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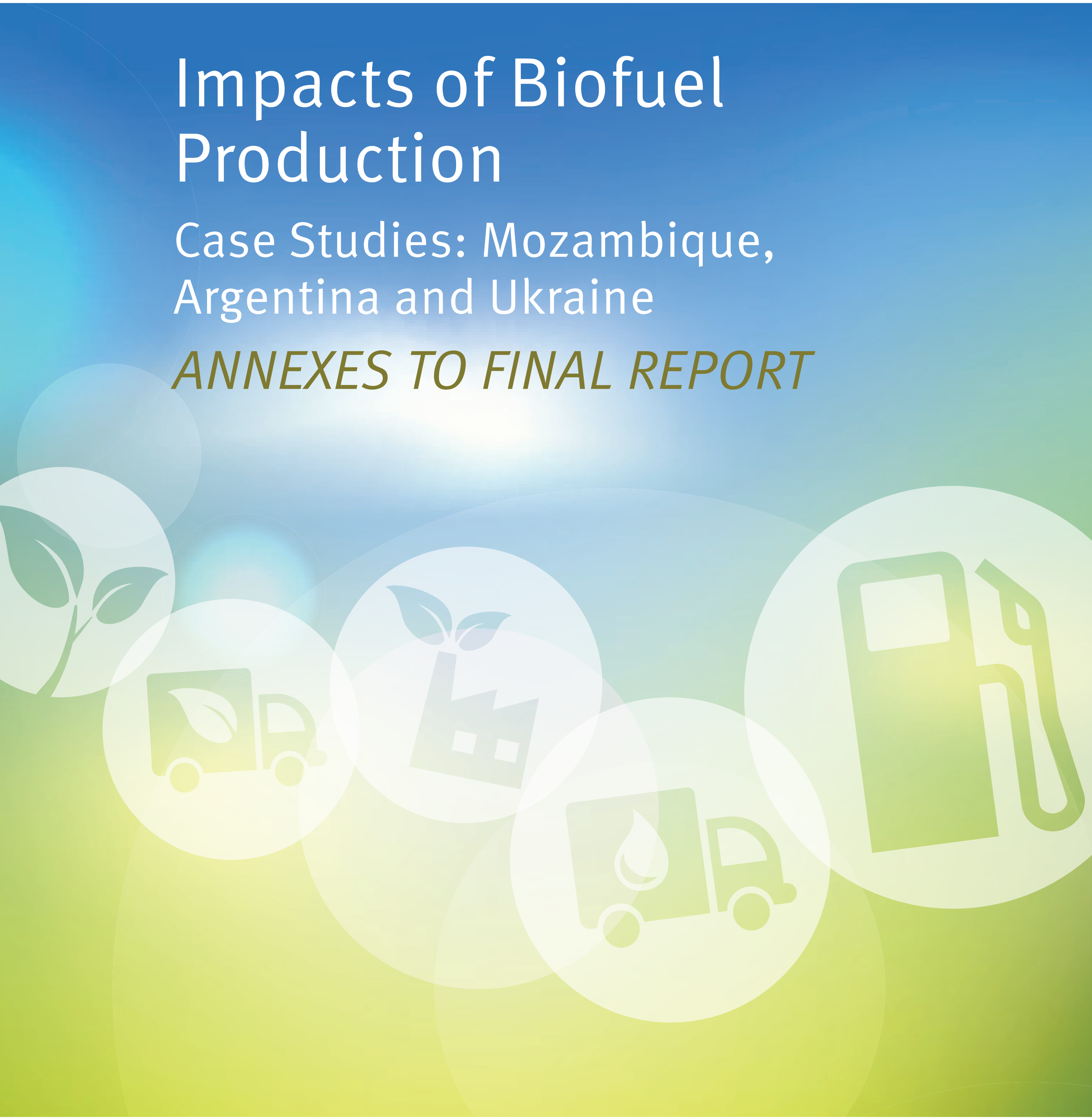
Global Assessments and Guidelines for Sustainable
Liquid Biofuel Production in Developing Countries



Impacts of Biofuel Production

Case Studies: Mozambique, Argentina and Ukraine

ANNEXES TO FINAL REPORT

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A1. Annex 1: Case study description

Several first and second generation biofuel production chains are considered in three potentially promising countries:

- Mozambique
- Ukraine
- Argentina

The three countries are selected because of the relatively high availability of land for energy crop production. Further, the countries represent very different biophysical and socio-economic conditions. This makes it possible to investigate and compare the impacts of biofuel production chains related to differences in supply chains and biophysical and socio-economic conditions.

Mozambique was selected as a case study area as it is a promising region for biomass production within southern Africa as a result of the availability of land (Batidzirai *et al.* 2006; 2006), the favourable environmental conditions for agricultural production (INE 2003; Batidzirai *et al.* 2006), and the current low agricultural productivity which offers a great potential for improvement. In addition, the low cost for labour and land offers potential for low cost production. Mozambique has several ports close to the Indian Ocean, which make the export of raw biomass and liquid biofuels to other regions possible. The main incentives for the government of Mozambique to focus on the development of a bioenergy industry are to decrease the country's dependence on oil imports and to enhance energy security and socio-economic and sustainable development, especially in rural areas (Conselho de Ministros da república de Moçambique 2009).

Argentina was selected because of the large areas of pasture land that are potentially available and suitable for the large-scale production of energy crops, such as perennial grasses. Argentina is regarded an economically attractive country for biofuel production with favourable climate and soil conditions, low land and labour costs, high quality existing infrastructure and human resources . In recent years, Argentina has emerged as a key player in the biodiesel market as a result of differential taxes over different agro-industrialized products and governmental market-creating initiatives which have resulted in an investment boom (Mathews and Goldsztein 2009; Sorda *et al.* 2010). Consequently, Argentina is currently the world's number one biodiesel exporter and its production volumes are expected to keep increasing in following years (Joseph 2010).

Ukraine was selected because studies on global and European bioenergy potentials have indicated large techno-economic production potentials for Eastern Europe and for Ukraine specifically (Smeets *et al.* 2007; de Wit and Faaij 2010; Fischer *et al.* 2010; de Wit *et al.* 2011a). Ukraine is considered to be a promising region for bioenergy production because of favourable climate conditions, rich agricultural resources, access to abundant water resources, and the proximity to major foreign markets (Morton *et al.* 2005). The decreasing population, the stable dietary intake, and the efficiency of the agricultural sector that is well below of what is agro-ecologically attainable provide opportunities to reduce the required area for food and feed production, and thereby increasing the potential land available for bioenergy crop production.

Dedicated bioenergy crops are assumed to be the main contributors to future bioenergy supplies (Smeets *et al.* 2007; Dornburg *et al.* 2010). In addition, the main impacts of biofuel production are expected to be caused by LUC related to land use for dedicated energy crops. For these reasons, this assessment focuses on biofuel supply chains from dedicated energy crops and does not include biofuel supply chains from primary or secondary residues. Currently biofuels are produced from first generation energy crops, but in the longer term an important role is expected from second generation energy crops (IPCC 2011). Several studies indicate that the use of dedicated lignocellulosic energy crops for the production of next generation biofuels is an attractive strategy to ensure a stable and low-cost feedstock supply, which is crucial for next generation biodiesel and ethanol conversion facilities. Therefore, both first generation and next generation biofuel production system are assessed, to highlight the differences in performance between different contexts, which are crucial information for policy makers. The supply chains included in this study are:

- Sugar cane ethanol in Mozambique
- Switchgrass ethanol in Mozambique
- Eucalyptus ethanol in Mozambique
- Switchgrass ethanol in Argentina
- Soy Biodiesel in Argentina
- Wheat ethanol in Ukraine
- Switchgrass ethanol in Ukraine

These supply chains are selected because of the potential high crop yields, the (potentially) suitability of the crops for the selected countries and for some crops the current existing experience with these crops in the selected countries, and the promising economic performance. In addition, the high differentiations in crop characteristics, properties and requirements makes assessment and comparison between very different types of supply chains possible and they could represent a very wide range of possible supply chains.

A1.1 Mozambique

A1.1.1 Case study area

Mozambique is located on the eastern coast of southern Africa bordered by the Indian Ocean in the east, Tanzania in the north, Malawi and Zambia in the North-West, Zimbabwe in the west and South Africa and Swaziland in the South South-West.

Mozambique has 10 provinces and 192 administrative districts. Mozambique has a population of 23.5 million inhabitants (2010) with an average population density of 29.5 people/km^2 (UNDP 2011b). The GDP per capita is $1085 purchasing power parity (PPP) and Mozambique is ranked 171st out of 180 countries on the lists of countries by gross domestic product at PPP per capita of the World Bank (2012). The last decade the economic growth was 7.5 % on average. Services account for 46% of GDP followed by agriculture (30%) and industry (24%) (African Development Bank Group 2011). 54% of the population lives below the poverty line. And it is ranked 184th out of 187 at the list of Human Development Index (UNDP 2011a).

It is a vast country of 801 590 km^2 of which 2% is interior waters. It has five main rivers (Zambezi, Limpopo, Rovuma, Save, Buzi) and there are four large lakes (Cahora Bassa, lake Niassa, lake Amaramba, Lake Chiuta), all situated in the north. The coastal belt and the area below the Save River have a low altitude. The middle plateau situated in the central and northern inlands ranges in 200-1000m in elevation. The high plateau and the mountainous areas close to the north western borders have average elevations of 1000m.

The climate varies from tropical and subtropical in the northern and central parts of Mozambique to dry semi-arid climate in the south. There are two main seasons: the warm and rainy season from October to March and the dry and somewhat cooler season from April to September. Rainfall patterns vary strongly within the country: along the coast the average precipitation is 800 to 1000 mm/y, close to Beira and Quilimane it exceeds 1200 mm a year. The average rainfall decreases inland to 400 mm/y near to border with South Africa and Zimbabwe. In the north and central part of Mozambique precipitation levels range from 1000 to over 2000 mm/y on average (FAO 2005). The Mozambican climate and geography is spatially highly heterogeneous.

A1.1.2 Biofuel supply chains

A1.1.2.1 Sugar cane ethanol

Sugar cane is a C4 plant with high sucrose content. Sugarcane cultivation is based on a ratoon-system, which means that after the first cut (after 12 or 18 months) the same plant is cut several times on a yearly basis. In this study of 24 years with 4 ratooning periods of 6 years is assumed. Before planting in the first year, the soil is intensively prepared. Because of the uneven temporal distribution of precipitation, irrigation is required for survival and in order to obtain high yield. Yield reported in Mozambique vary between 80-120 tons/ha. This is often higher than the yield reported in Brazil but this is mainly related to the high soil quality in the areas of the sugar cane estates and because of the irrigation which is lacking in Brazil.

It is (still) common to burn down the cane in order to enable manual harvesting. After cutting and sometimes chopping cane stalks by a chopped cane harvester, the cane stalks are loaded in trucks and transported by trucks to the industrial plant.

Ethanol production from sugarcane is a relatively well established technology. The production process consists of washing, milling, extraction, purification, fermentation and distillation. The bagasse resulting from the milling is used to feed the boilers to produce steam and electricity for the production process. Surplus electricity could be produced (depending on process and boiler efficiency) to be fed into the grid.

A1.1.2.2 Eucalyptus ethanol in Mozambique

Eucalyptus is a tree species native to Australia which can be grown as a short rotation coppice. It has high productivity under tropical conditions and is the most cost competitive woody energy crops for a region such as Mozambique (Batidzirai, 2011). Depending on the (hybrid of) species it can be fast growing and relatively tolerant for marginal conditions. In order to be fast growing it should be managed with care including application of fertilizers and pesticides. It is able to sustain periods of drought but for fast growth it requires relatively large amounts of water. It has a relatively low ash content and high lignin content which is advantageous for further processing. There is ample of experience with eucalyptus plantations in Mozambique. Eucalyptus is currently mainly used for poles and the timber industry and also increasingly for the paper and pulp industry. The lifetime and the coppice period depend on the biophysical conditions, variety and management applied. Current a lifetime of 21 years with 3 coppices of 7 years is commonly applied for the paper a pulp industry. After every coppice period, eucalyptus is harvested and chipped.

The production process of lignocellulosic biomass to ethanol consists of three stages, namely biomass pre-treatment, hydrolysis and fermentation. Chemical and physical pre-treatment breaks down cell structures and separates the lignin from cellulose and hemi-cellulose and thereby facilitates the hydrolysis (saccharification). Acid or enzymatic hydrolysis converts the cellulose and hemicellulose into fermentable monomeric and oligomeric sugars, with enzymatic hydrolysis using cellulases and hemicellulases being the preferred route. The lignin residue can be used for electricity generation. The sugars are fermented to ethanol, which is then purified and dehydrated (Franke *et al.* 2012).

A1.1.2.3 Switchgrass ethanol in Mozambique

Switchgrass is an herbaceous perennial C4 grass which is native to Northern America. Currently, it is primarily used as a fodder crop for livestock but it is considered to be a promising bioenergy crop because of its potential high yields and high content of cellulose and hemi-cellulose (Lewandowski *et al.* 2003). In addition, it is relatively tolerant to marginal conditions (Boehmel *et al.* 2008; Varvel *et al.* 2008; van Dam *et al.* 2009a) and has relatively low input requirements (Bullard and Matcalfe 2001). The lifetime of switchgrass is generally 10-20 years (Bullard and Matcalfe 2001; Lewandowski *et al.* 2003). It is sown in spring and after the second year, it can be harvested annually. Generally delayed harvest is applied in order to obtain the highest dry matter content and lowest ash and mineral content. The yields increase in the first few years after establishment but decreases at the end of the lifetime. Therefore, re-sowing is required after 10-20 years. The yields that can be obtained are highly related to the biophysical conditions, the varieties and the management applied. Reported average yields over the lifetime vary between 9.5 and 22 odt/ha (Bullard and Matcalfe 2001; Lewandowski *et al.* 2003; Boehmel *et al.* 2008; Khanna *et al.* 2008; van Dam *et al.* 2009a). Currently, there is no experience with the cultivation of perennial grasses in Mozambique, but there is ample of experience with switchgrass in the USA and also Argentina. The production process of lignocellulosic biomass to ethanol is described in Annex 1.

A1.1.3 Region and setting selection for impact assessment in Mozambique

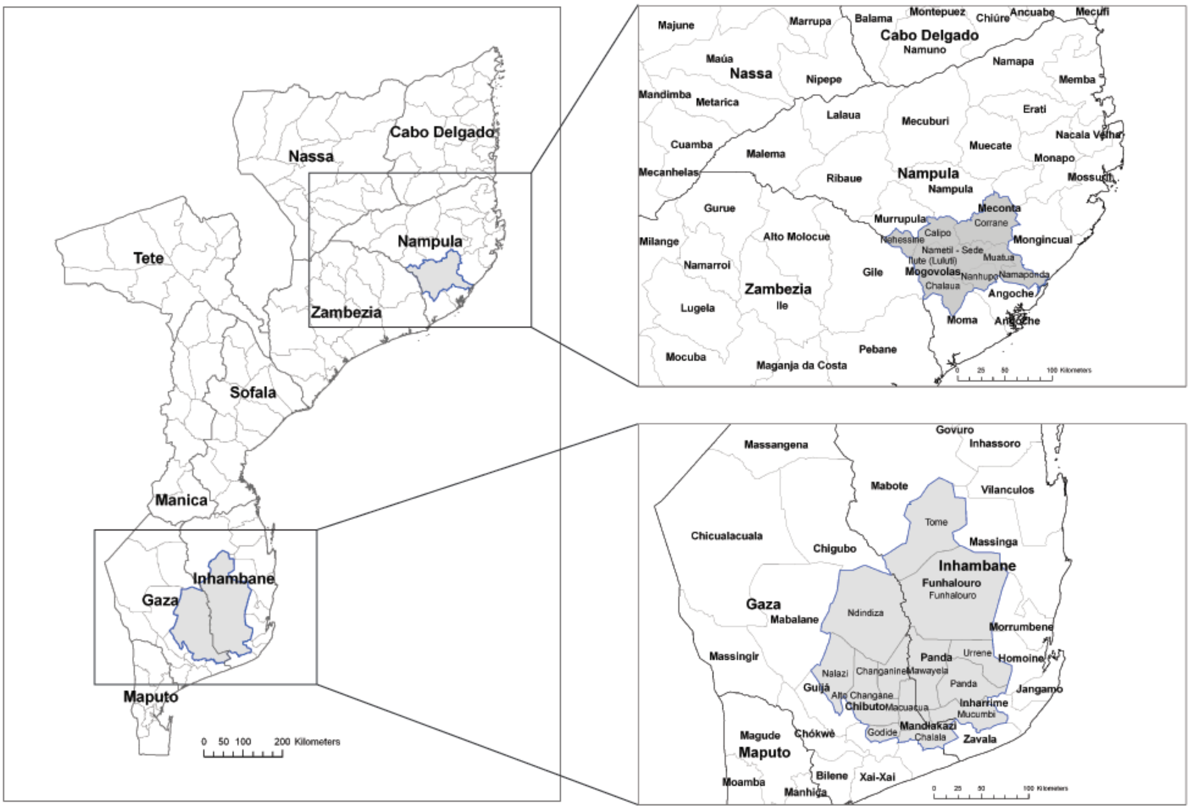
The settings in Mozambique are differentiated for the regions Nampula and Gaza-Inhambane, for the energy crops eucalyptus and switchgrass for the Business as Usual and the progressive scenario.

A1.1.3.1 Selected regions in Mozambique

Based on the findings of van der Hilst et al (2011, 2012) two areas were selected to make an environmental and socio-economic impact assessment. The Gaza-Inhambane and the Nampula region where selected. The areas are selected because they are quite different in terms of biophysical and socio-economic conditions such as current land use, land availability, climate, soil, population density, available infrastructure, employment etc. The boundaries of the selected areas are harmonised with administrative borders of districts and *localidades* (2rd and 3thorder administrative units). (See Figure A1.1.)

The selected region in the central south of Mozambique is in the border area of Gaza and Inhambane province. There is currently a lot of land yet available as most of the land is currently covered by grassland and shrubs. The suitability of

Figure A1.1: Administrative subdivision of the selected areas in Nampula province and Gaza-Inhambane province.



the land for agricultural production in this area is marginal to moderately. The province of Gaza and Inhambane have combined 2.7 million inhabitants and an average population density of 18-20 people/ km². But the majority of the province inhabitant of Gaza and Inhambane live in the coastal districts. Therefore, the average population density is not representative for the area of concern which is quite uninhabited. The central area of the central south has a very low density of road infrastructure. In addition, there are very limited services in this region.

The selected area in the Gaza-Inhambane region is relatively flat with an altitude varying between -2 and 215 m above sea level without steep slopes. The average maximum temperature ranges from 25 in July to 32 °C in January with an annual average of 29 °C. The minimum temperature ranges from 15-23 °C with an annual average of 19 °C. Annual precipitation levels amount 790mm/yr (in the eastern part of the selected areas and much lower levels in the more inland areas) with strong seasonal variations (20 mm/month in September and August and 120 mm/month in January and March). The rainy season is relatively short (<5 weeks). The average relative humidity is 76%. The evapotranspiration varies between 75 and 120 mm/month and is 102 mm/month on average. The climate is characterised a dry semi-arid (IIAM). There is a high spatial variation in land use and land cover in the Gaza-Inhambane region (See Figure A1.2).

The selected area is situated in the southern part of Nampula province. Currently there is little land available as most of the land is currently in use for agriculture or is covered by forest. The Nampula province has almost 4.6 million inhabitants and the population increases with 2.5 % per year on average. With 59 people per km² it is the second densely populated province of Mozambique (after Maputo). The area is close to the shore and in the vicinity of the Nacala port which is the largest port of east Africa. In addition two railways are rehabilitated from Nacala port to Malawi and Tete province. The port attracts a lot of economic activity and labour migration. The boundaries of the selected areas are harmonised with administrative borders of *localidades*. Figure A1.1 shows the districts and localidades involved in the selected areas.

