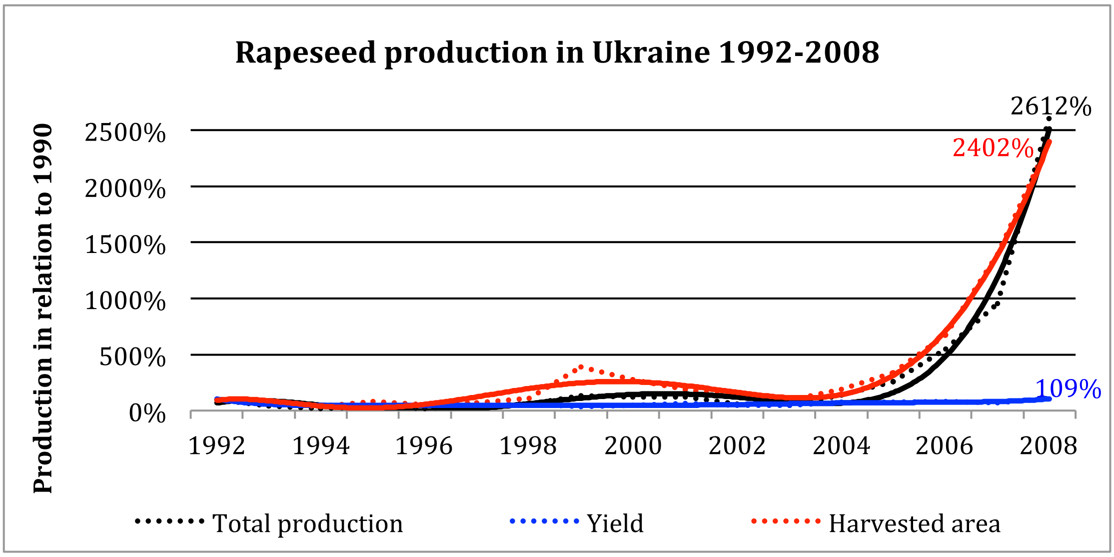
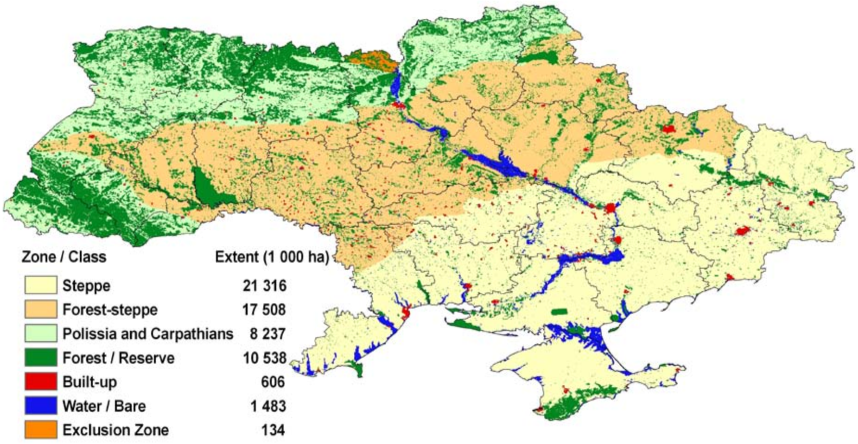


Figure 56: Change in rapeseed production, yields and harvested area in Ukraine, 1992-2008

Even though the expansion of rapeseed since 2004 is remarkable, no evidence has been found for expansion onto non-agricultural land. Instead, it seems like high EU demands, duty-free exports and high gross margins have made more farmers shift to rapeseed production (i.e. include rapeseed in their crop rotations). Technically, rapeseed is at present Ukraine's most profitable crop. In 2008, rapeseed, wheat and corn showed the greatest increases in sown areas. The acreage expansion took place chiefly at the expense of barley and sugar beet (FAO 2010).

Land-use dynamics from future production increases

About 70% of Ukraine's total land area is already used for agriculture of which 80% (56% of total land area) holds annual crop cultivation. Forest and forest-covered areas constitute 17% and built-up areas about 4% (Gumeniuk et al. 2010; FAOSTAT data). The main agro-ecological zones and land-use classes are illustrated in Figure 57.