The selected area in Nampula is characterised by low hilly landscape. The majority of the area has an altitude of <200m but in the North-Eastern part of the area altitudes rise towards 400m above sea level. Mostly in the northern part of the selected area the landscape is dotted with inselbergs (isolated large masses of volcanic granite) which rise up to a level of 700m (IIAM, fieldwork). The average maximum temperature ranges between 26 °C (in July) and 33°C (in November) with an annual average of 30 °C. The minimum temperature ranges from 16 °C to 22°C. Annual precipitation levels amount 1035 mm/yr with very strong seasonal variations of 1 mm/month in September to 310 mm/month in January. The rainy season lasts between 5 and 18 weeks. The average relative humidity is 67% and the average evapotranspiration is 125 mm/month with strong seasonal differences which vary between 75 and 210 mm/month. The climate is characterised as wet semi-arid (IIAM and INAM). There is a high spatial variation in land use and land cover in the Nampula region (See Figure A1.3).

A1.1.3.2 Selected supply chains in Mozambique

The selected supply chains are second generation ethanol from Eucalyptus and second generation ethanol from switchgrass. For both supply chains, a large scale ethanol conversion facility is assumed. The supply chains are normalised to the same biomass capacity referred to the input of 1400 $MW_{th\ LHV\ input}$. Given the feedstock to product ratio and the losses during the supply chain assumed, 2.2 Mton Eucalyptus feedstock and 2.3 Mton Switchgrass is required annually.

In all settings it is assumed that state-of-the-art management practices are applied with full use of mechanization and agrochemicals but all in respect to the environment and socio-economic context. Although there are many advantages of an outgrower scheme and it could have many positive environmental and socio-economic impacts and could therefore be more sustainable, at this point it is considered to be difficult to implement for large scale biomass production in Mozambique as it imposes risks for both the company and the farmers involved. For that reason and considering the scale of the project, the context, the selected crops and the timeframe, it is assumed that the large scale biomass production will be done in a large scale plantation.

A1.1.3.3 Selected settings in Mozambique

The settings are differentiated for two selected regions (Gaza-Inhambane and Nampula), two selected energy supply chains (eucalyptus ethanol and switchgrass ethanol), and

Table A1.1: Overview of the setttings inluded in the ex-ante analysis of the environmental and socio-economic impacts of large scale biofuel production in Mozambique.

Setting	Region	Scenario	Supply chain
1	Gaza-Inhambane	Business as Usual	Eucalyptus
2			Switchgrass
3		Progressive	Eucalyptus
4			Switchgrass
5	Nampula	Business as Usual	Eucalyptus
6			Switchgrass
7		Progressive	Eucalyptus
8			Switchgrass

Figure A1.2: Spatial variation in land cover in Gaza-Inhambane region.

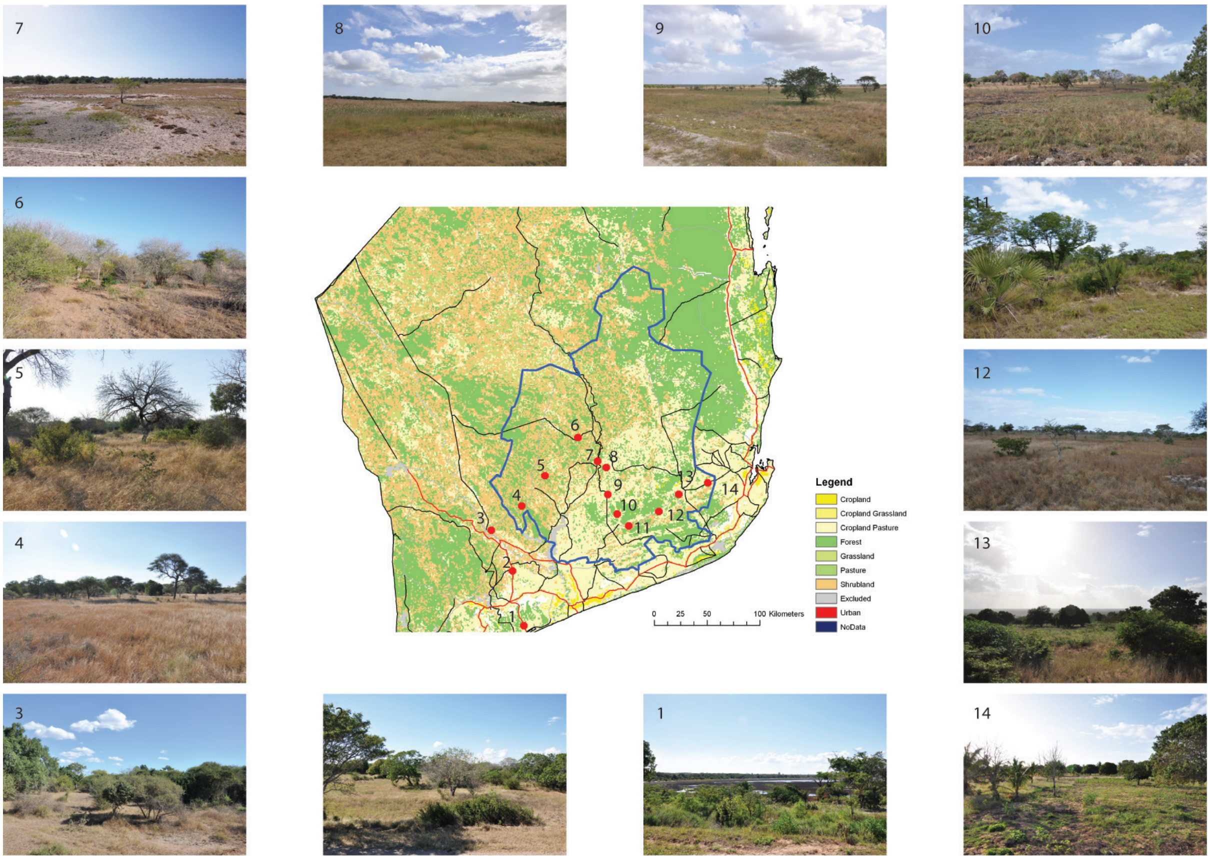
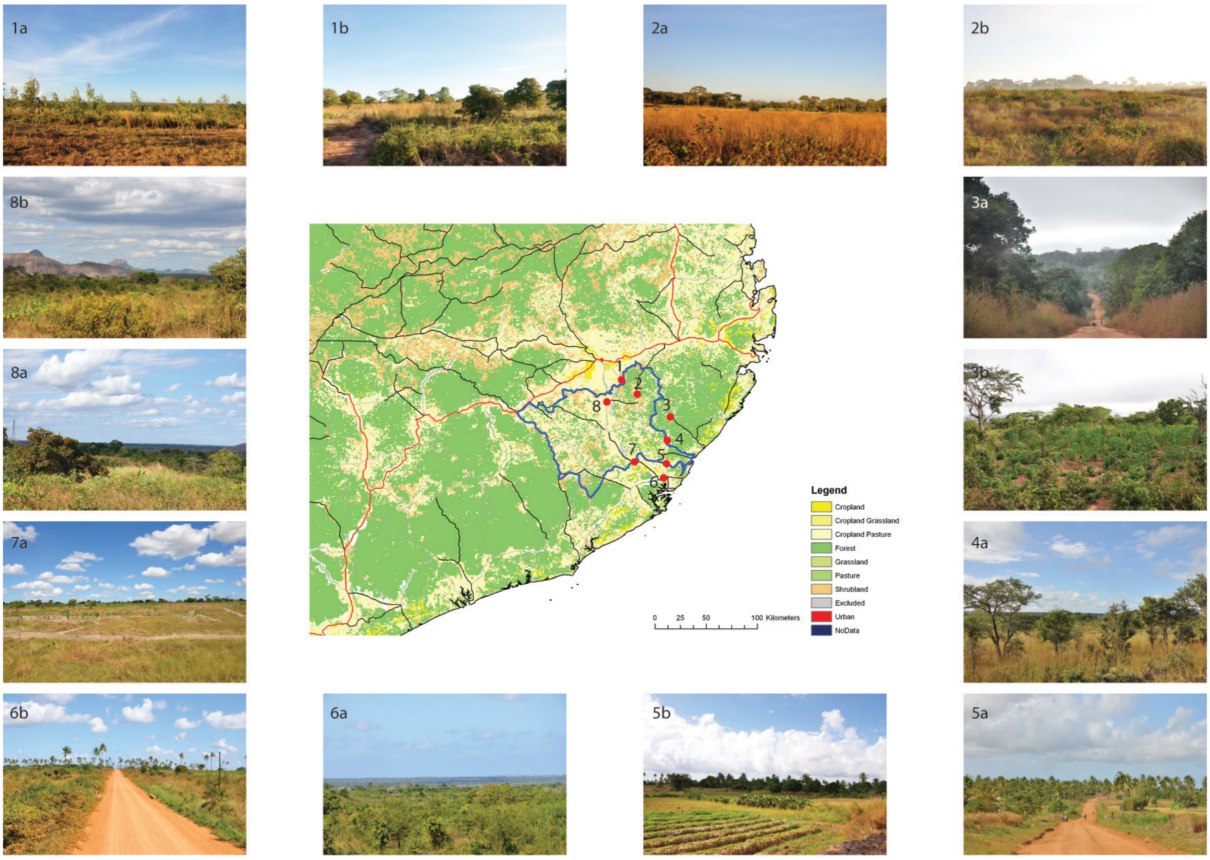


Figure A1.3: Spatial variation in land cover in Nampula region.



two scenarios (a BAU scenario and a Progressive scenario; the scenarios are described in Annex 2). This brings the total number of setting assessed in the environmental and socio-economic impact analysis at eight. In Table A1.1 an overview is provided of the settings that are included in the ex-ante analysis of environmental and socio-economic impacts of large scale biofuel production.

A1.2 Argentina

A1.2.1 Case study area

Argentina is located in the extreme south of America between the Andes mountain range in the west and the Atlantic Ocean in the east. It borders Bolivia and Paraguay in the North, Brazil and Uruguay in the North East and Chile in the East and South-East.

Argentina is divided into 23 provinces and one autonomous city, the federal capital Buenos Aires. Total population amounted to more than 40 million in 2010 (UNDP, 2010a), with roughly 92% living in urban settings (FAOSTAT, 2011). With a GDP per capita (PPP) of $18205, Argentina is ranked 52th out of 180 on the lists of countries by gross domestic product at purchasing power parity per capita of the World Bank (2012). Despite an acute economic crisis in 2001/2002, Argentina is nowadays a bustling economy with a GDP around 370 billion US$ in 2010 (World Bank, 2011), being one the largest in Latin America.

The services sector contributes 58% to the GDP followed by Industry (31%) and agriculture (11%).
30% of the population lives below the poverty line (CIA 2012) and it is ranked 45th out of 187 at the list of Human Development Index (UNDP 2011a).

Argentina comprises 2 780 400 km^2 which makes it the 4th largest country of the Americas after Canada, the United States and Brazil. 1.6% of the total surface consists of water. The main rivers are Paraná, Uruguay, Negro and Bermejo River. Argentina has six main regions: The Pampas are fertile lowlands in the centre and east; the Mesopotamia are the lowland enclosed by the Paraná and Uruguay rivers; the Gran Chaco is between the Mesopotamia and the Andes; Cuyo is at the east side of the Andes, and the Argentine Northwest is at the North of it and the Patagonia is the large plateau to the south. Extending for 3.700 km North to South, a large variety of climates can be identified along its territory, including temperate climate in the majority of the territory, subtropical climate in the North and cold semiarid climate in the South.

The different regions accounting for completely distinct climates, topographic and landscape features. Consequently, agricultural production systems are extremely varied along the country. In fact, more than 100 homogeneous agro-economic zones (HAZ) have been identified according to their environmental characteristics and socio-economic aspects (INTA 2009). Therefore, the study area for the assessment of large scale bioenergy production in Argentina was confined to the eco-regions of Region Pampeana and Chaco, which comprise the provinces of Buenos Aires, Santa Fe, Cordoba, Chaco, Formosa, Santiago del Estero and partially include the provinces of Entre Rios, Salta, Tucuman, Catamarca and La Rioja. These two eco-regions account for more than 90% of the total production and total area required to produce food commodities, 80% of total cattle heads and almost 100% of total milk production in Argentina (SIIA 2011). These are also the regions where the processes of agricultural expansion and displacement of livestock production have been more pronounced (World Bank 2006). Limiting the simulation area to these eco-regions will allow on the one hand to focus in the most relevant production systems in terms of land demand and on the other hand, to avoid computing issues resulting from dealing with large datasets.

A1.2.2 Biofuel supply chains

A1.2.2.1 Switchgrass ethanol

Switchgrass cultivation is described in A1.1.2.3. The production process of lignocellulosic biomass to ethanol is described in A1.1.2.1.

A1.2.2.2 Soy biodiesel

Soybean is often grown in crop rotation patterns. In case of double cropping (in rotation with wheat), seeding takes place in the months October or January in Argentina, and harvesting in the months March to June. As water is a limiting factor, the second cultivation only takes place if there is enough water available (Van Dam et al. 2009). Fertilizers are applied and cultivation can be performed in a no-tillage system.

Soy biodiesel is obtained by crushing soybeans into soy meal and soybean oil. The oil is usually filtered in a pre-treatment step to remove water and other contaminants. The soybean oil is then further processed into biodiesel by a transesterification step, where the oil is blended with an alcohol (usually methanol) and a catalyst. The oil molecules are broken and reformed into esters (biodiesel) and glycerine. Soy biodiesel is regarded as the most important biofuel option in Argentina due to two main reasons: 1) diesel is currently the main transportation fuel in Argentina, thus making soybean biodiesel a suitable option for the internal market to reduce diesel imports and supply vulnerability; 2) a robust industrial park for vegetable oil production and advanced agricultural sector are in existence already.

A1.2.3 Region and setting selection for impact assessment in Argentina

A1.2.3.1 Selected regions in Argentina

Based on the findings of Diogo *et al* 2013 (Forthcoming) on the development of land availability for bioenergy crops and the economic viability of biofuel production in Argentina, two regions were selected for the assessment of potential environmental and socio-economic impacts of large scale bioenergy production. The study of Diogo *et al* focussed on the eco-regions of Chaco and Pampena which comprises more than 90% of the total agricultural production and of the total agricultural land of Argentina (SIIA 2011). These are also the regions where the processes of agricultural expansion and displacement of livestock production have been more pronounced (World Bank 2006). The provinces Buenos Aires and Santiago del Estero have been selected because of the expected high LUC dynamics in these regions and because of the differences between the regions in terms of biophysical and socio-economic conditions such as current land use, land availability, climate, soil, population density, available infrastructure, employment, etc. Buenos Aires is in the eco-region Pampena and Satiago del Estero is situated within the Chaco region. Figure A1.4 shows the provinces of Argentina, the selected eco-regions, and the selected provinces.

The province of Buenos Aires is in the central east of Argentina and is situated within the Pampena eco-regions. It is named after the city of Buenos Aires which used to be the provincial capital. Currently, the city of La Plate is the capital of the province of Buenos Aires. The province has a total area of 30.6 Mha. The land use is dominated by agricultural activities: 93% of the land is used for agricultural crops and livestock. The suitability of the land for agricultural productivity is high. Buenos Aires is the most populated province of Argentina it has 15.6 Million inhabitants of which 12 Million live in the city of Buenos Aires and adjacent municipalities. Because of the size of the province, the population density is relatively low: 51 People/ km^2.

The landscape is mainly flat, with two low mountain ranges; Sierra de la Ventana in the south west of the province and Sierra de Tandil in the central area of Buenos Aires. The altitude varies between -43 and 1063 meter above sea level (NASA and NGA 2000; Rodríguez *et al.* 2005). The climate is relatively spatially heterogeneous with different climate characteristics in the regions within the province Buenos Aires. The average minimum temperature ranges between 2 C in June and July and 14 in January. The average maximum temperature varies between 14 and 29 C (Azul). Precipitation levels vary between 40 and 130 mm/month. The annual average precipitation levels amount +/- 960 mm/yr with variations between 40 and 230 mm/month. The climate is characterised by warm and semi-humid.

The province of Santiago del Estero is in the Central North of Argentina. The capital is also named Santiago del Estero. The province has a total area of 13.7 Mha. The land use is dominated by livestock (50%) and forest (32%) and to a lesser

Figure A1.4: Provinces of Argentina, the eco-regions Pampena (blue) and Chaco (light blue) and the selected provinces Buenos Aires and Santiago del Estero.

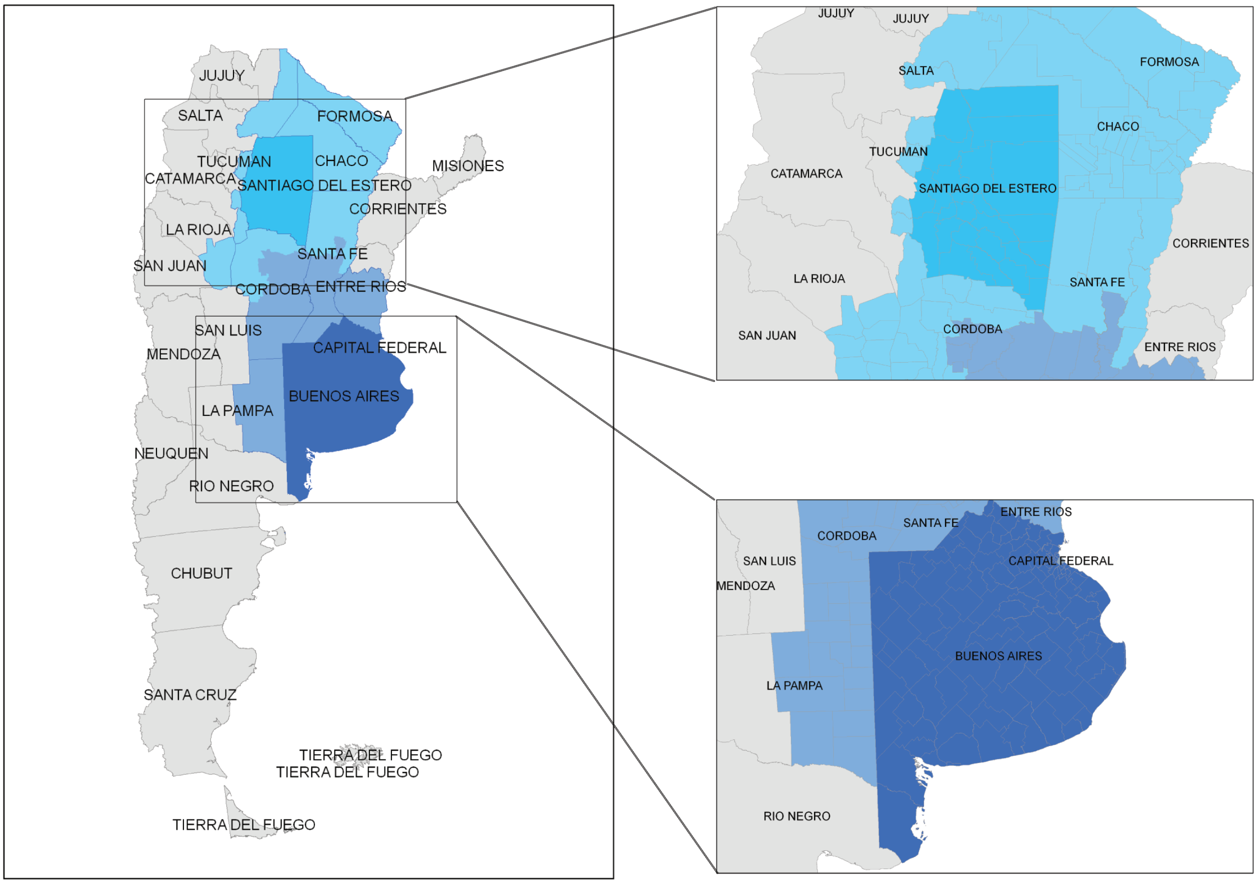


Table A1.2: Overview of the setttings inluded in the ex-ante analysis of the environmental and socio-economic impacts of large scale biofuel production in Argentina.