Source: (Gumeniuk et al. 2010)

Figure 57 Main agro-ecological regions and land use classes

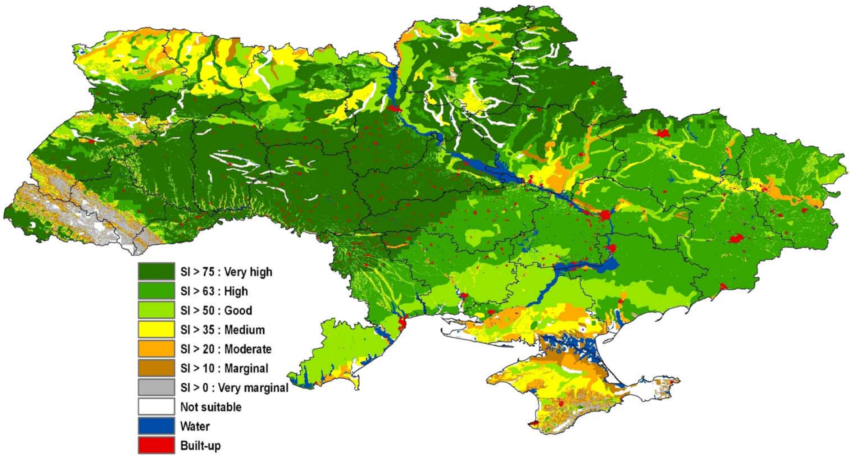
Cropping patterns in Ukraine seem to be strongly determined by gross margins (FAO 2010). A comparison between average past, present and projected prices, yields, revenues and gross margins in the three main agro-ecological zones in Ukraine, the "Forest" (northern parts), "Forest-steppe" (middle parts) and "Steppe" (southern parts) zones, indicates that future expansion is more likely to occur in the Forest-steppe zone than in the Steppe zone. Probability of rapeseed expansion in the Forest zone cannot be determined with this approach, since no data is provided. Table 61 shows average price, yield, revenue and gross margin (direct costs only) for rapeseed in the three main agro-ecological zones in 2009.

Table 61: Average price, yield, revenue and gross margin (direct costs only) for rapeseed in Ukraine's three main agro-ecological zones in 2009

Agro-ecological zone	**Price** (USD/tonne)		**Yield** (tonnes/ha)		**Revenue** (USD/ha)		**Gross margin** (USD/ha, direct costs only)	
	Modern	Trad.	Modern	Trad.	Modern	Trad.	Modern	Trad.
Forest	-	-	-	-	-	-	-	-
Forest-steppe	443	443	2.4	1.2	1055	527	1015	447
Steppe	436	436	1.8	0.9	783	391	780	357

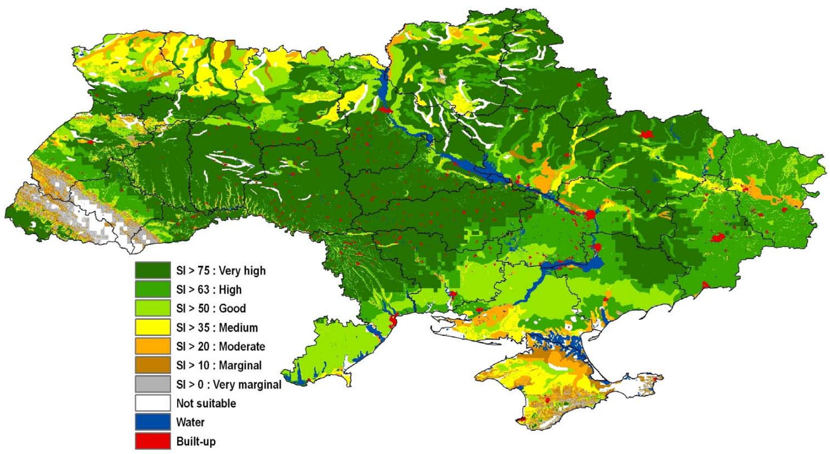
Source: (LMC International in FAO 2010)

Gumeniuk et al. (2010) determined the suitability for rapeseed production across Ukraine. Figure 58 (showing suitability for rain-fed spring rape) and Figure 59 (showing suitability for rain-fed winter rape) supports that rapeseed is most likely to expand in the Forest-steppe zone. It is also visible that large forested areas typically seem unsuitable for rapeseed production, although highly suitable land can be found in close vicinity to such areas.



Source: (Gumeniuk et al. 2010)

Figure 58: Suitability for rain-fed spring rape under high level of input and management (1971-2000)



Source: (Gumeniuk et al. 2010)

Figure 59: Suitability for rain-fed winter rape under high level of input and management (1971-2000)

A closer look at the suitability for spring rape (Figure 58) shows that 71.6% of the 16 Mha land suitable for rapeseed production in the Forest-steppe zone is classified as "very suitable". Corresponding shares for the Forest zone and Steppe zone are 47.5% (of 7 Mha) and 0.5% (of 19 Mha), respectively (Gumeniuk et al. 2010). Therefore, most signs point towards a potential expansion in the Forest-steppe zone while little expansion is likely in the Steppe zone. Some expansion is likely in the forest zone, although not likely in the forested areas.

Since most land suitable for rain-fed rapeseed production has already been cleared, significant expansion on natural vegetation is less likely. This is supported by Bauer et al. (2010), who claim that rapeseed is unlikely to expand onto new land but rather displace cereals or other break crops out of cereal brake rotations. Nesterov (2011) also supports this, claiming that expansion on already cultivated land is most likely, expansion on pastures is likely and on natural vegetation unlikely. More specific, Nesterov (2011) reports that barley, buckwheat, wheat and potato are crops most likely to be replaced in case of a rapeseed expansion. Historical events support this, as barley has recently competed for area in spring with corn and oilseeds and has declined significantly since 2003, despite increased demand (FAO 2010).

Displacement of replaced crops onto natural vegetation seems less likely, since even though certain crops (e.g. rapeseed) have expanded significantly since 2004, the total area under annual crop cultivation has remained rather unchanged. Therefore, a potential production increase of a certain crop (e.g. rapeseed) is likely to result in production decreases of other crops. Nesterov (2011) calls for caution to the fact that many land users are likely to change rotational practices to favour production of rapeseed. This could result in soil exhaustion, especially in traditional agriculture.

Sugarbeet

Historical developments

Since 1992, sugarbeet production in Ukraine has decreased with 53%. As seen in Figure 56, the harvested area has decreased even more than the production (-75%), but the production decrease has been limited due to significantly increased yields (+84%). Artiushyn (2010) suggests that the increased yields are thanks to the impact of large agricultural companies.

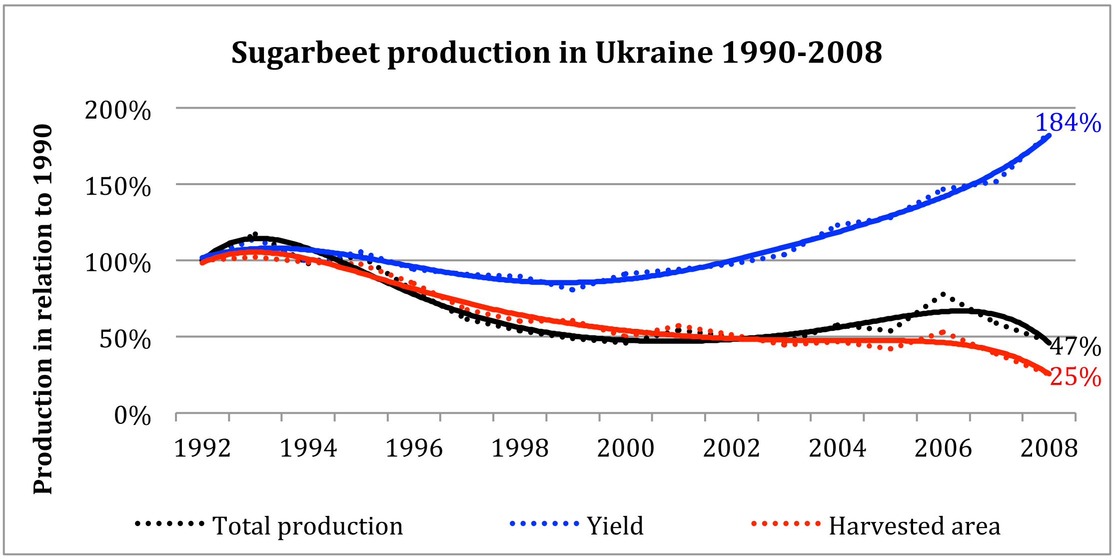
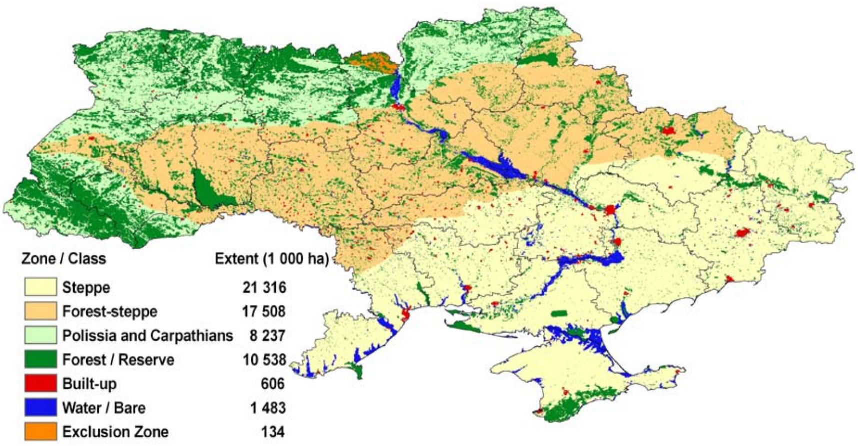


Figure 60: Change in sugarbeet production, yields and harvested area in Ukraine, 1992-2008

The share of sugar beets in the total area planted with agricultural crops in Ukraine is decreasing. Sugar beets are sown by both agricultural enterprises (farms) and private households. Only 9% of sugar beets were harvested from household plots in 2009, compared to 17% in 2008 (Artiushyn 2010). Sugarbeet is primarily produced in the Vinnytsya, Kyiv, Poltava, Rivne, Ternopil, Kharkiv and Khmelnytsk regions, in the Forest and Forest-steppe agro-ecological zones (State Statistics Committee of Ukraine in Artiushyn 2010).