Setting	Region	Scenario	Supply chain
1	Buenos Aires	Business as Usual	Switchgrass
2			Soy
3		Progressive	Switchgrass
4			Soy
5	Santiago del Estero	Business as Usual	Switchgrass
6			Soy
7		Progressive	Switchgrass
8			Soy

extent by agricultural rotation (12%). The suitability of the land of agricultural production is low to moderate. Santiago el Estero has 0.87 million inhabitants and has a very low population density of 6.4 people/km^2.

In Santiago del Estero the altitude varies between 68 and 770 meter with an average altitude of 178 meter above sea level (NASA and NGA 2000; Rodríguez *et al.* 2005). The average minimum temperature ranges from 5 degrees in July to 20 C degrees in January. The maximum temperature ranges from 20 to 34 degrees. The annual average precipitation levels are +/- 600 mm/yr and show strong seasonal variability with almost no precipitation in the months June, July and August to 135 mm/month in January. The climate can be characterised as predominant weather is sub-tropical with a dry season and relative high temperatures during the entire year.

A1.2.3.2 Selected supply chains in Argentina

The selected supply chains are second generation ethanol from switchgrass and first generation biodiesel from soy. The supply chains are described in section A1.2.2. For both supply chains, a large scale ethanol conversion facility is assumed. The supply chains are normalised for the same output capacity in GJ biofuel. The scale of the biodiesel plant is set at 108 000 ton biodiesel output which is currently the average biodiesel plant size in Argentina (Hilbert *et al.* 2012). This is equivalent to an output of 4.7 PJ/ yr. Also the output of the 2nd generation ethanol production from switchgrass is set at 4.7 PJ/yr output level. This is equivalent to 0.2 M m^3 ethanol production per year. This implies a 0.61 million ton of soy and 0.62 million ton of switchgrass is required annually.

In all settings it is assumed that state-of-the-art management practices are applied with full use of mechanization and agrochemicals but all in respect to the environment and socio-economic context. Considering the scale of the project, the context, the selected crops and the timeframe, it is assumed that the large scale biomass production will be done in a large scale plantation.

A1.2.3.3 Selected settings in Argentina

The settings are differentiated for two selected regions (Buenos Aires and Santiago del Estero), two selected energy supply chains (Switchgrass ethanol and soy biodiesel), and two scenarios (a BAU scenario and a Progressive scenario; the scenarios are described in section 2.1.2 in the final report). This brings the total number of setting assessed in the environmental and socio-economic impact analysis at eight. In Table A1.2 an overview is provided of the settings that are included in the ex-ante analysis of environmental and socio-economic impacts of large scale biofuel production.

A1.3 Ukraine

A1.3.1 Case study area

Ukraine in located in the east of Europe and borders the Russian Federation to the east and northeast, Belarus to the northwest, Poland, Slovakia and Hungary to the west, Romania and Moldova to the southwest, the Black Sea to the south, and the Sea of Azov to southeast.

Ukraine has 24 oblasts (provinces /states) and one autonomous republic (Crimea). The 24 oblasts and Crimea are subdivided into 490 raions (districts), or second-level administrative units. Ukraine has a population of 45 milion inhabitants (2010) with an average population density of 77 people/km^2 (UNDP 2011b). The GDP per capita (PPP) is $7233 and Ukraine is ranked 96th out of 180 countries on the lists of countries by gross domestic product at purchasing power parity per capita of the World Bank (2012). Between 2000 and 2008 there was a high economic growth of 7% on average. However, Ukraine was hit hard by the economic crisis in 2008 which resulted in an economic contraction of 15%. In 2010 and 2011 the economic growth resumed again (CIA 2012). Services contributed 56% to the national GDB followed by Industry (33%) and agriculture (11%) (CIA 2012). 35 % of the population lives below the poverty line (CIA 2012). And Ukraine it is ranked 76th out of 187 at the list of Human Development Index (UNDP 2011a).

Ukraine comprises 603,628 km^2 making it the second largest country of Europe. 7% of the area consists of inland waters. The main rivers are the Dnieper, Seversky Donets, Dniester and southern-Buh. The majority of the country consist of plans and low plateaus (90%) (Bogovin 2001) with an elevation up to 400m above sea level. In the Western part of Ukraine are the Carpathian Mountains and in the far south the Crimean Mountains. Ukraine has very fertile soils; especially the black soils covering a wide belt from west to east are very fertile. In the north east are peaty and swampy soils with high carbons stocks (Bogovin 2001).

Ukraine has a temperate continental climate with cool winters (up to minus 37 °C) and relatively hot summers (up to 38 °C). The Crimean coast in the south has a humid subtropical climate. The average rainfall varies from 300-700 mm on the plains, and up to 1200 mm in the mountainous areas (Bogovin 2001) and is fairly distributed over the year allowing for multiple cropping.

A1.3.2 Biofuel supply chains in Ukraine

A1.3.2.1 Wheat ethanol

Wheat is a cereal grain originally from North east Africa and the near east but is now amongst the most cultivated annual crops in the world (FAO 2002). In Ukraine, about 22% of the arable land is used for the cultivation of wheat (State Statistics Service of Ukraine 2011). Wheat has a relative high protein content compared to other cereal crops. It is mainly used as a food (staple) crop (70%), but is also used for fodder purposes (25%) (FAO 2010). The world average yield levels of the last decade of 2.86 ton/ha was slightly higher than the average yield levels of Ukraine of 2.72 ton/ha (FAO 2010). This is far below the yields reported in Western Europe of almost 8 tons/ha.

In this case study it is assumed that only the grain is used for energy production and that the wheat straw is used for other purposes. The production of ethanol form starch is a well established technology and consists of three main sub-processes: saccharification, fermentation, and distillation. Starch molecules are made up of long chains of glucose molecules which have to be broken into simple glucose molecules (saccharification). This is done in a reaction of starch with water (hydrolysis). Typically hydrolysis is performed by mixing the starch with water to form slurry which is then stirred and heated to rupture the cell walls. During the heating cycle, specific enzymes are added, which break the chemical bonds (Rutz and Janssen 2007).

A1.3.2.2 Switchgrass ethanol in Ukraine

Switchgrass cultivation is described in section A1.1.2.3. The production process of lignocellulosic biomass to ethanol is described in section A1.1.2.1.

A1.3.3 Region and setting selection for impact assessment in Ukraine

The regional assessment of the environmental and socio-economic impacts requires large amounts of very detailed (spatial) data on a multitude of parameters. This data is generally lacking for Ukraine. In collaboration with our Ukrainian partner and after consultation of several experts in Ukraine, we had to conclude that the data availability and quality was too low to make an ex ante environmental and socio-economic impact assessment.

Similar to the land use data for Mozambique and Argentina, the land use data for Ukraine is derived from Globcover. However, there is large spatial variability in the status of agricultural land. In some areas agricultural land is abandoned or degraded but maintain the status of agricultural land and in some areas there is intensive agricultural production. Although this is also true for Mozambique and Argentina these differences are more profound in Ukraine and could not be verified as there is no land use data available in Ukraine. The new land law and the land registration should provide more transparency on this, but this is still in progress (for some years now). For that reason the land use assessment is relatively uncertain. As all impacts of biofuel production are related to the change in land use, the uncertainty in the previous land use affects the ability to quantify these impacts to a large extent. In addition, limited climate data is available for Ukraine as there is no widespread network of weather stations. Spatial data on climate results from interpolation of climate data from weather stations inside and outside the boarders of Ukraine. As climate affects all environmental impacts (GHG emissions, soil, and water) inaccuracy in climate data will influence the ability to quantify the environmental impacts. The main shortcoming in data availability is the data on regional socio-economic conditions. This is often not available at all or not available in English. This was also confirmed by the reporting of SEC biomass, the local partner in Kiev Ukraine. Also a work visit of the authors of this report and longer working period of a Master student in Ukraine did not result in sufficient data. For these reasons, it was not feasible to conduct a full environmental and socio-economic impact analysis in this study. However, it is assumed that significant additional research efforts on data gathering and analysis could enable this type of analysis for Ukraine. This could include e.g. data interpretation of satellite images including ground thruthing for a better understanding of the status of the agricultural land; field visits to the region of interest; obtaining data from local (non-) (governmental) organisations and businesses on the socio-economic conditions in the region; collaboration with local institutes for information on biophysical characteristics of the region, interviews with local experts; etc.

A2. Annex 2:
Land availability for energy crops

A2.1 Detailed Method

A2.1.1 Land availability for energy crops

In recent years, an increasing number of studies have been published on bioenergy potentials on a global (e.g. Berndes *et al.* 2003; Hoogwijk *et al.* 2005; Smeets *et al.* 2007; Dornburg *et al.* 2010), European (e.g. Ericsson and Nilsson 2006; EEA 2007; Fischer *et al.* 2007; de Wit and Faaij 2010), national (e.g. Faaij *et al.* 1998; van den Broek *et al.* 2001; Walsh *et al.* 2003; Sang and Zhu 2011) and regional level (e.g. van Dam *et al.* 2009a). However, most of these studies have assessed biomass potentials on a spatially aggregated level. The disadvantage of such studies is that they provide only limited information on the location of the land available for bioenergy crops. Potential yield levels and environmental and socio-economic impacts of energy crop production are strongly related to the physical and socio-economic conditions of a location (van Dam *et al.* 2009a; 2009b; Van der Hilst *et al.* 2010; Beringer *et al.* 2011; 2011); therefore, it is important to assess where land is (or could become) available for bioenergy production.

LUC result from complex interactions between human and biophysical driving forces that act over a wide range of temporal and spatial scales (Verburg *et al.* 1999). Several methodologies and models have been developed to simulate and explore LUC (Veldkamp and Lambin 2001). These models differ in terms of scale (e.g. regional, global), process (e.g. deforestation, urbanisation), discipline (e.g. economic, environmental), approach (e.g. extrapolating historical trends, driving forces) and complexity (e.g. methods, resolution). A review of several land use models is provided by Agarwal *et al.* (2001) and Verburg *et al.* (2004). The Integrated Model to Assess the Global Environment (IMAGE) is an example of a framework that models LUC on a global level (Alcamo *et al.* 1998; MNP 2006). However, the global modelling level, the aggregated modelling approach, and the low number of both dynamic land use types and allocation factors makes it less suitable for regional or national assessments. Lapola *et al.* (2010) used the LandSHIFT model to simulate LUC on a national level in order to assess indirect LUC and related carbon emissions for a fixed biofuel production target in Brazil for 2020. However, due to the low resolution and the limited number of both dynamic land use classes and allocation factors, this type of modelling is less suitable for spatially detailed analyses of multiple dynamic land use types. The Conversion of Land Use and its Effects (CLUE) modelling framework was developed in 1996 and has progressively been improved since then (CLUE-s and Dyna-CLUE) (e.g.Veldkamp and Fresco 1996; Verburg *et al.* 1999; Overmars *et al.* 2007; Verburg and Overmars 2009). The CLUE modelling framework proves that it is possible to model LUC on a more detailed level, taking into account driving forces at different spatial levels. However, as the CLUE modelling approach is based on the competition between land use functions, it suggests some form of top-down land use planning. However, LUC is not always policy driven and is in less developed countries often related to local mechanisms. Moreover, CLUE does not consider the effects of the uncertainties in the input data on the results of LUC modelling.

The objective of this study is to develop a new modelling framework to assess the development in land availability for bioenergy crops on a detailed spatial level, taking into account the dynamics of several other land use functions and the uncertainties in drivers of LUC. The model is specifically developed for less developed countries characterised by subsistence farming, a low density of infrastructure, and a lack of top-down land use planning. The LUC in these types of countries are driven by environmental and socio-economic factors and are influenced by national or regional land use planning and policies to a much lesser extent. A multitude of driving forces and suitability factors are included in the model. The detailed spatial level, the number of dynamic land uses, the diversity in driving forces and suitability factors, and the possibility to model uncertainties in a spatially explicit way serves as a step forward in LUC modelling for less developed countries. This model is especially developed to assess the land availability for bioenergy crops and therefore provides opportunities to assess how iLUC effects are to be avoided. The technical characteristics of the model are described in Verstegen *et al.* (2011).

A2.1.2 Scenario approach

It is of key interest to assess how competition for land and related effects of iLUC can be avoided; therefore, the modelling of the land availability for energy crop production needs to take into account the land required for other land use functions. Land use requirements for crop and livestock production depend on the developments in food demand and agricultural productivity. Consequently, land use is dynamic over time. This study includes the demand for food, feed and materials (including wood) which results in a claim on land for crop production and grazing area as well as in deforestation. In order to project the dynamics in these land use functions over time, future developments regarding the main drivers for LUC need to be identified and quantified.

The main LUC drivers are the developments in the demand for food, feed and materials and the productivity of the agricultural sector. The demand for domestically produced food and feed is related to developments in population size, GDP, food intake per capita and self-sufficiency ratio (SSR, i.e. the extent to which domestic supply meets domestic demand) (FAO 2003). The amount of land required to meet the total demand for food, animal products and materials depends on the efficiency of the agricultural sector. Developments in the efficiency of crop production are related both to the exploitable yield gap, i.e. the gap between current yields and agro-ecological or maximum attainable yields (FAO 2003), and to the rate of technology adoption, i.e. the implementation pace of improvements in crop production. The efficiency of livestock production is related to the distribution of supply between types of production system (pastoral or mixed), the feed composition (the share of feed supplied by grazing, scavenging, residues and feed crops), and the feed conversion efficiency (the amount of animal product per unit feed) of the production systems. The land requirements for feed crops and pastures depend on the feed crop yield and the carrying capacity of pastures.

Developments in the demand for wood are related to the developments in total population, the ratio between urban and rural population, the adoption of improved cooking technologies, the domestic use of poles and other timber, and the export quantity of industrial round wood. The domestic wood supply can be roughly divided into two categories: wood that is sustainably extracted from the forest and wood whose logging results in deforestation. As this study focuses on LUC dynamics, only the wood demand that leads to deforestation has been included, defined as the illegal and unsustainable wood harvesting in forest areas. Thus, sustainable logging and logging in other woodland is not included.

Since it is uncertain how LUC drivers evolve and the prediction of land use developments is problematic (Verburg *et al.* 2004), a scenario approach was used to explore potential long-term developments in LUC driving forces. The use of scenarios to explore potential LUC developments has already been demonstrated by Stengers *et al.* (2004), Westhoek *et al.* (2006), De Vries *et al.* (2007) and Hoogwijk *et al.* (2005; 2009). In this study, the narratives developed for the Special Report on Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC) (Nakicenovic *et al.* 2000) were translated into storylines for the three selected countries to develop a consistent set of assumptions for the assessment of future land use dynamics. A storyline describes a demographic, social, economic, technological, environmental, and policy future for one scenario. The storylines were formulated in close cooperation with different stakeholders in the countries in a process in which the driving forces, key uncertainties are identified. The storylines approach will allow policy makers (and the GEF) to evaluate the feasibility and performance of various policy measures across the different sustainability aspects for different biofuels scenarios and production pathways. Two divergent storylines were developed: a BAU scenario

Table A2.1: Key scenario paremeters for the Business as Usual scenario and the Progressive scenario for Mozambique, Argentina and Ukraine.

Scenario Characteristic	Business as Usual Scenario	Progressive Scenario
Population	Based on outlooks of UNDP	
Diet	Development in caloric intake and composition based on outlooks of FAO	
SSR	Development in self-sufficiency and exports based on FAO	
Farming practices	Continuation of trend towards more commercial farming.	Abandonment of subsistence farming and shifting cultivation, increased shift towards large scale commercial farming.
Technology adoption	Continuation of current trends in input levels.	Increased adoption rate of improved seeds, fertilizers, agro-chemicals, knowledge, machinery and irrigation.
Agricultural productivity	A modest increase in yield and cropping intensity in line with historical trends.	High increase in crop yields and cropping intensity.
Livestock sector	Modest shift towards mixed systems and modest increase in conversion efficiencies.	Shift towards high productive farms. Increased feed conversion efficiencies in both pastoral and mixed systems.
Deforestation [a]	No additional policies, regulation and enforcement. Continuation of current trends in deforestation.	Additional policies, regulation and enforcement to prevent further deforestation
Bioenergy implementation	Abandoned agricultural land is used for bioethanol crops.	

[a] For Ukraine and Argentina the deforestation as a result from agricultural expansion is modelled. For Mozambique, in addition to the deforestation as a result from agricultural expansion, the deforestation resulting from illegal logging and fuel wood consumption is modelled.

based on the B2 storyline and a Progressive scenario based on the A1 storyline. The development in the key drivers of LUC, demographics, consumption patterns, and GDP, are rather unpredictable, which justifies the creation of divergent scenarios regarding the development of these driving forces. Still, for reasons of transparency, the developments in these main drivers are kept equal for the two scenarios and an uncertainty analysis in which these drivers are modelled stochastically is assumed to be the most suitable way to address the sensitivity of the results to these parameters. This implies that population; GDP, diet and SSR will change over time, but that the rate of change is equal for the two scenarios. The divergent storylines were used to explore possible developments in technological, institutional and societal changes which result in changes in productivity in the agricultural sector. In Table A2.1, the key parameters and the differences for the BAU and Progressive scenario for the three selected countries are depicted.

A2.1.3 Land use change allocation

Due to variations in agro-ecological conditions, the yields of crops, pasture and wood are spatially highly heterogeneous. Therefore, the total amount of land required to meet the demand for food, wood and animal products is directly related to the location of the specific land use class. Several studies on LUC have developed methodologies for land use allocation. Land use classes can be modelled dynamically (related to LUC drivers), passively dynamically (not linked to a demand but susceptible to change when other land use functions expand), or statically (excluded from any LUC). More information is found in van der Hilst *et al.* (2012).

In this modelling framework the allocation of land to dynamic land uses classes is based on the suitability of the location for a specific land use class which is defined by a combination of several selected spatially explicit suitability factors. Typical suitability factors for land use allocation are the agro-ecological suitability, the accessibility, the land conversion elasticity and the neighbourhood characteristics (Rounsevell *et al.* 2006; Verburg *et al.* 2006; Overmars *et al.* 2007; Verburg *et al.* 2008; Verburg and Overmars 2009; Britz *et al.* 2011).

The agro-ecological suitability indicates the relative attainable yield per land use class: cropland is preferably located in areas with a potentially high yield. The accessibility represents often a proxy for socio-economic factors of influence. For crops and pasture typically a location close to roads and cities is preferred in order to minimize transport costs, and the proximity of water indicates the potential option for irrigation and of cropland and/ or the access to water sources for cattle in pastures. Wood is preferably harvested at the edge of the forest, because this makes harvesting easier. The population density and the cattle density represent the local pressure on land: the higher the population density in an area the higher the probability that native vegetation is converted to managed lands. By incorporating neighbourhood characteristics it is assumed that land uses attract land uses of the same or a related type i.e. that related land uses tend to cluster. The number, kind and importance of suitability factors differ per land use type. In order to differentiate the importance of the suitability factors, weights are assigned to the individual suitability factors. There are several ways to identify the driving forces and their characteristics and quantify the relative importance of these factors of influencing LUC:

- Expert consultation
- Logistic regression analysis
- Particle filter

A2.1.3.1 Expert consultation

In case there is little information on historic land use patterns, or when historical developments are characterised by discontinuities, such as war or natural disasters, extrapolation of regression analysis may produce dubious results as historical driving forces for LUC may no longer be detected or no longer be relevant. In that case expert consultation is the best way to obtain information on the most important driving forces for current LUC. This method is applied in the case study for Mozambique and for Ukraine. Based on literature review and expert estimates the suitability factors were identified and ordered according their importance. Based on the order of importance weights were allocated to the different suitability factors applying an expected value method.