Land-use dynamics from future production increases

About 70% of Ukraine's total land area is already used for agriculture of which 80% (56% of total land area) holds annual crop cultivation. Forest and forest-covered areas constitute 17% and built-up areas about 4% (Gumeniuk et al. 2010; FAOSTAT data). The main agro-ecological zones and land-use classes are illustrated in Figure 61.

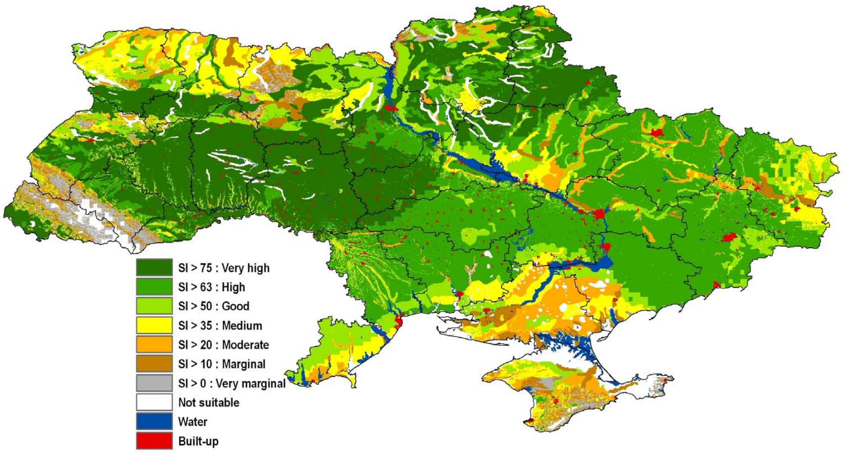


Source: (Gumeniuk et al. 2010)

Figure 61 Main agro-ecological regions and land use classes

Since LMC International (in FAO 2010) only presents values on price, yields, revenue and gross margins for sugarbeet production in the Forest zone, this approach (as used for rapeseed) cannot be used to determine where expansion is more likely to occur. However, expansion in the Steppe zone is regarded as less likely since little production takes place there (State Statistics Committee of Ukraine in Artiushyn 2010)

The suitability for sugarbeet production across Ukraine is illustrated in Figure 62. This supports that sugarbeet is less likely to expand in the Steppe zone than in the Forest and Forest-steppe zones. As for rapeseed, large forested areas typically seem unsuitable for sugarbeet production, although highly suitable land can be found in close vicinity to such areas.



Source: (Gumeniuk et al. 2010)

Figure 62: Suitability for rain-fed sugar beet under high level of input and management (1971-2000)

A closer look at the suitability for sugarbeet shows that 54.4% of the 16 Mha land suitable for sugarbeet production in the Forest-steppe zone is classified as "very suitable". Corresponding shares for the Forest zone and Steppe zone are 41.2% (of 6.4 Mha) and 0% (of 17 Mha), respectively (Gumeniuk et al. 2010). Therefore, most signs point towards a potential expansion in the Forest-steppe zone while little expansion is likely in the Steppe zone. Some expansion is likely in the forest zone, although not likely in the forested areas.

Since most land suitable for rain-fed sugarbeet production has already been cleared, significant expansion on natural vegetation is less likely. This is also supported by Nesterov (2011), who reports that expansion on already cultivated land is most likely, expansion on pastures is likely and on natural vegetation unlikely. More specific, Nesterov (2011) states that barley, buckwheat, wheat and potato are crops most likely to be replaced in case of a sugarbeet expansion.

Displacement of replaced crops onto natural vegetation seems less likely, since even though certain crops (e.g. rapeseed) have expanded significantly since 2004, the total area under annual crop cultivation has remained rather unchanged. Therefore, a potential production increase of a certain crop (e.g. sugarbeet) is likely to result in production decreases of other crops.

It should be noted that potential expansions of sugarbeet and rapeseed are expected to occur in similar areas and the crops may therefore compete for land. Gross margins, international demands for rapeseed and sugar and potential changes in national export taxation systems will most likely affect which crop that would be favoured by farmers. Currently, rapeseed is the most profitable choice.