A2.1.3.2 Logistic regression

An approach to calibrate a LUC model uses empirical methods to quantify the relations between land use and driving forces instead. These type of approaches often rely on statistical techniques, mainly regression, to quantify the defined models based on historic data of LUC (Verburg *et al.* 2004; Koomen and Stillwell 2007). Logistic regression is a multivariate generalized linear model that allows predicting a discrete outcome from a set of explanatory variables. Because land-use change is usually represented as a discrete change from one land-use type to other, logistic regression is deemed as an appropriate statistical model to analyse these phenomena (Millington *et al.* 2007). When applying logistic regression analysis to land use modelling, the dependent variable (i.e. land use) is categorical, with each category referring to one of the dynamic land-use types. Logistic regression analysis is used to determine the local suitability of each land-use type, by quantifying the relation between the occurrence of land-use types and sets of explanatory variables that are considered to drive land use allocation (Verburg *et al.* 2008). The model transforms the dependent variable into a logit variable by estimating the odds of a land-use type occurring in a certain cell in relation to a reference class and then calculates the regression coefficients through maximum likelihood (Lesschen *et al.* 2005). See Equation 1.

The reference land use category is usually the land-use type that is more prevalent and has a homogeneous distribution along the study area. The logistic regression coefficients indicate the direction and intensity of each explanatory variable on explaining the occurrence of land-use type *i*, e.g., the effect of distance to roads on the allocation of cropland. These coefficients are used to calibrate the allocation module of the model, according to which the allocation of future food production is simulated. This approach has been applied to identify and quantify the driving forces for LUC in the case study of Argentina (Diogo *et al.* 2013).

Equation 1

$$S_{c,i} = \ln\left[\frac{P_{c,i}}{P_{c,refclass}}\right] = b_{o,i} + b_{1,i}X_{1,c} + b_{2,i}X_{2,c} + \ldots + b_{n,1}X_{n,c}$$

$P_{c,i}$	Probability of cell c being used for land-use type i
$P_{c,\text{ref class}}$	Probability of cell c being used for the land-use type considered as a reference category
X_1 to X_n	Suitability factors
b_o	Constant (the intercept)
b_1 to b_n	Logistic regression coefficients

A2.1.4 Land use change modelling

The spatial data of the suitability factors are standardized resulting in grids with cell values between 0 and 1. For each suitability factor, the direction of the relation (e.g. does the suitability increase or decrease with distance to road), the type of correlation (exponential, linear, inversely related), and the maximum distance of effect (e.g. up to what distance from the road does the road still influence LUC) were determined.

Equation 2

$$s_{n,t} = \sum_{i=1}^{y} \left(w_{i,n} \cdot u_{i,n,t}\right) \qquad \sum_{i=1}^{y} \left(w_{i,n}\right) = 1$$

$\mathbf{s}_{n,t}$	Total suitability map (spatially)
y	Amount of suitability factors
$w_{\mathbf{i,n}}$	Weight of suitability factor i for land use type n
$\mathbf{u}_{i,n,t}$	Normalised map (values between Is 0 and 1) of suitability factor i for land use type n at time step t (spatially)

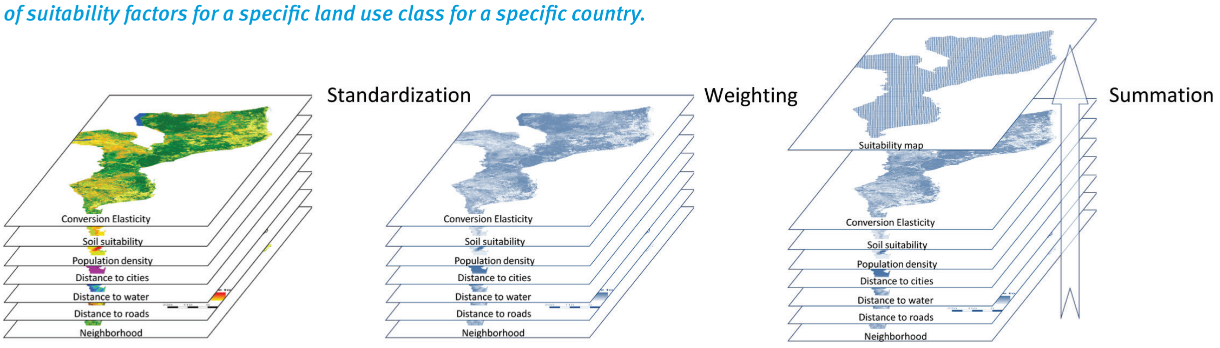
Not all suitability factors are equality important. The differentiation in importance of suitability factors for land use allocation is expressed in a weight factor. All weight factors have value between 0 and 1 and all weight factors sum to a total of 1. For every land use type a total suitability map $S_{n,t}$[0, 1], indicating the aggregated appropriateness of a given location for land use *n* at time step *t*, is computed from its suitability factors (Verstegen *et al.* 2012):

For each land use class, a suitability map was constructed based on the spatially weighted summation of a specific set of individual suitability factors (See Figure A2.1). The characteristic of the suitability factors for land use allocation for each dynamic land use type for each case study country are further explained in (van der Hilst *et al.* 2012; Diogo *et al.* Forthcoming; Van der Hilst *et al.* Forthcoming).

Areas that are not suitable (e.g. steep slopes) or not allowed (e.g. conservation areas) to be converted to agricultural land were excluded. In some land use models (such as CLUE), the allocation of land has been based on the highest suitability of one land use class compared to the other land use classes (Verburg and Overmars 2009). This approach serves top-down land use planning, which regulates land use in such a way that land is used for the best possible application. Yet, in this study, a fixed order for allocation is used. This implies that one land use category is allocated first to the best suitable places for that specific land use type until the demand (for that land use type) is met. Subsequently, the next land use class is allocated to the locations best suitable for that land use class, until the demand of that particular year is met by the production (Area x Location specific productivity x Management level). Subsequently, all remaining dynamic land use classes are allocated.

Land is allocated to a land use class in time steps of one year. This allocation of land within one time step continues until the production of that land use class has met the demand for that particular time step. The amount of land required to meet the demand depends on the productivity of the land allocated, and on the agricultural efficiency during that time step. Once the land has been allocated, it cannot change to another land use class during the same time step (because in

Figure A2.1: The standardisation, weighting and summation of suitability factors for a specific land use class for a specific country.



that case supply will not meet demand). The total allocation is completed for one time step when all the land use classes have been allocated and the production of these land use classes meets the total demand for that particular time step. This results in a new land use map for that time step. The modelling comprises a feedback loop: the land use resulting from the allocation in time step *t* serves as input for the allocation in time step *t*+1.

Figure A2.2 shows how the dynamics of land use classes are modelled and how they influence the land availability for energy crop production. LUC drivers (population, diet, GDP and SSR) determine the demand for food crops and animal products for each time step. The scenario characteristics determine the developments in the productivity of both crop cultivation and the livestock sector, the fuel wood demand per capita, and the deforestation rates. Based on the demand for animal products and the efficiency of the livestock sector, the amount of feed crops and pasture is calculated. Based on population growth and the fuel wood demand per capita, the total fuel wood demand is calculated. Based on a specific set of suitability factors, the excluded land, and the order of allocation, land is allocated to the different land use functions. This results in a new land use map. Based on this land use map and a map of the areas that are excluded for bioenergy crops (such as community land) in addition to the areas already excluded for LUC, the land availability for bioenergy crops is determined. The land use map which results from the land use allocation of year *t* serves as input for the land use allocation in year *t*+1.

In order to enable the modelling of future land use as depicted in Figure A2.2, a spatio-temporal land use model has been developed based on the building blocks of the PCRaster Phyton framework (Karssenberg *et al.* 2010; PCRaster 2010). The key inputs for the PCRaster Land Use Change model (PLUC) are: time series of demand and productivity development, dynamic land use classes, suitability factors per land use class, the initial land use map that designates the initial configuration of these land use classes and several maps of suitability factors (e.g. population density and distance to road). The parameterisation of these and additional inputs are discussed in the online supporting information.

The major advantage of this model framework is its ability to deal with stochastic input data. This enables spatio-temporal Monte Carlo (MC) runs that evaluate uncertainty propagation. PLUC can stochastically model time series (e.g. crop demand and agricultural productivity), spatial input parameters (e.g. population density and productivity), and characteristics of suitability factors (e.g. the maximum distance of effect in the distance to road). The stochastic inputs can be based on different error models: a uniform distribution between two values, a normal distribution given the mean and fixed standard deviation (SD), and a relative distribution given the mean and a relative SD. When a uniform error model is applied, all values between the upper and lower limit have equal probability. The normal error model has a normal distribution of probabilities, with 95% of all selected values within the range of the mean + /- 1.96 SD. The relative error model also has a normal distribution, but with the SD relative to the mean. The probability distribution of stochastic inputs is equal for each time step. The probability of the availability of land for bioenergy can be calculated by means of an MC analysis. The probability can not only be analysed at a grid cell level but also at a provincial or national level. More information on the technical characteristics and stochastic input modelling of PLUC can be found in Verstegen *et al.* (2011). The software package Aguila enables the visualisation of the results of the PLUC model for every individual time step (de Jong 2009; Karssenberg *et al.* 2010). It can show the development in LUC and the land availability for bioenergy crops for a deterministic run, as well as the development in the probability of land availability for bioenergy crops for a MC run.

A2.1.5 Biomass Potentials

Due to variations in agro-ecological conditions, the yields (and related production costs) of energy crops are spatially highly heterogeneous. In order to calculate the development in the total biomass production potential spatially explicitly, the map of land availability of year *y* is combined with the crop suitability map and the maximum attainable yield given the level of management in year *y*.

Equation 3

$$Y_{ay} = A_{ay} \cdot S_a \cdot M_y$$

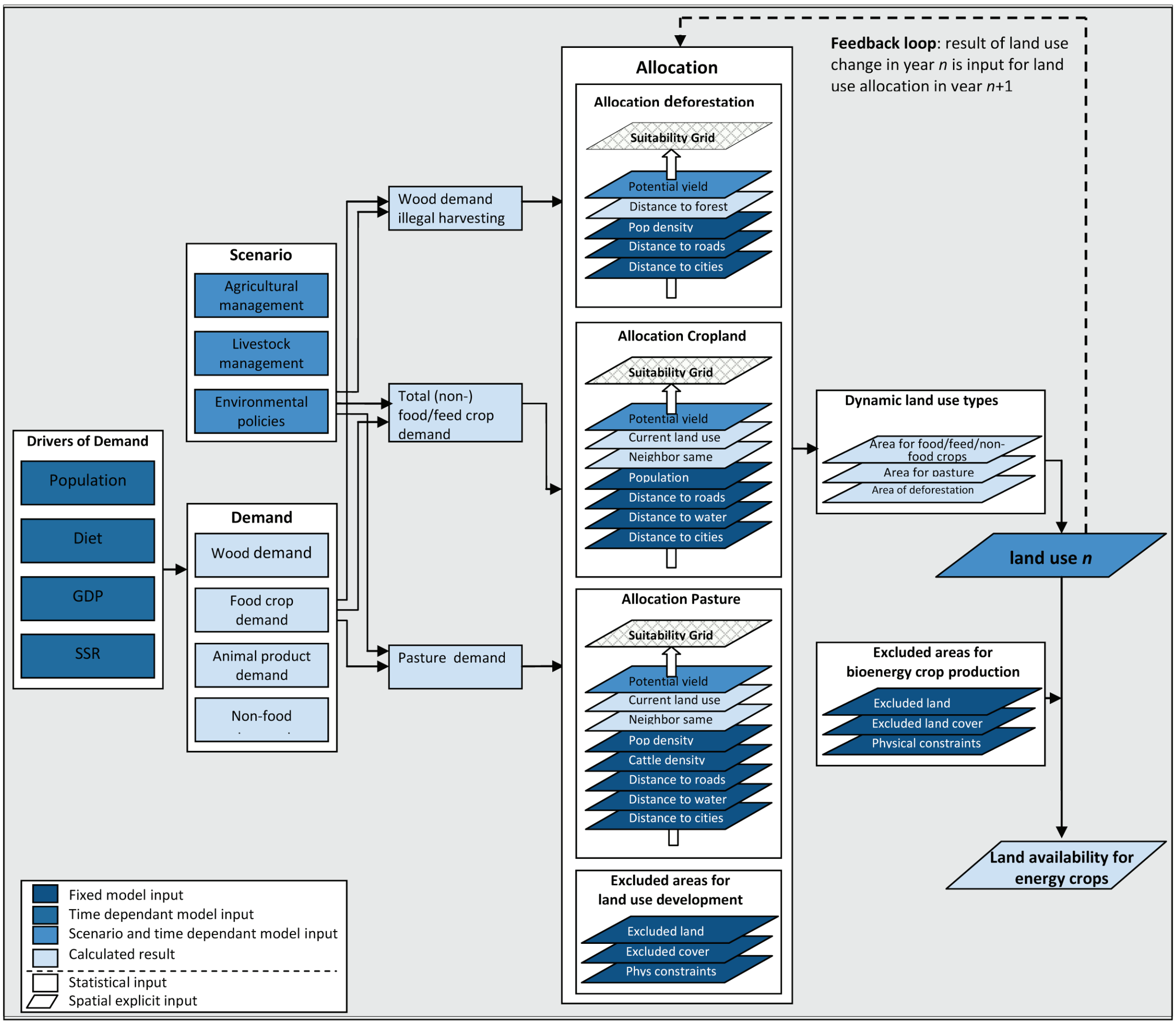
Y_{ay}	Yield of energy crop at location a in year *y*	[ton/ha]
A_{ay}	Land availability of lactation a in year *y*	[I /o]
S_a	Suitability of land at location a in year *y*	[%]
M_y	Maximum yield given management level in year *y*	[ton/ha]

The total biomass potential in year y (y_y) is the summations of the potential yield levels in all areas that are available in year y. See Equation 4.

Equation 4

$$Y_y = \sum_{i=1}^{a} \left(Y_{a,y} \right)$$

Figure A2.2: Overview of the modelling of land availability for bioenergy crops derived from van der Hilst et al. (2012)



A2.2 Detailed Results

A2.2.1 Mozambique

A2.2.1.1 Developments in demand, productivity and land requirements

Figure A2.3 depicts the total domestic food and non-food production for the timeframe 2005-2030. The total food demand that needs to be produced domestically is expected to increase from 11.5 Mt in 2005 to 24.7 Mt in 2030. In the BAU scenario, the total wood demand increases from 19.4 million m^3 in 2005 to 39.0 million m^3 in 2030, of which 43% is expected to result in deforestation. In the Progressive scenario, the total wood demand increases to 20.2 million m^3 for 2030. This lower wood demand results from the adoption of improved stoves and alternative fuels. As in this scenario deforestation is to be prevented, 9.2 million m^3 should be produced in alternative ways by 2030. The prevention of deforestation is a result of strong policy measures assumed in the progressive scenario.

The land required to meet the demand depends on the developments in agricultural productivity. In Figure A2.4, the developments in the productivity of crop cultivation and livestock production are presented for the two scenarios. It shows the normalised productivity increase compared to the level of the year 2005, based on the weighted summation of the productivity increase per crop (based on the proportion of cultivated area) and the weighted summation of the productivity increase per animal product (based on the proportion of total volume). The bandwidth of the curves of the development in crop productivity in the BAU and Progressive scenarios represent the range of the stochastic input of the maximum attainable yield.

Figure A2.5 presents the land requirements to meet the total crop and grazing demands for the BAU and the Progressive scenarios, assuming the same distribution of cropland and pasture over potential yield classes as in 2005. In the BAU scenario (left), there are two reasons why the land required for crops and pasture increases: an increased demand caused by population growth and a rise in food intake per capita, and a relatively low growth in productivity. In the Progressive

Figure A2.3: Total food and non-food crop demand in timeframe 2005-2030 considering the developments in population growth, dietary intake and SSR ratios. The error bars indicate the range in demand given the lower and higher projections for population growth (32 million- 36 million people in 2030; (UNDP 2008) and dietary intake (2050-2980 Kcal/cap/day in 2030; (FAO 2003) (van der Hilst et al. 2012)

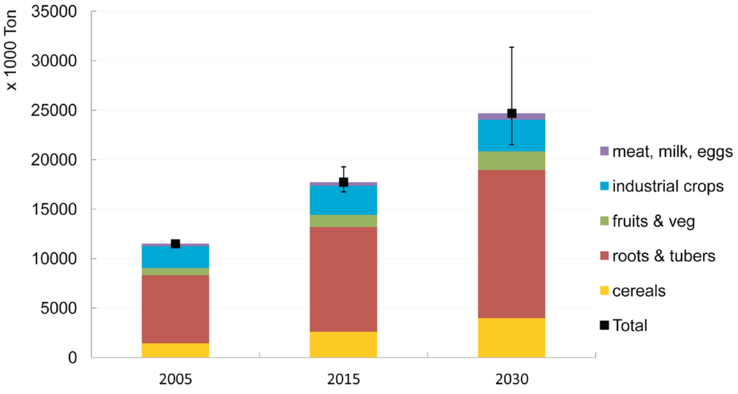


Figure A2.4: Development in crop and livestock productivity in the BAU and Progressive scenarios in the time frame 2005-2030, normalised for the productivity levels of 2005 (2005=1). The bandwidths represent the range of the uniform distribution of the stochastic input of yield developments for the BAU and Progressive scenarios.

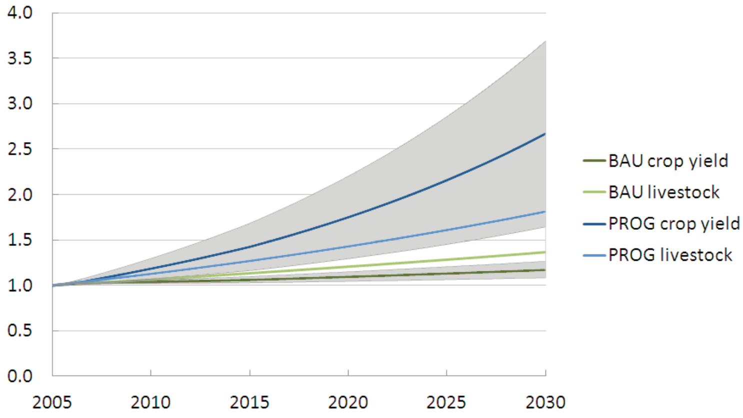
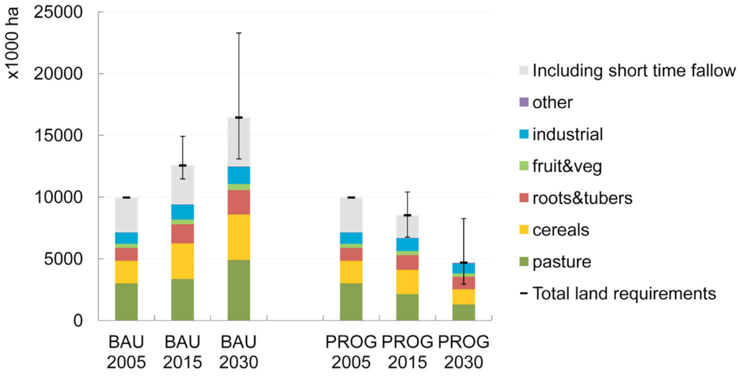


Figure A2.5: Land requirements for livestock grazing and crop production for the timeframe 2005-2030 for the BAU (left) and Progressive (right) scenarios, given the same distribution over productivity classes of pasture and arable land as in 2005. The error bars represent the range in total land requirement given the uncertainties in total demand (Figure A2.3) and productivity (Figure A2.4).



scenario (right), both pastures and arable land areas decline due to increased yield levels of pasture and crops, and a higher efficiency in livestock production. The upper sections of the bars (grey shade) indicate the additional land required due to low cropping intensities, i.e. it accounts for the land that is left fallow for a short time. The error bars indicate the uncertainty in the total land requirements given the uncertainty in the development in demand (see Figure A2.3) and the uncertainty in crop productivity in both scenarios (see Figure A2.4) The positive error value is bigger than the negative error value as a consequence of the uncertainty distribution of demand (see Figure A2.3), which is also skewed. By 2030, the land requirements in the BAU scenario are 3.3-3.7 times higher than in the Progressive scenario.