Production system characteristics and local environmental impacts

Production system characteristics for rapeseed and sugarbeet in Ukraine are summarised in Table 62.

Table 62: Production system characteristics for rapeseed and sugarbeet in Ukraine

System component	Rapeseed	Sugarbeet
Large scale		
Small scale	Household farms; 25% of total production	Household farms: 9% of total production (2009) and decreasing
Mechanized farming system		
Manual farming system		
Tillage		
Reduced and no tillage		
Irrigated		
Rain-fed		
Mono-cropping		
Multi-cropping		
Crop rotation		
Mineral fertilizer used	60-65% of farmers	
Chemical pesticides used		
GMO seeds for sowing		
Land preparation with fire		
By-products (from harvesting)		

Legend: Blue = occurring; orange = not occurring; white = occurrence unknown due to lack of information
Sources: (Dufey, 2006; FAO, 2005; FAO/EBRD, 1999; The National Centre for Plant Genetic Resources of Ukraine, 2008; USDA-FAS 2001).

Observed local environmental impacts from rapeseed and sugarbeet production in Ukraine are summarised in Table 63.

Table 63: Observed local environmental impacts from rapeseed and sugarbeet production in Ukraine

Environmental impact	Rapeseed	Sugarbeet
Deforestation		
Loss of agro-biodiversity		
Loss of biodiversity		
Air pollution		
Water pollution		
GMO contamination		
Eutrophication		
Soil fertility decline		
Erosion		

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information
Sources: (Dufey, 2006; FAO, 2005; FAO/EBRD, 1999; The National Centre for Plant Genetic Resources of Ukraine, 2008; USDA-FAS 2001).

Local environmental impacts allocated to domestic biofuel production

Since no production of domestic biofuels from rapeseed has been identified for 2008; no local environmental impacts from cultivation of rapeseed can be allocated to domestic biofuel production in Ukraine.

The share of the total sugarbeet area that was harvested for domestic biofuel production was 5.1% in 2008. However, the net area requirement is lower since sugarbeet biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 3% of the total sugarbeet area in 2008. Since sugarbeet cultivation for domestic biofuels has the same characteristics as sugarbeet cultivation for other purposes, local environmental impacts are also the same and the importance of domestic biofuel production is proportional to the share of the total sugarbeet area used for production of domestic biofuels (3%).

Local environmental impacts allocated to EU biofuel demands

The share of the total rapeseed area that was harvested for EU biofuel production was 26.5% in 2008. However, the net area requirement is lower since rapeseed biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 15.5% of the total rapeseed area in 2008. Since rapeseed cultivation for EU biofuels has the same characteristics as rapeseed cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total rapeseed area used for EU biofuel production (15.5%).

The share of the total sugarbeet area that was harvested for EU biofuel production was close to 0% in 2008. Therefore, no local environmental impacts from cultivation of sugarbeet can be allocated to EU biofuel demands.

References

Artiushyn, O., 2010. *USDA Global Agriculture Information Network report: Ukraine Sugar Annual.* Available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Sugar%20Annual_Kiev_Ukraine_3-9-2010.pdf Accessed on April 29, 2011.

Bauen, A., Chudziak, C., Vad K. and Watson P., 2010. *A causal descriptive approach to modelling the GHG emissions associated with the indirect land use impacts of biofuels*. Available at: http://www.dft.gov.uk/pgr/roads/environment/research/biofuels/pdf/report.pdf Accessed on April 28, 2011.

Dufey, A., 2006. *Biofuels production, trade and sustainable development: emerging issues*. London: Environmental Economics Programme/Sustainable Markets Group.

FAO, 2005. *Fertilizer Use by Crop in Ukraine*. Rome: Food and Agriculture Organization of the United Nations.

FAO, 2010. *Ukraine: Grain Sector Review and Public Private Policy Dialogue*. Rome: FAO Investment Centre / EBRD Cooperation Programme. Available at: http://www.eastagri.org/publications/pub_docs/ebdr_Ukraine72c.pdf Accessed on April 28, 2011.

FAO/EBRD, 1999. *Sugar beets/White Sugar*. Rome: FAO/EBRD.

FAPRI, 2010. *U.S. and World Agricultural Outlook.* Available at: http://www.fapri.iastate.edu/outlook/ Accessed on April 28, 2011.

Gumeniuk, K., Mishchenko N., Fisher, G. and van Velthuizen H., 2010. *Agro-ecological Assessment for the Transition of the Agricultural Sector in Ukraine: Methodology and Results for Baseline Climate*. Available at: http://www.iiasa.ac.at/Admin/PUB/Documents/XO-10-002.pdf Accessed on April 29, 2011.

MVO, 2008. *Product Board for Margarine, Fats and Oils: Factsheet Rapeseed 2008*. Available at: http://www.mvo.nl/Portals/0/statistiek/factsheets/Factsheet-rapeseed-2008.pdf Accessed on April 28, 2011.

Nesterov, Y., 2011. *Expert consultation: Yuriy Nesterov, Animal Genetic Resources Branch (AGAG) Food and Agriculture Organization of the United Nations.*

The National Centre for Plant Genetic Resources of Ukraine, 2008. *Country Report on the State of Plant Genetic Resources for Food and Agriculture - Ukraine*. Kharkiv: Food and Agriculture Organization of the United Nations.

USDA-FAS, 2001. *US Department of Agriculture Foreign Agriculture Service: World Sugar Situation*. Available at: http://www.fas.usda.gov/htp2/sugar/1998/98-11/world.html Accessed on February 25, 2011.

REGIONAL PROFILE - EUROPEAN UNION

This chapter describes local environmental impacts from cultivation of selected biofuel crops in the EU.

Selected biofuel crops include wheat, rapeseed and sugarbeet. As seen in Table 64, 1.4% of the total area under wheat cultivation and 8.6% of the total area under sugarbeet cultivation was used for producing ethanol fuel in 2008, while about half of the total area under rapeseed cultivation was used for producing biodiesel.

Table 64: Area used for production of EU's selected biofuel crops, including area used for domestic biofuel production

Crop	**Total harvested area in 2008** (kha)	**Cropland used for biofuel feedstock production in 2008**	
		kha	% of total
Wheat	26,491	360	1.4%
Rapeseed	6,129	3,171	51.7%
Sugarbeet	1,531	131	8.6%

The conditions for agriculture differ a lot between different member states and the main conclusions presented are average estimations for the EU region.

Most biofuel crops in the EU are ordinary agricultural crops and the cultivation is more or less the same, regardless of whether the crop is grown for food or biofuel purposes. In this summary, sugarbeet, rapeseed and wheat have been selected as the main crops for biofuel purposes in the EU.

Compared to most other regions in the world, agriculture within the EU is intensive. This is certainly the case with the main crops described in this summary. The share of total cropland that is cultivated with sugarbeet, rapeseed and wheat is 1%, 6% and 24 % respectively. Yields for the selected crops compared to average EU yields are presented in Figure 63 and distribution of production between member states is illustrated in Figure 64.

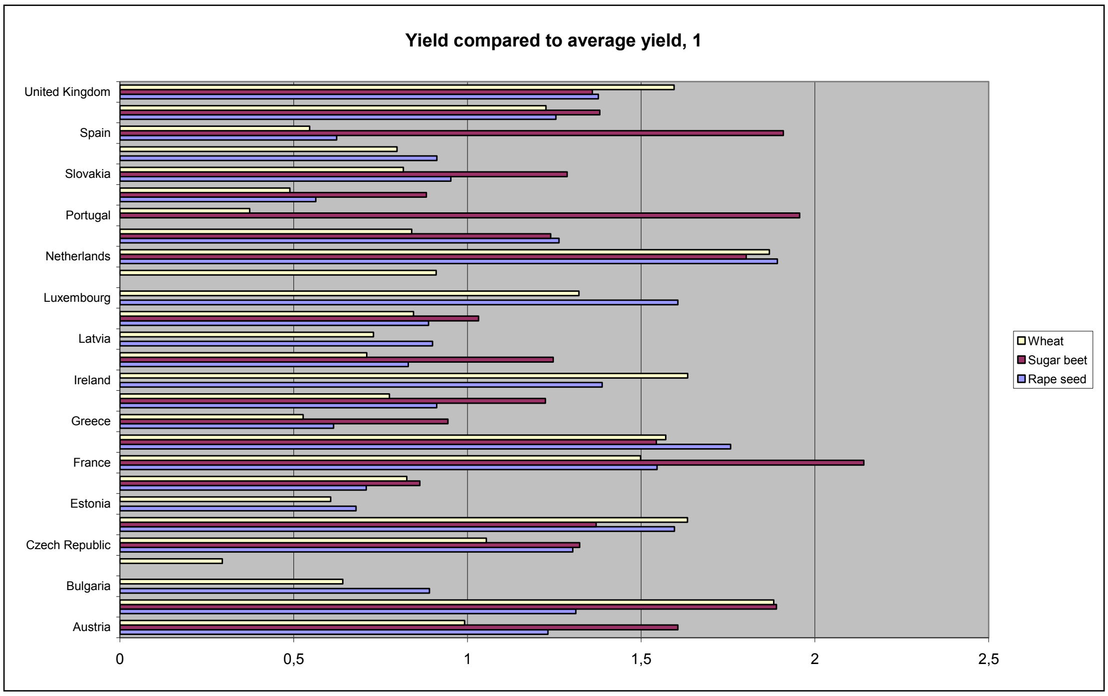


Figure 63: Yield compared to average yield (2009 set to 1). The difference can be explained by intensity differences and due to different natural given conditions as soil type and climate.