Figure A2.6 displays the development in available land for bioenergy crop production until 2030 according to the run of the LUC model for the two scenarios. For the BAU scenario, land availability decreases over time from 9.1 Mha to 7.7 Mha. For the Progressive scenario, the land availability for bioenergy crop production increases from 9.1 to 16.4 Mha.

A2.2.1.2 Biomass potentials

Based on the time and spatially explicit calculations, dynamic cost supply curves can be constructed for torrefied pellets and sugarcane ethanol supply chains (see Figure A2.7). The cost supply curves rank the potential supply according to the total cost of the supply chain which includes feedstock production, primary transport, pre-treatment/conversion, secondary transport, storage and international shipping. The solid lines represent the cost supply curves for the BAU scenario for 2010, 2020 and 2030. The dashed lines represent the cost supply curves for the progressive scenario. The supply curves of both bioenergy chains show that in both scenarios, the costs decrease over time. However, the low-cost production potential is much higher in the progressive scenario compared to the BAU scenario. For eucalyptus pellets the total potential is quite large (3200 PJ in 2030 in the progressive scenario), especially compared to the potential of sugarcane ethanol (866 PJ in 2030 in the progressive scenario). This is due to two main reasons:

Figure A2.6: The development of land availability for bioenergy crop production over time for the BAU (lower trend line) and Progressive scenarios (upper trend line).

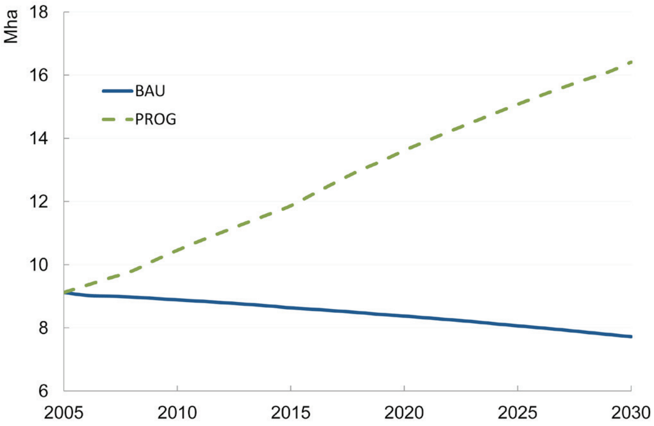


Table A2.2: Land characteristics of Gaza-Inhambane region for the Busines as Usual and the Progressive scenario

Nampula		**BAU**			**PROGRESSIVE**		
	Unit	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Land availability [1]	Km^2	1019	837	666	1259	3146	4846
Average suitability [2]	% of max	63%	63%	64%	63%	62%	62%
Max Yield Eucalyptus [3]	odt/ha	22.6	26.3	30.5	22.6	26.3	30.5
Max Yield Switchgrass [4]	odt/(van Dam *et al.* 2009b) ha	17.0	19.7	22.9	17.0	19.7	22.9
Land that becomes available [5]	% grassland	0%	0%	0%	0%	0%	0%
	% shrubland	100%	100%	100%	80%	30%	19%
	% pasture	-	-	-	0%	0%	0%
	% cropland-pasture	-	-	-	18%	67%	79%
	% cropland-grassland	-	-	-	2%	0%	0%
	% cropland	-	-	-	0%	3%	2%
Land requirements to meet input Eucalyptus [6]	~ % of available land	153.6%	161.1%	175.1%	123.5%	43.2%	24.3%
Land requirements to meet input Switchgrass [6]	~ % available land	213.4%	223.9%	243.3%	171.6%	60.0%	33.8%

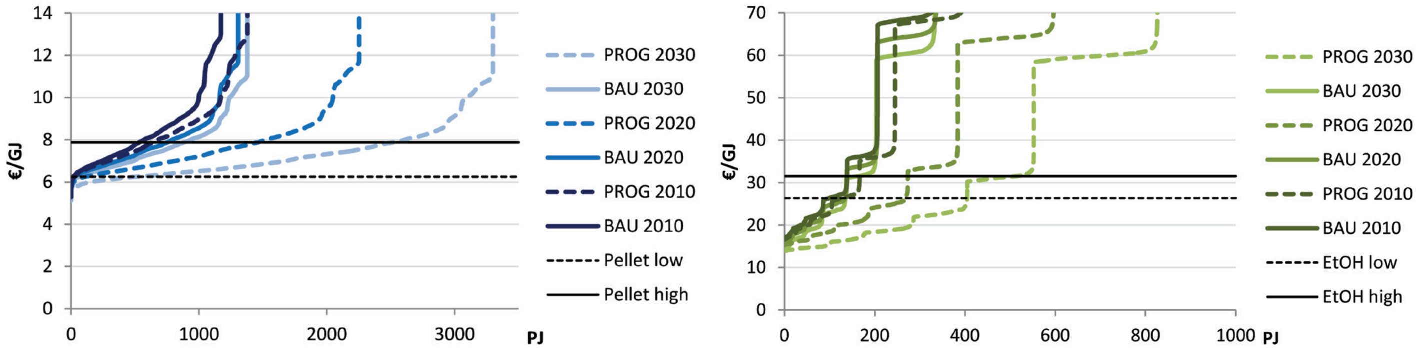
[1] Based on the deterministic runs of land use change model PLUC for Mozambique 2005-2030. (Van der Hilst, Verstegen et al. 2011). The borders of the selected regions are harmonized with administrative borders of localidades.
[2] The average suitability is the average suitability for the land that is available. Derived from the study of van der Hilst and Faaij (2012)
[3] The maximum yield of Eucalyptus is derived from van der Hilst and Faaij (2012).
[4] As there is no practical experience with switchgrass in Mozambique, yields are hard to estimate. The yield levels are based on study of van Dam et al (van Dam, Faaij et al. 2009) and consistently linked to the expected yield levels of eucalyptus.
[5] Percentage of the total available land in the region at a certain time which was previously in use as grassland, shrubland, pasture or mosaic cropland-pasture.
[6] The percentage of the total available land in the region at that time that is required to meet the assumed input requirements of the conversion facilities, given the development in land availability, the development in max yield of bioenergy crops, and the development in average suitability of the total land availability.

Table A2.3: Land characteristics of Nampula region for Business as Usual and Progressive scenario

Gaza-Inhambane		**BAU**			**PROGRESSIVE**		
	Unit	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Land availability [1]	Km^2	8643	8323	7890	10887	16129	19791
Average suitability [2]	% of max	0.32	0.31	0.31	0.32	0.34	0.36
Max Yield Eucalyptus [3]	odt/ha	22.6	26.3	30.5	22.6	26.3	30.5
Max Yield Switchgrass [4]	odt/ha	17.0	19.7	22.9	17.0	19.7	22.9
Land that becomes available [5]	% grassland	7%	6%	6%	5%	4%	3%
	% shrubland	93%	94%	94%	74%	50%	41%
	% pasture	-	-	-	3%	4%	4%
	% cropland-pasture	-	-	-	18%	42%	52%
Land requirements to meet input Eucalyptus [6]	~ % available land	36.1 %	32.6 %	30.2%	28.6 %	15.4 %	10.3 %
Land requirements to meet input Switchgrass [6]	~ % available land	50.2%	45.3%	41.9%	39.7%	21.4%	14.3%

[1] Based on the deterministic runs of land use change model PLUC for Mozambique 2005-2030. (Van der Hilst, Verstegen et al. 2011). The borders of the selected regions are harmonized with administrative borders of localidades.
[2] The average suitability is the average suitability for the land that is available. Derived from the study of van der Hilst and Faaij (2012)
[3] The maximum yield of Eucalyptus is derived from van der Hilst and Faaij (2012)
[4] As there is no practical experience with switchgrass in Mozambique, yields are hard to estimate. The yield levels are based on study of van Dam et al (van Dam, Faaij et al. 2009) and consistently linked to the expected yield levels of eucalyptus.
[5] Percentage of the total available land in the region at a certain time which was previously in use as grassland, shrubland, pasture or mosaic cropland-pasture.
[6] The percentage of the total available land in the region at that time that is required to meet the assumed input requirements of the conversion facilities, given the development in land availability, the development in max yield of bioenergy crops, and the development in average suitability of the total land availability.

Figure A2.7: Cost supply curves of (torrefied) pellets (left) and sugarcane ethanol (right) for 2010, 2020 and 2030 in the Business As Usual and the Progressive scenario. The cost supply curve is a ranking of the supply potential according to the total supply costs.



First, sugarcane is already converted to ethanol in which energy is lost, whereas pellets are still about to be converted to power and heat. And second, much more land is suitable for eucalyptus cultivation than for sugarcane cultivation.

A2.2.1.3 Regional land availability for selected settings

In Table A2.2 and Table A2.3 the land availability and suitability for energy crops is depicted for the Gaza-Inhambane and the Nampula region for the BAU and the progressive scenario.

A2.2.2 Argentina

A2.2.2.1 Developments in demand, productivity and land requirements

The demand for food crops tends to grow in both scenarios, not only due to population growth and increasing exports but also as a result of the increase on the demand for animal products, and consequently on the demand for feed (see Figure A2.8) . The demand for food crops is slightly higher in the progressive scenario, due to higher demand for feed from food crops resulting from the shift of livestock production from pastoral to intensive landless systems and underlying changes in feed composition.

In BAU scenario, the overall feed demand tends to increase in time, following the increase on the demand for animal products. In progressive scenario, the overall feed demand is lower than in the BAU scenario, due to an increase on the feed conversion efficiency. Moreover, while in BAU scenario feed demand for grass increases due to the increase of demand for animal products, in the PS scenario it tends to decrease, following the change in feed composition.

Figure A2.9 shows the projected development in crop and livestock productivity compared to the levels of 2010. In the BAU scenario, the developments are in line with historical trends. In the progressive scenario, there is a steep increase in the productivity. Although the increase in livestock productivity seems modest, the implications of the productivity increase for land requirements for the livestock sector are large as the productivity increase corresponds to a shift towards more landless systems.

A2.2.2.2 Biomass potentials

According to the dynamic simulation of future land-use following BAU scenario assumptions, no surplus land is expected to become available for biofuel production by 2030 and therefore, there is no potential for biofuel produced from switchgrass in this scenario. Biodiesel production is nevertheless expected from the existing soy complex for feed production, through conversion of oil resulting as a by-product of soy meal production that is not required to fulfil the expected demand for soy oil. Hence, taking into account the expected demand for soybean exports, soy meal and soy oil, the technical and economic potential for soybean-based biodiesel by 2030 is 81PJ. According to PS scenario, an increase on the demand for soy (8.5*10^6 odt) is expected in this scenario, due to the increase of soy meal in the feed composition for livestock production, which could provide an additional potential of 60PJ, thus leading to a potential of 141 PJ as a by-product of feed production. In addition, 32 Mha of surplus land could become available for dedicated soybean cultivation (44*10^6 odt) leading to potential production of 309 PJ and thus leading to a technical potential of 450PJ soy-based biodiesel.

However, soybean cultivation appeared to be economically competitive only in a portion of the available surplus land. Taking into account the local specific yields and the share of soy in each production system, a soybean production of 34*10^6 odt could be attained on the surplus land, which after dedicated conversion to biodiesel could lead to a potential of 205PJ. Taking into account the existing soy complex for feed production, a total economic potential of 346PJ soybean biodiesel could be attained by 2030.

Although no land is available for switchgrass in BAU scenario, a production volume of 170*10^6 odt could be attained in the available surplus land in progressive scenario, leading to a technical potential of 1.4 EJ switchgrass-based ethanol production. The economic assessment on the surplus land also showed that switchgrass could become an attractive crop in a large portion of the available surplus land. Considering the local specific yields, an economic potential of 1.1 EJ bioethanol could be expected by 2030, through the conversion of 124*10^6 odt switchgrass.

Figure A2.8: Projected development in demand for foodcrops in Argentina in the timeframe 2010-2030 for the Business as Usual scenario.

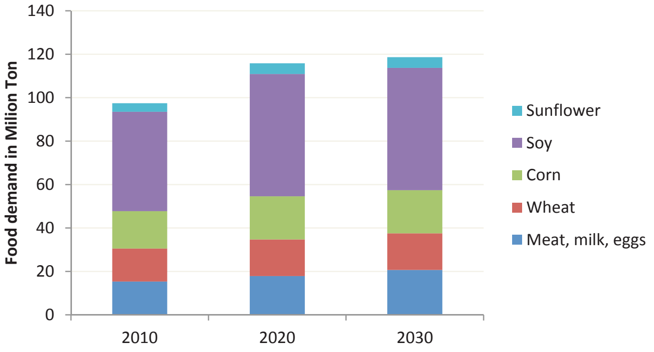


Figure A2.9: Projected development in crop yields and livestock efficiency in Argentina towards 2030 relative to the levels of 2010 for the Business as Usual and the Progressive scenario.

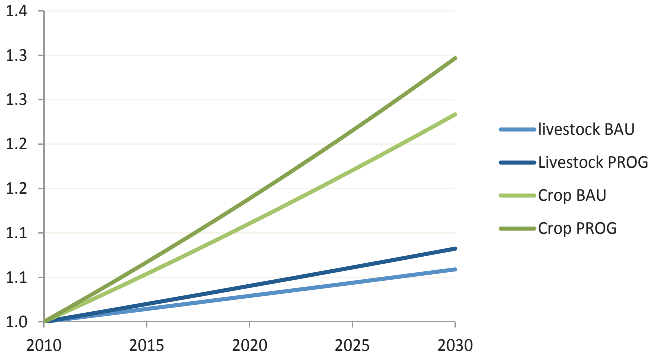


Figure A2.10: Cost-supply curve of soy (left) and switchgrass (right) in Argentina in 2030.

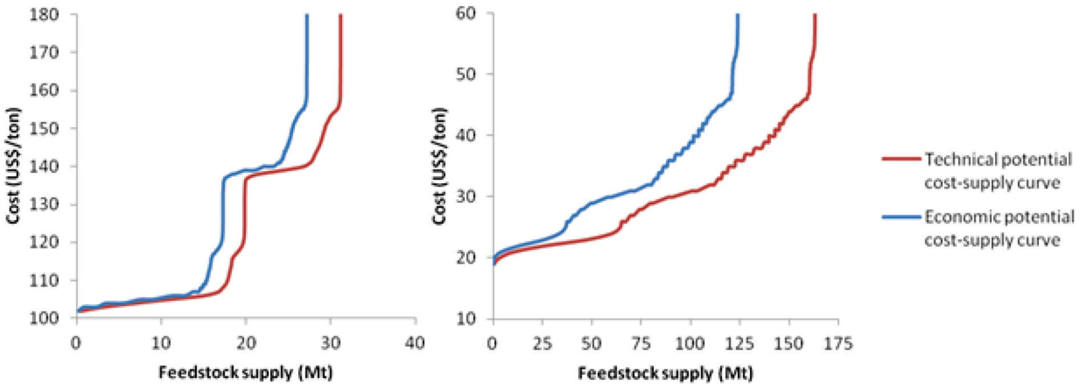


Figure A2.10 compares the cost of feedstock supply between the technical and the economic potential for soy and switchgrass cultivation on the surplus land. It can be seen that most part of soy economic and theoretical potential could be obtained at a feedstock production cost between 100 and 155 US/ton, while for switchgrass feedstock production costs range between 20 and 45 US$/ton. Switchgrass production costs per unit of mass are much lower than for soy due to higher attainable yields, less input and field operation requirements and high suitability in locations with low land rental prices. More information is found in (Diogo *et al.* Forthcoming).

A2.2.3 Ukraine

A2.2.3.1 Developments in demand, productivity and land requirements

In Figure A2.11 the developments in production of food and feed in million ton dry weight is depicted up to 2030 for the BAU and progressive scenario. Although it is assumed that the increase in consumption is the same in the BAU and in the progressive scenario, the demand for feed is lower in the progressive scenario as the livestock sector becomes more efficient. Therefore, less feed input is required for the same meat and milk output in the progressive scenario. In addition, in the progressive scenario a shift towards more feed crop consumption at the expense of grass consumption is assumed. Therefore, the total crop demand is higher and the total grass demand is lower in the progressive scenario compared to the BAU scenario. However, differences between the two scenarios in terms of total production are limited.

In Figure A2.12, the developments in crop and pasture yields and the efficiency in the livestock sector are presented for the two scenarios compared to the levels of 2010. It is clear that the productivity increase is close to zero in the BAU scenario, whereas in the progressive scenario the productivity increases rapidly; especially the crop and pasture yields.

Figure A2.13 presents the total land requirements for crop production and grazing given the demand depicted in Figure A2.11 and the productivity presented in Figure A2.12 and assuming an average agro-ecological suitability of cropland and pasture equal to the average suitability of the cropland and pasture currently in use. The currently low cropping

Figure A2.11: Development in demand for domestic produced food and feed in the Business as Usual and Progressive scenario in million ton dry weight product.

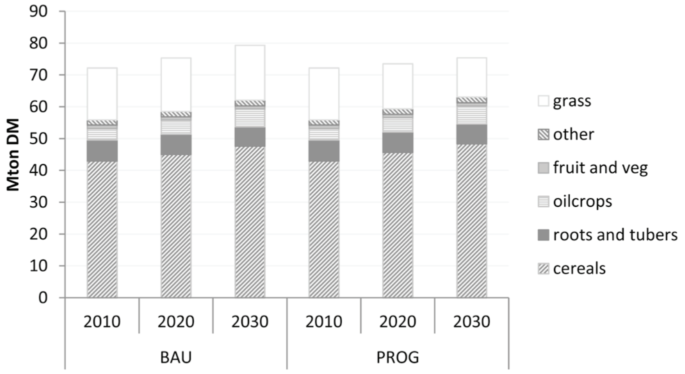


Figure A2.12: Developments in crop and pasture yield and livestock productivity for Business as Usual and Progressive scenario compared to 2010 levels (2010= 1).

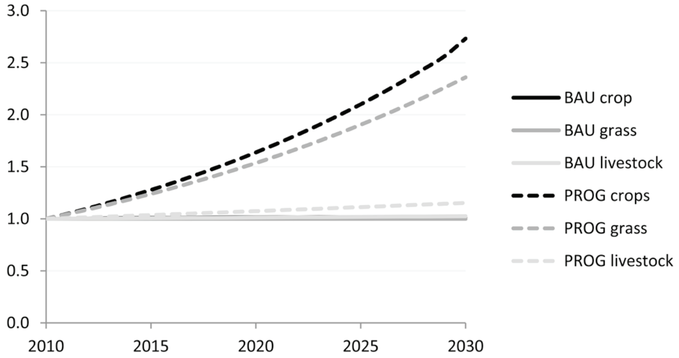


Figure A2.13: Developments in land requirements for crop production and grazing for BAU and progressive scenario based on the food and feed requirements, the yield and efficiency development of the two scenarios and assuming the current average agro-ecological suitability of arable land and pastures.