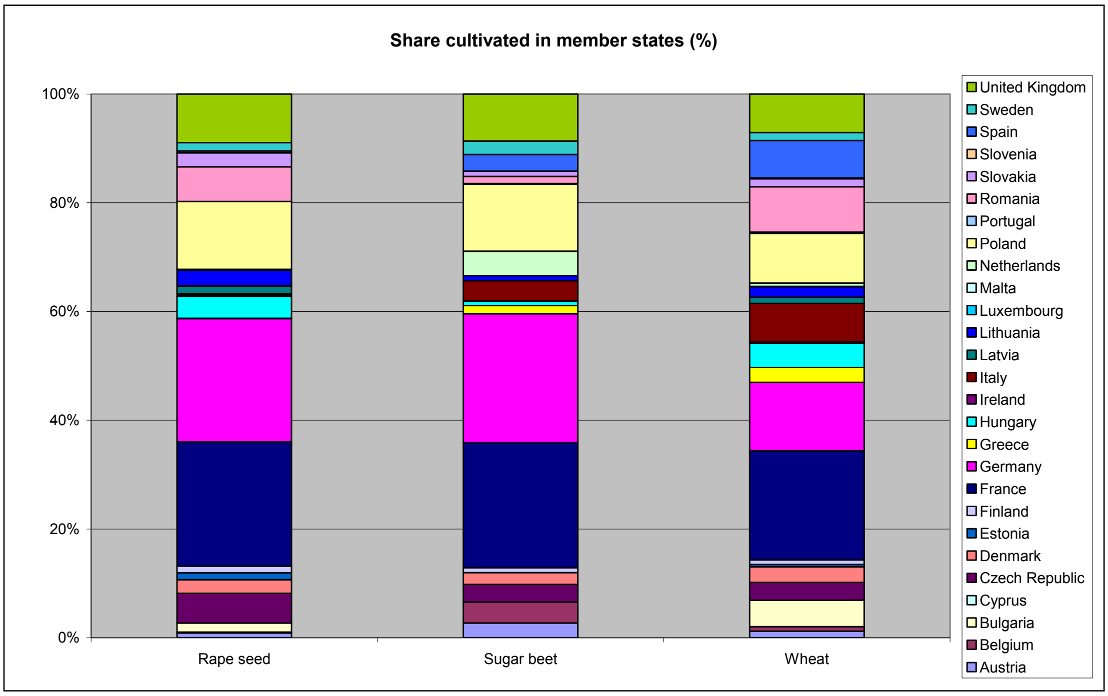


Figure 64: Distribution of rapeseed, sugarbeet and wheat between EU member states in 2009

Table 65: presents a grouping of member states based on the area under intensive cropping compared to total area under cultivation. It also shows how large share of the total EU area under cultivation that each group constitutes. Several of the new member states fall into the group with the lowest share of intensive agriculture. The agriculture in these countries will change due to adaption to the Common Agricultural

Practices (CAP). It is likely that the area cultivated with wheat, rapeseed and sugar beet are more intensively cultivated.

Table 65: Grouping of member states based on the area under intensive cropping compared to total area under cultivation, and share of the total EU area under cultivation that each group constitutes

Member states	Est. share of national cultivated area under intensive cropping (%)	Share of total EU area under cultivation that each group constitutes (%)
Belgium, Czech rep, Denmark, Germany, the Netherlands, Finland, Sweden, UK	70	31
Greece, Spain, France Austria, Portugal, Ireland, Italy	50	45
Estonia, Hungary, Lithuania, Latvia, Poland, Slovenia, Slovakia	40	23

Production system characteristics and observed local environmental impacts

Production system characteristics for wheat, rapeseed and sugarbeet in the EU are summarised in Table 66.

Table 66: Production system characteristics for wheat, rapeseed and sugarbeet in the EU

System component	Wheat	Rapeseed	Sugarbeet
Large scale	Dominating	Dominating	Dominating
Small scale			
Mechanized farming system			
Manual farming system			
Tillage	Some parts non-tillage systems		Dominating
Reduced or no tillage	Some parts where soil conditions are suitable		
Irrigated			Parts of Southern Europe
Rain-fed			
Mono-cropping			
Multi-cropping			
Crop rotation	Rape seed the year before wheat is appropriate	Needed	Needed but not with maize or rapeseed
Mineral fertilizer used			
Chemical pesticides used	Dominating	Dominating	Dominating
GMO seeds *			
Land preparation with fire			
By-products (from harvesting)	Straw	Straw	Crop residues can be harvested

* Many EU-states are very restrictive regarding GMO-crops. No data found.

Observed local environmental impacts from wheat, rapeseed and sugarbeet production in the EU are summarised in Table 67.

Table 67: Observed local environmental impacts from wheat, rapeseed and sugarbeet production in the EU

Environmental impact	Rapeseed	Sugarbeet	
Deforestation			
Loss of agro-biodiversity			
Loss of biodiversity			
Air pollution			
Water pollution			
GMO contamination	*	*	*
Eutrophication			
Soil fertility decline	Not if proper soil management is practised	Not if proper soil management is practised	Not if proper soil management is practised
Erosion	No large scale	No large scale	No large scale

* many EU-states are very restrictive regarding GMO-crops. However, no information found.

Legend: Red = occurring; green = not occurring; white = occurrence unknown due to lack of information

In an approach to describe local impacts from cultivation of the main biofuel crops in a more detailed way, Table 68 shows a ranking of wheat, rapeseed and sugarbeet, based on the risk of them causing certain environmental pressures. To allow for comparisons, the same ranking for maize and "other cereals" is presented in Table 69. The tables are based on EEA studies.

Table 68: Ranking of wheat, rapeseed and sugarbeet based on the risk of them causing certain environmental pressures

Environmental pressure	Wheat		Rapeseed		Sugarbeet	
	Rank	Reason	Rank	Reason	Rank	Reason
Erosion	A	Winter wheat provide good soil cover	B	Row crop, but dense soil cover	C	Row crop, sown late, thus bare soil into late spring
Soil compaction	A	Intensive rooting system, harvest in dry weather	A	Deep end dense root system	C	Heavy machinery and harvested mass lead to soil compaction
Nutrient leaching	A	Higher fertiliser demand but good uptake	B/C	High demand, leaching risk depends on use of harvest residues	B/C	High fertiliser demand and soil erosion risk
Pesticide pollution to soils and water	B	Generally high number of pesticides treatments	C	Various pesticide treatments	B	Various pesticide treatments
Water abstraction	B	Highest water demand of all cereals	n/a	n/a	A/C	Often irrigated in southern Europe
Link to farmland biodiversity	B/C	Mostly high input use, dense crop	B/C	High pesticide use, some pollen offer but very dense crop	A/B	Often pesticide use, but can provide nesting habitat and shelter in autumn
Diversity of crop types	C	Most common cereal	A/B	Common	B	Common in intensive areas but not self tolerant

A=low risk, B= medium risk, C= high risk n/a=non applicable

Table 69: Ranking of maize and "other cereals" based on the risk of them causing certain environmental pressures

Environmental pressure	Maize		Other cereals	
	Rank	Reason	Rank	Reason
Erosion	C	Soil uncovered over long period, row crop	A	Winter cereals provide good soil cover
Soil compaction	B	Poorly developed root system, average machine use	A	Intensive rooting system, harvest in dry weather
Nutrient leaching	C	High demand and often highly fertilised	A	Moderate demand and good uptake
Pesticide pollution to soils and water	C	High pesticide use	A	Moderate number of pesticide treatments
Water abstraction	A/B	High water efficiency (C4) but often irrigated	A	Moderate water demands
Link to farmland biodiversity	C	High pesticide use, low weed diversity, some shelter in autumn	B	Medium use of inputs, can have open structure; nesting habitat when spring crop
Diversity of crop types	B/C	Is dominant crop in some regions; self tolerance	B	Very common

A=low risk, B= medium risk, C= high risk n/a=non applicable

Local environmental impacts allocated to EU biofuel demands

The share of the total wheat area that was harvested for EU biofuel production was 1.4% in 2008. However, the net area requirement is lower since wheat biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 0.8% of the total wheat area in 2008. Since wheat cultivation for EU biofuels has the same characteristics as wheat cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total wheat area used for EU biofuel production (0.8%).

The share of the total rapeseed area that was harvested for EU biofuel production was 52% in 2008. However, the net area requirement is lower since rapeseed biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 30% of the total rapeseed area in 2008. Since rapeseed cultivation for EU biofuels has the same characteristics as rapeseed cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total rapeseed area used for EU biofuel production (30%).

The share of the total sugarbeet area that was harvested for EU biofuel production was 8.6% in 2008. However, the net area requirement is lower since sugarbeet biofuel production generates by-products that substitutes for other crop production: using RED allocation principles the area allocated to biofuels corresponded to 6.1% of the total sugarbeet area in 2008. Since sugarbeet cultivation for EU biofuels has the same characteristics as sugarbeet cultivation for other purposes, local environmental impacts are also the same and the importance of EU biofuel demand is proportional to the share of the total sugarbeet area used for EU biofuel production (6.1%).