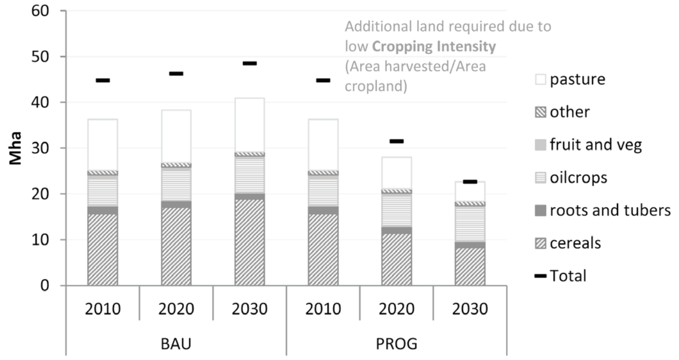
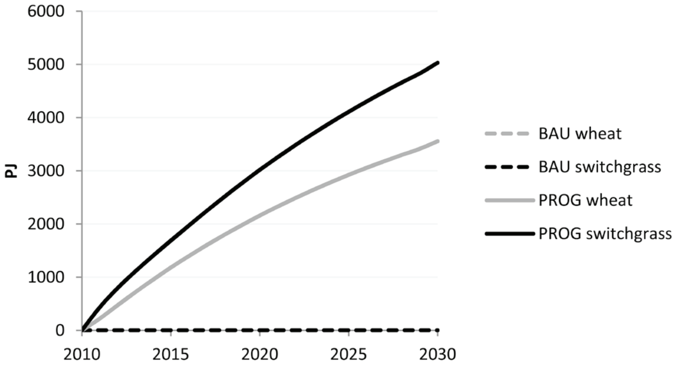


Figure A2.14: Development in annual biomass production (whole crop for switchgrass and grain only for wheat) for the Business as Usual and Progressive scenario in PJ/yr.



intensity indicates that considerable land areas of cropland and pasture are left fallow. In the progressive scenario, land is used more efficiently and no land is left fallow by 2030. Because of the higher yields and the higher cropping intensity, only half of the land currently in use for agricultural production is required to meet the demand in 2030. However, the actual land area depends on the location-specific productivity of the land (the agro-ecological suitability) and therefore of the location of production. For that reason, developments in actual land requirements and land availability for other land use functions can only be assessed using a spatiotemporal LUC model.

A2.2.3.2 Biomass potential

Figure A2.14 shows the development in potential annual biomass feedstock production of switchgrass (whole plant) and wheat (grain only) for the period up to 2030. Although the assumed conversion efficiency from wheat to ethanol is higher than from switchgrass to ethanol, the potential ethanol yield per hectare is higher for switchgrass due to the higher biomass yields (a maximum yield of 170 GJ/ha/yr for switchgrass and 100 GJ/ha/yr for wheat). In the progressive scenario, up to 5.0 EJ biomass could be produced on the available land (2030) compared to the potential wheat production 3.6 EJ (grain). As in the BAU scenario little land becomes available, potential annual production is low compared to the progressive scenario (±2 PJ for wheat and switchgrass in 2030).

A3. Annex 3: Environmental and socio-economic impacts indicators

A3.1 Description of Sustainability criteria

A3.1.1 Environmental criteria

A3.1.1.1 Greenhouse gas emissions

One of the main drivers of the development of bioenergy is the reduction of GHG emissions. Therefore, criteria related to GHG emissions and the conservation of carbon stocks are included in the criteria of all certification schemes. In most certification schemes, the GHG emission is reduction is ensured in multiple ways: the overall GHG reduction requirements of bioenergy (including all emissions during lifecycle and LUC) should meet a certain level, and land with high carbon stock (vegetation / soil) is excluded for the use for biomass production for bioenergy. A lifecycle assessment of the GHG emission during the entire supply chain requires detailed data on the pre-processing and the conversion of the biomass. This study focuses is on the impacts of the cultivation phase of biomass feedstock production. Therefore, the emissions related to the cultivation including the LUC will be assessed. Large carbons stocks such as forest and mangroves were already excluded for bioenergy production in the modelling of the land availability. In this study, the changes in carbon stocks (including soil, above ground biomass, below ground biomass, dead wood and litter) and the GHG emissions related to the cultivation of the energy crops are quantified.

A3.1.1.2 Biodiversity

In most of the developed sustainability criteria for bioenergy, impacts on biodiversity have been identified as an important area of concern. LUC is a strong driver of changes in biodiversity (Sala *et al.* 2000; UNEP 2002; Foley *et al.* 2005; Reidsma *et al.* 2006). Because of the loss, modification and fragmentation of habitats, the (indirect) expansion of agricultural land for energy crop production is perceived to be a major threat for biodiversity (Sala *et al.* 2009). Biodiversity is also affected by LUC related depletion, degradation and pollution of ecosystems and invasive species (Foley *et al.* 2005; Groom *et al.* 2008). Changes in habitats due to energy crop production are most significant when natural areas are converted to (intensive) agriculture areas (Schlegel *et al.* 2007). Most bioenergy sustainability criteria deal with this issue by proposing process indicators, e.g. by referring to national regulations and by excluding protected areas and land identified as area with high biodiversity from bioenergy production. Some certification schemes request maintenance or an enhancement of the biodiversity value or a minimization of negative effects.

In this study, natural reserves and protected areas are already excluded for LUC. In the assessment of land availability for bioenergy, natural reserves and protected areas have been excluded for LUC. In addition, forest areas and mangroves have been excluded for bioenergy production. However, both the natural areas and the semi-natural/agricultural areas outside the protected areas could have significant biodiversity value. Therefore, the risk of biodiversity loss when these areas are converted to energy crop plantations could be significant. For this, these areas should be identified. In addition, even outside the protected areas and the high nature conservation areas, biodiversity could be significant. Also, in some areas the biodiversity is very low due to unsustainable agronomy practices such as soil nutrient depletion and slash and burn. In these areas, biodiversity could be enhanced through the introduction of well managed energy crop production. In order to show if the biodiversity is reduced, maintained or enhanced, the biodiversity value of the current and future situation needs to be determined.

A3.1.1.3 Soil

In the sustainability criteria the preservation of the soil is an important area of concern. The criteria in the certification schemes refer to the preservation of the soil quantity and soil quality. Preservation of the soil (quantity) implies that erosion by means of water runoff and sol loss trough wind erosion should be prevented. The main on-site problem caused by erosion is desertification, the loss of fertile top soil which leads to land degradation of arable soils, and crop damage caused by abrasion or burial of seedlings or plants and the exposure and loss of seed. In addition, the transport of minerals, organic matter, residues and pesticides could cause sedimentation and contamination of surrounding surface water. Furthermore, airborne particles due to wind erosion could affect human and animal health, machinery and infrastructure. The main factors determining the actual erosion risk, are the soil characteristics (especially soil moisture and soil structure), vegetation (soil cover) and slope (in case of water erosion). It is therefore important to assess the effect of LUC or farm management on these factors in regions with high erodible soils and periods with high erosive rainfall or wind.

The soil quality is a broad and wide-ranging concept. Soil organic carbon (SOC) is in addition to carbon accumulation, associated with other important functions of the soil like water holding capacity, nutrient retention and soil structure (Kuikman *et al.* 2003; Rowe *et al.* 2009). SOC is therefore considered to be the most prominent indicator for soil quality (Reeves 1997). SOC is also one of the main issues mentioned in sustainability criteria concerning soil quality. The change in soil organic carbon content due to land use and management changes when current land use is converted to energy crop production are also assessed in order to calculate the impacts on GHG emissions. These calculations on SOC changes can also be used to provide a proxy for the soil quality. The change in the risk on soil erosion related to land use, crop, and management change can be quantified.

A3.1.1.4 Water

Water use and water quality are often addressed in proposed sustainability criteria for bioenergy. The majority of the total water consumption during biofuel production is used during the cultivation stage (>90%)(Berndes 2002; Dornburg *et al.* 2008; de Fraiture and Berndes 2009; Gerbens-Leenes *et al.* 2009). The change from current land use to energy crops may change the water balance of an area due to changes in evapotranspiration, runoff and percolation (Smeets *et al.* 2009b). The amount of water lost through evapotranspiration depends on crop type, growth stage, climate, soil characteristics growing period and agronomic practice and irrigation (Brouwer and Heibloem 1986; Berndes 2002; Bessembinder *et al.* 2005; Dornburg *et al.* 2008). Preferably, the impact of energy crops on fresh water availability for other functions is assessed on a water basin level (Dornburg *et al.* 2008). This approach however, requires detailed knowledge and data about the hydrologic flows within a specific water basin. This type of information is generally lacking in Mozambique. Therefore simpler methods need to be applied to provide a first order assessment of the impacts on water. Straightforward water balances and water use efficiencies can provide an indication of the direction and order of magnitude of the change in water use. In combination with an indication of the susceptibility of the region for changes in the water balance could give a first order impression of the effects of large scale biomass production on water availability in these regions.

A3.1.2 Socio-economic criteria

A3.1.2.1 Legality

Several sustainability schemes refer to good agricultural practices and compliance with national laws and regulations. Generally these are references to compliance with national legislation regarding land acquisition, agricultural practices, environment, human rights and labour conditions and require reporting and auditing on these themes. In some sustainability criteria legality is a separate criterion in which compliance with all kinds of laws, legislation and procedures is addressed; in others sustainability schemes, the compliance with laws and regulations are addressed in every individual environmental and socio-economic criteria.

The general criteria referring to compliance with laws and regulations are not quantifiable. It is assumed that is part of good practice that the biomass producer complies with all applicable laws an regulation. The entrepreneur should make sure it is fully aware of the (inter-)national legislation and regulations regarding land acquisition, agricultural practices, environment, and labour conditions, should act to that and should be able to provide evidence of compliance. For this ex ante assessment, an overview is provided of the most important laws and regulations to which the biomass producer should comply.

A3.1.2.2 Food security

The impact of bioenergy production on food security has been heavily debated in the last few years. The World Food Summit (1986) defined food security as follows: "*Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" (FAO, 2003). The four internationally-agreed dimensions of food security are: availability, access, stability and utilization (GBEP 2011). These dimension where also used by the impact assessment of small and large scale bioenergy systems in east Africa by van Eijck et al. (2013). These dimensions are related to: land use; land access; household income; access to energy; nutrition; and food supply and prices (GBEP 2011). These factors could both positively and negatively be affected by the implementation of bioenergy production. Investing in and improving agricultural systems could lead to increased production of food, feed, and fibre. Moreover, modern bioenergy developments can lead to an increase in household income, especially in rural areas, by stimulating both employment creation and rural development. At the same time, bioenergy can create increased demand for certain agricultural commodities and competes with food production for resources and inputs (such as land, water, fertilizers and labour) which is likely to result in increased food prices. These aspects will be assessed and putted in context with the current food security conditions in the regions described by socio-economic background indicators.

A3.1.2.3 Economic viability

The economic viability of a bioenergy project is of high importance of its sustainability. Economically viable means that the project should be able to sustain operation on the basis of current and projected revenues equal to or in excess of current and planned expenditures. Project failure due to financial problems to could have detrimental socio-economic effects for the region as many households and therefore large amounts of people depend on the incomes and expenditures of the project. The economic viability can be assessed accounting for all the cash flows during the lifecycle of the project and accounting for the time value of money in order to appraise long-term projects. This can be done by calculating the Net Present Value (NPV) in which all the cost and benefits during the lifetime of the project are discounted to the present value taking into account the discount rate accounting for the interest rate and opportunity costs. This assessment requires assumptions on the market and market developments of the inputs required for the project and the end products sold to the market, and on the time and magnitude of all cash flows of the project. A negative NPV indicates that the revenues cannot cover the costs of the project. This means that the project is not economically viable.

A3.1.2.4 Local prosperity

Most certification schemes that included socio-economic criteria refer to the importance of the contribution of the bioenergy project to the economic development of the local and rural communities. This is especially important in less developed countries and regions. The bioenergy production project could contribution to the local prosperity in multiple ways such as providing employment and increasing expenditures in the region, attract new activities and generate spin-offs.

The effect of the new economic activity of biomass production on the local or national economy could be computed using an input-output (I/O) model. I/O analysis studies the relationships within and between economic sectors of a country and can be used to determine the impacts of an economic activity on the whole economy in terms of GDP, employment, and imports. I/O modeling enables to include not only direct but also indirect and induced impacts. The direct impacts are those impacts caused by bioenergy production directly (e.g. employment on a bioenergy plantation); indirect impacts are those of the secondary economic activities needed to make bioenergy production possible (e.g. employment in producing machinery required on the plantation) and induced impacts are those caused by the re-spending of the income and profits earned from the direct and indirect activities (e.g. employment caused by additional spending from plantation workers)(Wicke, Smeets et al. 2009). This type of analysis has been frequently successfully applied in studies on macro-economic impacts of bioenergy production on a national level (Wicke, Smeets et al. 2009, van den Broek, van den Burg et al. 2000, Faaij, Meuleman et al. 1998).

However, in this study the economic impact of one single project is assessed. It is likely that the contribution of one single project to the national economy is relatively insignificant. However, at a regional level the impact of a single project could be substantial. For that reason, a regional oriented input-output model would be a required to assess the impact of the project on the local prosperity. Regional input-output analysis has previously been applied for the assessment or regional impacts of bioenergy production (Herreras Martinez, et al. 2012). However, for this regional assessment detailed information on the regional economy such as a regional Social Accounting Matrix (SAM) is required. For Mozambique this SAM is only available on a national level and is relatively outdated (2008). For that reason, a simple approach to obtain the first order direct macro-economic effects in terms of project investments, regional investment, employment, and salaries will be applied and will be evaluated in the context of macro-economic background indicators (such as total population, unemployment rate, regional economic activity, poverty) of the selected regions.

A3.1.2.5 Social well-being

In many certifications schemes, social issues are addressed in addition to the labour conditions and to the contribution to the local prosperity. However, the descriptions of these criteria vary widely between the schemes and the indicators generally remain fairly indistinct. The main topics addressed are land tenure procedures; provision of sanitarily and energy services, contribute to institutional and physical infrastructure, and compliance with cultural and societal practices. The social impacts depend on the policy, management and practices of the project that is to be established and can therefore not be assessed beforehand. However, as it is assumed that sustainability criteria are to be met, it is assumed that compliance with national laws en regulations and social responsibility is part of good practice. Therefore, minimum requirements and recommendations for best practices are provided. In addition, the impact of a project on the local social well-being largely depends on the current social situation. Therefore, background indicators on themes such as land use, health care, education, housing, infrastructure, and access to energy services are of main importance to estimate and interpreted the impact of a biomass project on the social well-being in the region.

A3.1.2.6 Labour conditions

Labour conditions are one of the socio-economic impacts included in many of the certification schemes. The issues most often addressed in these criteria refer to working conditions, health and safety, working hours, contracts, wages, child labour, forced labour, capacity building and training, freedom of association and sometime equality and gender issues. In addition, the sustainability criteria often refer to national legislation and regulation related to labour rights and to international labour rights standards ILO.
The labour conditions depend on the policy, management and practices of the project that is to be established and can therefore not be assessed beforehand. However, as it is assumed that sustainability criteria are to be met, it is assumed that compliance with labour rights and international labour standards are part of good practice. For this ex ante assessment, an overview is provided of the most important laws and regulations to which the biomass producer should comply and recommendations are provided for good practices.

A3.2 Detailed Method

A3.2.1 Environmental impacts

A3.2.1.1 GHG emissions

GHG emissions from biofuel / bioenergy production and use can be differentiated in emissions related to land use and cultivation and emissions during the life cycle. This assessment is limited to the assessment of the GHG emissions during the feedstock cultivation including the emissions related to LUC. The GHG emission included in this study are CO_2 N_2O and CH_4.

A3.2.1.1.1 Life cycle assessment biomass production

GHG emitted during the cultivation of energy crops are related to diesel for agricultural machinery, seed, pesticide and fertilizer production. The emissions related to fertilizer application are included in the LUC related emission as they are strongly related to variations in biophysical conditions. The GHG emissions related to the production of biomass feedstock were calculated using a LCA approach. The LCA is performed according to the ISO 14040-14049 guidelines and in line with the steps described by the Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy from GBEP (2010). There are several ways to calculate the GHG emission over the lifecycle differentiating in complexity and accuracy. The LCA can be performed:

- By making use of the default values provided by e.g JRC (JRC 2009) for different supply chains; or by spreadsheet calculations using GHG emission factors;
- by making use of the IFEU Biofuel GHG calculator developed o.a. for this project including specific supply chains (Franke *et al.* 2012);
- by using LCA software such as Simapro including several databases (such as ecoinvent) on country and product specific emission factors.

The JRC database or other generic databases provide only very generic data for biofuel supply chains and does not discriminate between different settings. Therefore, this database provides valuable information on the order of magnitude of GHG emissions for different supply chains and for the fossil counterparts, but provides too little information for the specific setting. In addition, for most of the selected case study countries there is no country specific data available in the databases of the LCA software and there is little information about the origin of several inputs of the process as they are often not produced domestically (such as fertilizers). For that reason, there was little added value for using LCA software and related databases. Moreover, the GHG emissions related to the lifecycle are relatively limited compared to the emissions related to the LUCs. The IFEU Biofuel GHG calculator provides specific data for all different supply chains in different settings. Therefore, this tool will be used to provide an overview of the GHG emissions over the lifecycle. However, although it differentiates between different settings, the GHG emission will be quite different for the same setting but in different locations because of the differences in biophysical conditions. For that reason, we will demonstrate the impacts of these differences in locations on the GHG emission for a specific setting making use of spreadsheet calculations taking into account the site specific conditions.

A3.2.1.1.2 LUC related GHG emissions

GHG emissions due to LUC are caused by changes in soil carbon stocks, above and below ground biomass and residues. In addition, LUC causes changes in N_2O emissions due to changes in fertilizer and manure application and drainage of organic soils. The livestock related emissions are not incorporated in this study. The IPCC guidelines are used to calculate the GHG emissions due to LUC (IPCC 2006).

The net greenhouse gas balance is calculated per grid cell taking into account CO_2 emissions from carbon stock changes and N_2O emissions. Equation 5 depicts the total GHG emissions in CO_2-equivaents.

Equation 5

$$GHG = \left(\Delta C \cdot -\frac{44}{12} \cdot GWP_{CO2}\right) + \left(N \cdot \frac{44}{28} \cdot GWP_{N2O}\right)$$

GHG	Net Green house gas emissions	Kg CO_2-eq/ha/yr
ΔC	Change in carbon stock	Kg/ha/yr
GWP_{CO2}	Global warming potential CO_2	factor
N_{N2o}	N emitted in the form of N_2O	Kg/ha/yr
GWP_{N2O}	Global warming potential N_2O	factor

The global warming potentials (GWPs) are derived from (IPCC 2007) and assume a time horizon of 100 year.

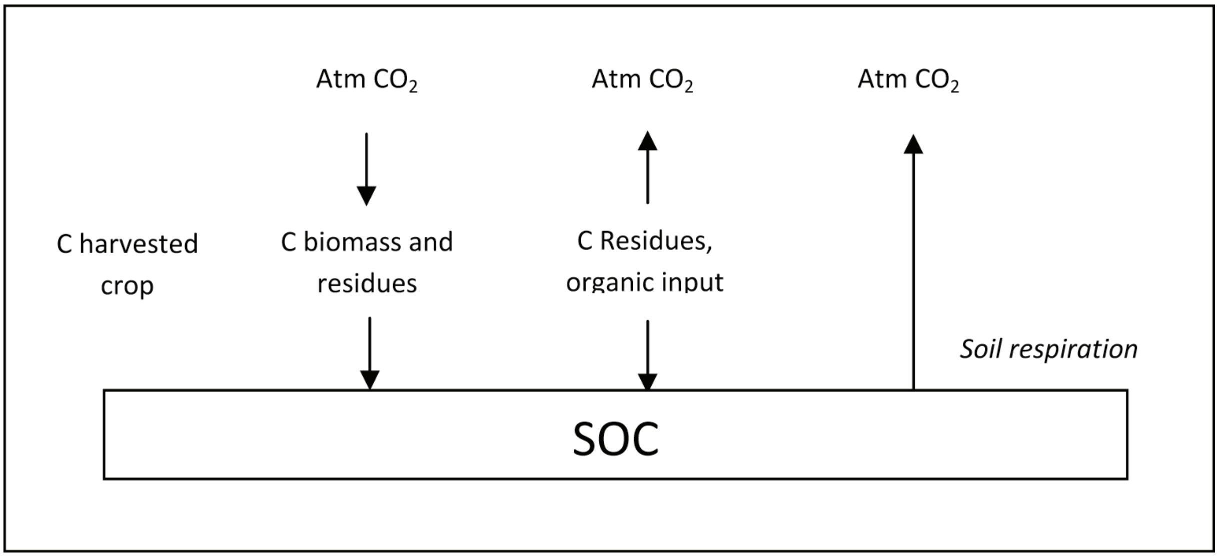
A3.2.1.1.3 CChanges in carbon stock

When land is converted from one land use to another or when land use management changes, carbon can accumulate (carbon sequestration) or diminish (carbon emissions). In this study, the IPCC approach (IPCC 2006) to calculate CO_2emisisons related to changes in carbon stocks is applied which involves five carbon pools: above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter.

Soil organic carbon

The organic carbon content of soils is related to the soil type, climate, land use and applied agricultural management and is therefore spatially highly heterogeneous. Land use and management changes affect the soil organic carbon content: e.g. a permanent vegetation cover reduces respiration of the soil and therefore the oxidation of soil organic carbon, whereas intensive tillage and drainage increases the loss of soil organic carbon. The application of organic inputs such as manure and crop residues could increase soil organic carbon (SOC). Figure A3.1 depicts the relations between the soil organic carbon content and other carbon pools.

Figure A3.1: Schematic overview of carbon exchange between atmosphere, biomass and soil.



The annual change in SOC is calculated according to Equation 6:

Equation 6

$$\Delta C_{SOC} = \left(\frac{SOC_t - SOC_{t-1}}{D}\right)_{Mineral} + \Delta C_{Organic}$$

ΔC_{SOC}	Annual change in SOC	Ton C/ha/year
SOC_t	SOC at time step t	Ton C/ha
SOC_{t-1}	SOC at previous time step	Ton C/ha
D	Time required for equilibrium	Years
$\Delta C_{organic}$	Annual flux of C in organic soil	Ton C/ ha/year

The change in carbon in *organic* soils is a fixed annual carbon flux (in ton/ha/yr) depending on the land use and climate region. The SOC in *mineral* soils is calculated given the soil type, climate, land use and management based on default values of the IPCC (2006). The attribution of the climate regions is based on the IPCC climate classification related to average annual precipitation and temperature (IPCC 2006).

The new and the reference land use are specific for the setting (region, scenario, energy crop). The management level of the agricultural land use including the tillage regime and the organic carbon application levels are scenario specific. The land use, management and organic input factors affecting the SOC content. Some studies indicate that it could take up to 50-100 years to reach a new SOC equilibrium (Kuikman et al. 2005). However, in this study a time horizon of 20 years is assumed in line with the IPCC (2006), and as proposed by the EC (2008) and NTA 8080 (NEN 2009).

Biomass carbon

The carbon stocks in *above and below ground biomass* depend on the land use, the productivity of the land and the management applied. The change in carbon stocks when one land use is converted to anther can be calculated according to the IPCC method. See Equation 7 and Equation 8.

Equation 7

$$\Delta C_B = \Delta C_G + \Delta C_{Conversion} + \Delta C_L$$

Equation 8

$$C_{Conversion} = \sum_i \left(B_{After_i} - B_{Before_i}\right)\cdot CF$$

ΔC_B	Annual change in biomass carbon stocks on land converted to another land use category	TC yr^{-1}
ΔC_G	Annual increase in biomass carbon stocks due to growth on land converted to another land use category	TC yr^{-1}
$\Delta C_{Conversion}$	Initial change in biomass carbon stocks on land converted to another land category	TC yr^{-1}
ΔC_L	Annual decrease in biomass carbon stocks due to losses	TC yr^{-1}
B_{After}	Biomass stocks on land type *i* immediately after the conversion	Tdm ha^{-1}
B_{Before}	Biomass stocks on land type *i* before the conversion	Tdm ha^{-1}
CF	Carbon Fraction of dry matter	T C Tdm^{-1}
i	Type of land use converted to another land use category	

For annual crops, the increase in biomass stocks in a single year is assumed to be equal to biomass losses due to harvest and degeneration in that same year: there is no net accumulation of biomass carbon stocks in annual arable crops (IPCC 2006). For natural vegetation such as forest, shrubland and natural grassland and for tree plantations the carbon in both the above and the below ground biomass are included. The above ground biomass of SRC and perennial grasses accumulates until it is harvested and then after which it will accumulate again. The below ground biomass accumulates until the highest above ground biomass levels is achieved and is then assumed to remain at the same level. The total carbon stock in biomass fluctuates over the lifetime. In this study, the forest areas and mangroves are excluded for bioenergy crops. Therefore, the land that becomes available for bioenergy crops will not include these important carbons stocks.

A3.2.1.1.4 Nitrous oxide emissions

The N_2O that is formed during the nitrification and denitrification processes in the soil is emitted to the atmosphere. The amount of nitrous oxide emitted is related to the amount of inorganic or mineral nitrogen available. The IPCC guidelines (2006), propose a default emission factor (EF) of 1% for nitrogen inputs from mineral fertilisers, organic amendment, and crop residues. Many studies regarding GHG emission from energy crop production or GHG in agriculture in general, apply this default emission factor (Smeets *et al.* 2009a; de Wit *et al.* 2011b; Popp *et al.* 2011).

N_2O emissions from agricultural soils are directly related to the amount of mineral nitrogen available. In this study, balanced fertilisation is assumed in line with the MITERRA-EUROPE model (Velthof et al. 2009). Balanced fertilisation implies fertiliser and manure application rates in accordance with the nitrogen crop demand after accounting for the crop uptake factor and the nitrogen losses. This method has been applied for the assessment of GHG emission in the Mozambique case study. Which is deemed to be appropriate because it is a wide recognised approach and as in Mozambique nitrous oxide emissions are low compared to carbon emissions.

A3.2.1.2 Soil

The criteria in the certification schemes refer to the preservation of the soil quantity and soil quality. Soil Organic Carbon (SOC) is considered to be the most appropriate indicator for soil quality (Reeves 1997). The methods to calculate the expected changes in SOC due to land, crop and management changes are described in section 3.2.1.2 in the final report. Preservation of the soil (quantity) implies that erosion by means of water runoff and soil loss trough wind erosion should be prevented. Water related erosion can be calculated using the Revised Universal Soil Loss Equation (RUSLE). The risk on wind related erosion can be quantified using the Wind erosion Equation (WEQ).

A3.2.1.2.1 Wind erosion

Areas with sandy soils and intensive management in combination with dry spells and high wind speeds are susceptible to wind erosion (Riksen and de Graaff 2001; USDA and NRCS 2002). Several methods have been developed to model wind erosion for different temporal and spatial scales, functionalities (specific circumstances) and impacts (soil loss, particle concentration). Ideally, soil erosion is continuously measured in the field or estimated by very exact wind erosion models fed with continues data on physical parameters. However, this is very time and capital intensive. In this study, the wind erosion equation (WEQ) method is applied. This is a relatively simple methods that requires less detailed input data and can be applied on a regional level as demonstrated by Van Kerckhoven (2009). The WEQ estimates the average soil loss due to wind erosion (in ton ha^{-1} yr^{-1}).Equation 9, gives the parameters of the WEQ derived from USDA and NRCS (2002), Morgen (2005) and van Kerckhoven (2009).

Equation 9

$$E = \int(IKVCL)$$

E	Erosion	Ton $ha^{-1\,yr}$
I	Soil erodibility index	ton ha–1 y
K	Soil surface roughness factor	dimensionless
C	Climate factor	dimensionless
L	Length of field	m
V	Vegetation factor	dimensionless

When land is converted from conventional use to bioenergy crops, most factors included in the WEQ remain constant. The soil surface roughness factor will change due to modifications in tillage and planting practices. The main factor that will change is the equivalent vegetative cover. The erosion risk is determined for every crop for every month of the year. In line with the WEQ guidelines, the most critical month is being selected based on the calculations. The risk on erosion is also highly dependent on management practices such as planting time, harvesting time, row direction, intercropping and weeding practices.

A3.2.1.3 Water

In this study, two indicators to assess the impact of bioenergy cropping on water quantity are used. The simple water balance is used to calculate the water deficit based on local effective precipitation and local evapotranspiration. The water use efficiency (WUE) indicator is used to express the water requirements per unit biomass.

To assess the potential water depletion due to the introduction of bioenergy crops, a simple water balance was made by comparing the evapotranspiration to the effective precipitation like done in the studies of Smeets and Faaij (2010) and van Dam *et al* (2009b). See Equation 10 and Equation 11.

Equation 10

$$WS_i = \sum\left[-\left((ET_{0i} \cdot Kc_i) - EP_i\right)\right]$$

Equation 11

$$EP_i = \left(P_i \cdot \left(125 - 0.2P_i\right)/125\right)$$

WS	Total water shortage in month *i*	mm/month
ET_o	Reference evapotranspiration of month *i*	mm/month
Kc	Crop evapotranspiration coefficient for specific growth stage in month *i*	Factor
EP	Effective precipitation in month *i*	mm/month
P	Precipitation in month *i*	mm/month
i	Month January to December	

The water shortage is calculated for every individual month and the cumulative seasonal water shortage is the sum of the water shortages for the subsequent months in which the depletion is not replenished. The ET_o (reference evapotranspiration) is calculated using the Penman-Monteith equation. The effective precipitation (EP) is defined as the rainfall that is useful or usable in any phase of the crop production (Dastane 1978) and is derived from the actual rainfall making use of the USDA formula in the CROPWAT 8.0 model (FAO 2009). The monthly precipitation levels and the ET_o (reference evapotranspiration level) are location specific. The Kc factors mainly depend on crop type, growth stage of crop and climate (Allan *et al.* 1998).

The Water Use Efficiency (WUE) indicator is frequently applied in bioenergy related studies, like in Berndes *et al* (2002), Dornburg *et al* (2010), van Dam *et al* (2009b), Fraiture and Berndes (2009) and Smeets and Faaij (2010). In this study, the WUE is used as a second indicator of water consumption. It provides an indication about the water requirements per unit crop produced, whereas the water deficit methodology only provides figures for water use per hectare. In order to assess the spatial explicit WUE of bioenergy crops, knowledge on water availability (precipitation and ground water) and the effect of different growth limitation factors on evapotranspiration rates should be considered. This information is however not available. Therefore the water use efficiency provides only a rough indication of the differences in water use efficiency in the two regions for the two crops.

A3.2.1.4 Biodiversity

Over the last decades, several indicator systems have been developed to assess changes in biodiversity. These indicator systems vary to a great extent according to scale (global, national, regional or local), purpose (policy targets), and focal area of biodiversity (species, genetic variation, population size or ecosystems). The impact of energy crop cultivation on biodiversity depends on both local scale effects (choice of crop, management intensity, vegetation structure, substituted land use) and landscape scale effects (geographical location, scale and distribution of crops) (Eggers *et al.* 2009).

LUC is a strong driver of changes in biodiversity (Sala *et al.* 2000; UNEP 2002; Foley *et al.* 2005; Reidsma *et al.* 2006). Because of the loss, modification and fragmentation of habitats, the (indirect) expansion of agricultural land for energy crop production is perceived to be a major threat for biodiversity (Sala *et al.* 2009). Biodiversity is also affected by LUC related depletion, degradation and pollution of ecosystems and invasive species (Foley *et al.* 2005; Groom *et al.* 2008). Changes in habitats due to energy crop production are most significant when natural areas are converted to (intensive) agriculture areas (Schlegel *et al.* 2007). Most bioenergy sustainability criteria deal with this issue by proposing process indicators, e.g. by referring to national regulations and by excluding protected areas and land identified as area with high biodiversity from bioenergy production (EC 2008). In this study, the national conservation and protected areas are excluded for agricultural expansion and for energy crop cultivation in the LUC modelling. In addition, all forest and mangrove areas are excluded. However, these excluded areas do not include all high biodiversity areas. The availability of spatial data on biodiversity hotspots, high nature conservation areas and or other indicators of high biodiversity value will be assessed. However, also outside the protected areas and the high nature conservation areas, high biodiversity values are present. Currently, few guidelines are available about quantitative result indicators and methods to assess the impacts of energy crop production on biodiversity (Cramer 2007). This is especially true for assessing agro-biodiversity on a regional level.

To indicate the effect of LUC of current land use towards bioenergy crop production, the Mean Species Abundance (MSA) will be used as indicator. The Mean Species Abundance (MSA) is a quantitative indicator for change in biodiversity. It does not reflect individual species responses but represents the average response of the total set of original species relative to their abundance in undisturbed ecosystems (Alkemade *et al.* 2009). This indicator does not cover all aspects of the complex concept of biodiversity, but it can be used appropriately to assess changes in biodiversity due to changes in land use for bioenergy crops. It was successfully applied in several global en regional studies concerning changes in biodiversity (MNP 2006; Secretariat of the Convention on Biological Diversity and Netherlands Environmental Assessment Agency 2007; Dornburg *et al.* 2008).

The MSA indicator is based on several drivers for changes in biodiversity: land cover change, land use intensity, fragmentation, climate change, atmospheric nitrogen deposition and infrastructure development (Alkemade *et al.* 2009). As this study focuses on short term LUC, only the effect of land cover change combined with land use intensity, fragmentation and infrastructure are taken into account. The effects of alteration due to climate change and nitrogen deposition operate on long time scales and are therefore less appropriate to incorporate for an assessment for 2020.

The change in MSA can be assessed per hectare that is converted from the current land use towards bioenergy crop cultivation. However, due to spatial variation in agro-ecological conditions and to differences in potential yield levels of the different crops, the amount of land required to meet the input requirements of the ethanol conversion plant differ per setting. Therefore, the change in MSA in GJ feedstock or in GJ ethanol should be calculated. See Equation 12:

Equation 12

$$\Delta MSA_{GJ_{EtOH}} = \sum \left(\frac{MSA_{new} - MSA_{currnet}}{Y_{c,ay} \cdot E_c \cdot Ef_{conversion}} \right)$$

$\Delta MSA_{GJ\ EtOH}$	Change in MSA per GJ ethanol produced	$MSA \cdot GJ_{EtOH}^{-1}$
MSA_{new}	MSA value of new land use (energy crop)	dimensionless
$MSA_{current}$	MSA value of current land use	dimensionless
Y_{ay}	Yield of crop C for location a in year y	$Odt \cdot ha^{-1}$
E_c	Energy content of energy crop C	$GJ \cdot odt^{-1}$
$Ef_{conversion}$	Conversion efficiency to ethanol	%

A3.2.2 Socio-economic impacts

A3.2.2.1 Legality

As the criteria in the sustainability schemes related to compliance with national law and legislation refer to non-measurable and non-quantifiable principles. No methods are developed to assess these criteria. The results section on this topic will be limited to references to the most important legislations and regulations.

A3.2.2.2 Land rights

In order to prevent conflicts over land, several areas are excluded for land use allocation in the land use modelling for the assessment of land availability for bioenergy crops. The land use types that are excluded (in addition to biophysical limitations) for land use allocation are: urban areas, community areas, protected areas, previously assigned land use rights and concession areas. In addition, all land in use for agricultural purposes is excluded for energy crop cultivation.

In this section both a quantitative and qualitative analysis is performed. The quantitative analysis is based on results from the land analysis that include the total feedstock production potential [%] taking into account the amount of required land per region [km^2] and the suitability. If this production potential is below a 100%, land availability is problematic.

The qualitative analysis consists of an evaluation and description of the land tenure or acquisition procedure, and an overview of the most important issues with land rights in the case study countries, following the methodology outlined in (Franke *et al.* 2012). The evaluation provides best practise recommendations which are applicable for both regions and feedstocks.

A3.2.2.3 Food security

The four internationally-agreed dimensions of food security are: availability, access, stability and utilization (GBEP 2011). Availability of food related to the agricultural production of food (crops). This is influenced by (agricultural) land availability, suitability of the land for farming production, farming practices, and crop selection. The access to food primarily refers to people's ability to afford food and overcome barriers such as remoteness and social marginalisation. Food prices and income are the main factors influencing access to food. Stability of food refers to the steadiness of the availability and the accessibility of food this can be endangered by conflicts, natural disasters, market failure, and loss of resources. The utilization of food refers to the ability to use food products and absorb the nutrients of the food. The ability to cook is generally an important precondition for the efficient use of food. How the project will affect the food security in the region depend on the current food security conditions and the policy, management and practices of the project.

The current food security condition will be analysed on two levels, *nationally* and regionally. If statistical data is available, common food security indicators will be used such as % of the population that is undernourished. If these figures are not available (Mozambique), the food basket methodology is used (Franke *et al.* 2012). This methodology consists of two steps (Franke *et al.* 2012):

- Step 1: Determination of relevant food basket and of its components
- Step 2: Indication of changes in prices and/or supply of the food basket in the context of biofuels

The result indicates possible risks of deterioration of the food security situation. The other level is the regional level; several background indictors will be analysed to determine the current status of food security in the two regions. Both analyses will provide background information on the current situation. In addition, a qualitative analysis will be used to determine the potential improvement or decrease in food security in the regions due to biofuel investments. This will depend largely on project implementation, e.g. on agricultural knowledge provided. But also on wages that are paid by the projects, as income effects are a major determinant of food security. If food security is an issue in the case study country, recommendations are provided to increase positive impacts by the biofuel companies. 62B

A3.2.2.4 Economic viability

A3.2.2.4.1 Feedstock production costs

Feedstock production costs are assessed by calculating the net present value (NPV) of all costs items and the biomass yield during the lifetime of the biomass production plantation[1]. This method has frequently been used for the

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[1] The lifetimes of plantations assumed are 21 year for eucalyptus (3 growing cycles of 7 years); 15 years for switchgrass (14 harvests from 2nd year on); a 5 year ratoon for sugar cane (5 harvests); and an annual cycle of soy. The discount rate assumed in this study is 12%.

calculation of the costs of (perennial) biomass feedstock production (e.g. van den Broek *et al.* 2000; van Dam *et al.* 2009a; Van der Hilst *et al.* 2010). Some of cost items are costs 'per hectare' such as cost for land, land preparation and pesticide application. Other cost items are related to the production volume such as the costs for fertilizers (as application levels are linked to nutrient removals) and harvest costs (per m^3 or ton harvested). Equation 13 provides the method used to calculate the discounted cost per tonne feedstock.

Equation 13

$$C_{cr} = \sum_{Y=1}^{Y=x} \frac{\sum_{n=1}^{N}\left(I_{ny}\cdot C_{ny}\right)+\sum_{m=1}^{M}\left(J_{my}\cdot C_{my}\cdot Y_{y}\right)}{(1+a)^{y}} \Big/ \left(\sum_{x=1}^{y=x}\frac{Y_{y}}{(1+a)^{y}}\right)$$

Ccr	Discounted costs feedstock production	€/odt
I	occurrence cost item per ha n in year y	#
Cny	cost of cost item n in year y	€/ha
J	occurrence of cost item per odt m in year y	#
Cmy	cost of cost item m per odt	€/odt
Y	yield in year y	odt/ha
a	discount rate	%
y	annuity period (lifetime plantation)	y

Due to variations in agro-ecological conditions, the yields and related production costs of energy crops are spatially highly heterogeneous. In order to calculate the spatially explicit feedstock production cost, the map of land availability of year *y* is combined with the crop suitability map and the maximum attainable yield given the level of management in year *y*.

Equation 14

$$Y_{ay} = A_{ay}\cdot S_{a}\cdot M_{y}$$

Yay	Yield of energy crop at location a in year y	ton/ha
Aay	Land availability of lactation a in year y	l /o
Sa	Suitability of land at location a	%
My	Maximum yield given management level in year y	ton/ha

The length of the annuity is based on the lifetimes of the crops. As the lifetimes of the perennial crops are not equal, the equivalent annual series are used. The costs and revenues of crop production depend on soil and climate, the economic environment, and the farm management system. The cost estimates for this study are specific for a state of the art plantation and assumes best practices.

For the calculation of the economic performance of crop production, only costs and benefits directly related to cultivation are taken into account. Overhead costs and general farm activities (e.g. maintenance of barns and farm area, cleaning, and administration) are not considered in this study.

The costs are calculated per hectare and per ton of crop. The total NPV of the project are calculated taking into account the yield per hectare and the amount of hectares required to meet the input requirements of the conversion facility.

A3.2.2.4.2 Conversion costs

The conversion costs comprise investment costs, operation and maintenance (O&M) costs, and energy input costs. It is assumed that the costs of pre-treatment and conversion are not location specific and are therefore not calculated spatially explicitly. The costs of conversion are calculated by using the annual cost including depreciation and interest and the annual production.

A3.2.2.4.3 Transportation costs

Biomass logistics contribute significantly to the total cost per GJ bioenergy produced and delivered (Dornburg and Faaij 2001; Hamelinck *et al.* 2005). Key factors of determining the cost of primary transport are the scale of conversion plant and the biomass availability in an area. The cost of transportation of end products from the conversion plant to the harbour depends on the spatial distribution of biomass production and the availability and the quality of road infrastructure. For these reasons, the costs of primary and secondary transport are spatially highly heterogeneous.

There is a trade off between minimizing the transport distances of the low density raw feedstock and minimizing the conversion cost due to economies of scale. The optimization of the feedstock transportation distance depends on the scale factor (r) of the technology, the required supply radius (due to distribution and productivity of available land), and the availability and quality of infrastructure.

A3.2.2.5 Local prosperity

Based on the data required to calculate the economic viability of the total investment, the total required labour and the affluent of wages into the region can be calculated. The size of the regional unemployed labour force, compared with required labour is used as proxy for labour migration. To what extent the project affects the local prosperity in the region, depend also on the current conditions. Therefore several background indicators are selected such as total population, labour force, current unemployment rate, poverty index, GDP, in order to put the extend of the effect into perspective.

A3.2.2.6 Social well-being

The contribution of the project to the social well-being in a region depends on the policy, management and practices of the project that is to be established and can therefore not be assessed beforehand. However, as it is assumed that sustainability criteria are to be met, it is assumed that compliance with national laws en regulations and social responsibility is part of good practice. The impact of a project on the local social well-being largely depends on the current social situation. Therefore, background details on the most important issues in the case study country are provided in order to interpret the potential impact of a biomass project on the social well-being in the region. These can be land use, health care, education, illiteracy, housing, labour immigration, infrastructure, and access to energy services. If social well-being is potentially significantly affected, the number of people affected by the project living in the immediate surroundings provides an indicator of the impact of the project on the community.

A3.2.2.7 Labour conditions

Labour conditions are one of the socio-economic impacts included in many of the certification schemes. The issues most often addressed in these criteria refer to working conditions, health and safety, working hours, contracts, wages, child labour, forced labour, capacity building and training, freedom of association and sometime equality and gender issues. The labour conditions depend on the policy, management and practices of the project that is to be established and can therefore not be assessed beforehand. For this ex ante assessment, current regulations are described if available and recommendations are provided for good practices. The indicators are based on the international standards by the International Labour Organisation, see (Franke *et al.* 2012).

A3.2.2.8 Gender

This aspect cannot be analysed ex-ante as it depends on project implementation. A description of the current status in the countries of gender equity will be used to assess the potential impact of the biofuel supply chain. Furthermore, recommendations for best practice to include gender equality aspects will be provided based on the methodology provided by Franke et al. (Franke *et al.* 2012)

A3.3 Detailed results for Mozambique

A3.3.1 Environmental impacts

A3.3.1.1 GHG emissions

A3.3.1.1.1 GHG emissions life cycle cultivation

The GHG emissions during the cultivation include the emissions from the diesel usage, the production of seeds, pesticides, herbicides and fertilizers and the direct N_2O emissions from nitrogen fertilizer application. In Figure A3.2, the GHG emissions in kg CO_2-eq per /GJ feedstock of switchgrass and eucalyptus care depicted for the two selected regions and for the two scenarios.

The GHG emissions for eucalyptus and switchgrass per hectare are higher in Nampula compared to the Gaza-Inhambane region. This is a direct result of the higher nitrogen inputs related to the higher yield levels. However, there is little difference between the two regions in terms of GHG emission per GJ feedstock produced because Most of the inputs (fertilizers and diesel) are directly related to the yield level. The GHG emissions per GJ feedstock are higher for switchgrass compared to eucalyptus in both regions. This is mainly due to the higher nitrogen requirements for switchgrass and the related emissions from nitrogen fertilizer production and the N_2O emission from nitrogen application in the field. And also because of the lower yields and lower energy content of switchgrass compared to Eucalyptus. The ranges provided are based on the uncertainty in direct N_2O emissions from nitrogen application. All other inputs have also uncertainties but due to a lack of information these are not quantified.

A3.3.1.1.2 LUC related GHG emissions

Soil Organic Carbon

The SOC is affected by soil type, climate, land use, land use management and input level. Therefore, SOC is highly heterogeneous and also quite uncertain. In Figure A3.3 the soil organic carbon levels in ton C ha^{-1} (or the soil 0-30 depth) for the different land uses in the two selected regions are depicted. Figure A3.3 shows that the uncertainties in SOC levels are very high. This is mainly related to the high uncertainties in reference SOC level (90%) and to the uncertainties of the effect of land use, tillage regime and input levels on the these SOC levels. The uncertainties are especially high for the cultivation of switchgrass and cropland (50% uncertainty for the land use factor, according to the IPCC).

The SOC levels are higher in Nampula compared to the SOC levels in Gaza-Inhambane region because soils have generally more SOC in moist climates. This is partly balanced out by the difference is soil types: the high active clay soils such as in Gaza-Inhambane contain generally more SOC than low active clay soils such as in Nampula. Highest SOC levels are achieved when switchgrass is cultivated due to the no tillage regime and inputs applied. The lowest SOC levels are achieved when annual crops are cultivated because of the (reduced) tillage and low input levels. This is partly compensated by the shifting cultivation, as in the time without cropland SOC levels partly recover.

Above and below ground biomass

The above and below ground biomass of natural vegetation (shrubland, forest, natural grassland) is assumed to be in equilibrium, so no net accumulation is assumed. For eucalyptus plantations it is assumed that the above ground biomass is harvested after 7 years after which it is accumulates again. For switchgrass, it is assumed that the above ground biomass is harvested every year. And for cropland it is assumed that both above and below ground biomass accumulates and is harvested every year. For the fluctuating biomass stocks of eucalyptus, switchgrass and cropland, the average standing stock over 20 years is assumed. Figure A3.4 shows the carbon accumulation patterns over time of the different land use types for typical soil and climate conditions in the two regions. Shrubland has a high carbon stock which remains constant over time. Only after several years, the carbon stock of a eucalyptus plantation reaches the same level as shrubland. After harvest the carbon stock of switchgrass and eucalyptus is not zero, because the below ground biomass is still present.

The total carbon stock in ton C per hectare including the above and below ground biomass and the soil organic carbon per land use type for typical soil and climate conditions for each of the selected regions is depicted in Figure A3.5.

Figure A3.5 shows that the biomass carbon stocks are generally higher in Nampula compared to the levels in the Gaza-Inhambane region, which is directly related to the assumed suitability (62% versus 34%) of the two selected regions. Shrubland has the highest carbon stocks compared to the other land uses because of the continuous high above and below ground biomass and because of the high SOC level of undisturbed land. The lowest carbon stocks are found in cropland as there is little biomass carbon and soil organic carbon is lost because of management of the soil. The soil organic carbon levels have a key contribution to the total carbon stocks. For shrubland and Eucalyptus, the above ground biomass has a higher contribution to the total carbon stock compared to the below ground biomass, whereas for pasture and switchgrass it is the other way around. The uncertainties on the calculations of SOC (see previous section), on the biomass yield (20%), on the root to shoot ratios, and on the carbon content (0.44-0.49) are included and result in large uncertainty ranges. The ranges

Figure A3.2: GHG emission related to the cultivation of eucalyptus and switchgrass in the selected area in Gaza-Inhambane and in Nampula for the BAU and the PROG scenario.

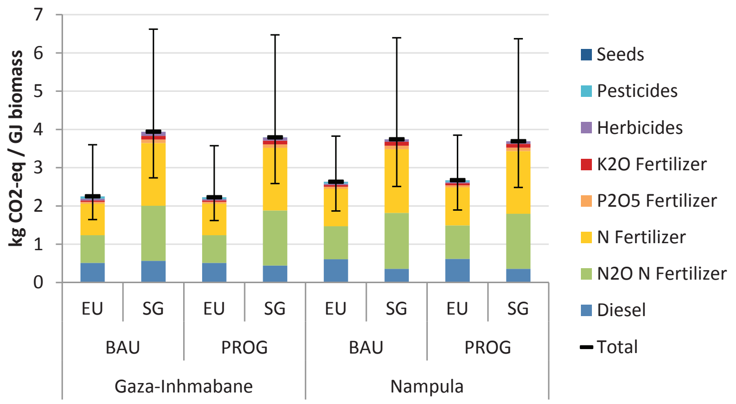


Figure A3.3: Soil organic carbon levels in ton C ha-1 for the several land use classes in the two selected regions

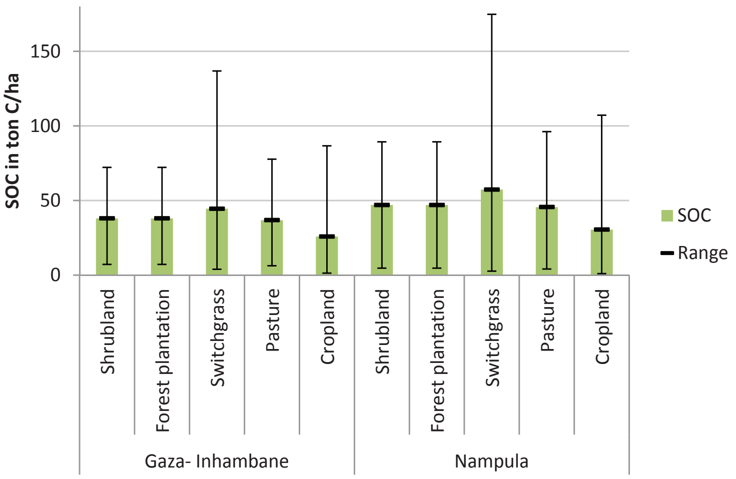


Figure A3.4: Patterns of carbon accumulation and losses for different land use types in the selected areas in Gaza-Inhamabne (GI) and Nampula (N).

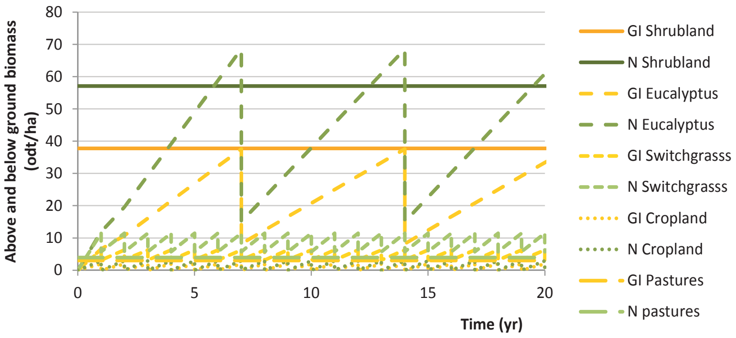


Figure A3.5: The carbon stocks in soil (SOC) above ground biomass (AGB) and below ground biomass (BGB) in ton C per hectare for different land use types and typical soil and climate conditions for the selected regions.

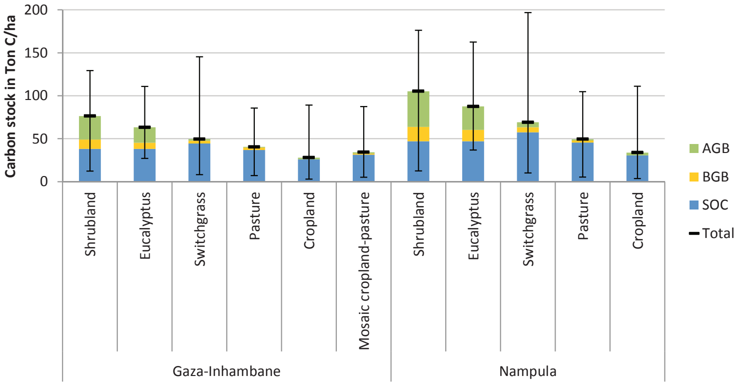


Figure A3.6: GHG balance per ton feedstock for the two selected energy crops in the two selected regions under two different sets of scenario conditions.

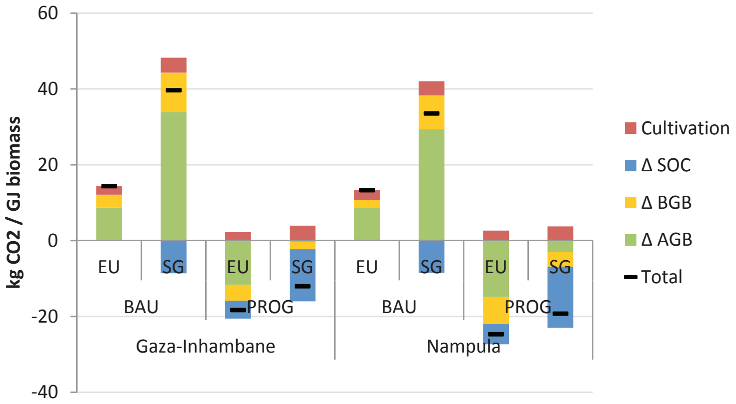
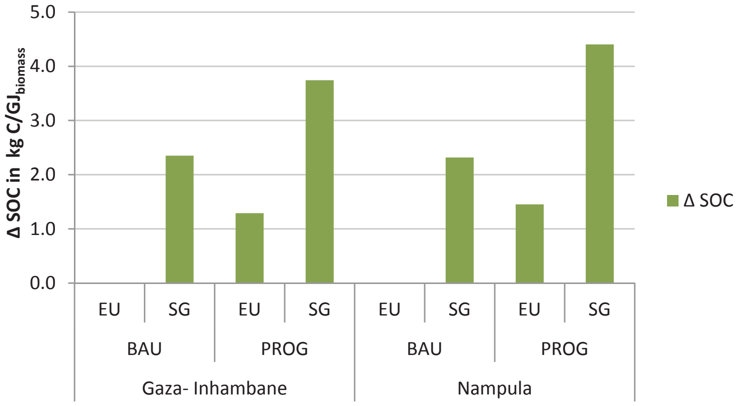


Figure A3.7: Change in soil organic carbon in kg C/ $GJ_{biomass}$ due to the conversion from current land use to eucalyptus and switchgrass.



in uncertainty exceed the differences in carbon stocks of the different settings.

A3.3.1.1.3 Total GHG impact

The total effect of the cultivation of the two selected bioenergy crops in the two selected regions under the two scenario conditions was assessed by calculating the GHG emissions per ton feedstock produced. In line with the IPCC (2006) and EU RED (EC 2009) a time horizon of 20 years is assumed. Consequently, the changes in carbon stocks are allocated to 20 years of bioenergy crop yield. The total GHG balance per ton energy crop for eucalyptus and switchgrass is depicted in Figure A3.6.

Figure A3.6 shows that in the progressive scenario, the cultivation of energy crops result in carbon sequestration by means of higher soil organic carbon and biomass carbon levels compared to the replaced mosaic-cropland pasture. The carbon sequestration is higher when land is converted to eucalyptus than when land is converted to switchgrass. This is the result of the higher above and below ground biomass carbon stock of eucalyptus. In the BAU Scenario, the cultivation of energy crops results in significant GHG emissions. To what extent and in what timeframe this will be offset by avoided emissions related to the replacement of fossil fuels depend on the efficiencies in the remainder of the production chain and the type of fuel that is replaced.

Although there a significant differences between the two regions in terms of climate, soil and productivity, the carbon stock changes per unit feedstock are quite comparable for the two selected regions. In Nampula, both the biomass carbon stock and the SOC are significantly higher than in Gaza-Inhambane region. However, as the changes in carbon stock are divided over the total biomass yield in the timeframe of 20 years and the yield levels are significantly higher in the Nampula area, the carbon stock changes per unit biomass feedstock are levelled.

Figure A3.6 summarises the results of section A3.2.1.1. In the previous Figures the uncertainty ranges were provided. In this assessment it is all about the relative change (Δ) in Carbon. It is likely that some of the uncertainties will affect the carbon stocks of the different land use classes in the same direction. For example: if the SOC in the HAC soil in Nampula is underestimated this will result in lower SOC values for all land use classes. However, the relative change is likely to change as the SOC under different land uses will be affected differently. The same is true for the uncertainties in suitability, carbon fraction, and root to shoot ratios. As the uncertainties are relative and are in some cases interlinked (likely to be in the same direction), the uncertainties cannot be cumulatively summated to find the uncertainties in the relative changes. Although the uncertainties are not quantified in Figure A3.6 they are significant as shown in Figure A3.3 Figure A3.4, and Figure A3.5.

A3.3.1.2 Soil

A3.3.1.2.1 Soil organic matter

The change in soil organic carbon is used as a proxy indicator for the change in organic matter content of the soils and therefore as an indicator of the quality of the soil. The change in soil organic carbon as a result of the conversion form current land use to energy crop production is calculated yet in order to assess the total GHG balance of bioenergy production (see section A3.2.1.1). The change in soil organic carbon is expressed in Δkg C/ GJ biomass produced and is depicted in Figure A3.7. These figures are highly uncertain because of the high spatial variation in soil characteristics and the uncertainties in the interactions between crop and soil over time under different conditions. These uncertainties are discussed in section A3.2.1.1. The change in soil organic carbon is discounted for 20 years: the total expected change in carbon is divided over the yield obtained in 20 years. Because of the high soil organic carbon content of both forest plantations (eucalyptus) and perennial grasses (switchgrass) there is no net loss of soil organic carbon. In the BAU scenario, when shrubland is converted to eucalyptus there is no loss and no gain of SOC, as it is assumed that for both land used the same SOC content in the soil can be obtained. In practice, there will be a loss at the moment of conversion but this will be restocked during the lifecycle of eucalyptus. When shrubland is converted to shrubland there is a small gain in soil organic carbon. Also Because of the lower yields per hectare and the lower energy content of switchgrass the gain per GJ produced relatively high compared to eucalyptus. Especially when agricultural land is converted to switchgrass high increases in soil organic carbon are expected.

A3.3.1.2.2 Soil erosion

The soil losses due to water erosion are not included. The steep slopes which are prone to water erosion are already excluded for LUC in the land availability modelling. In addition, the regions assessed in this study have relatively flat landscape characteristics. The risk on soil loss due to wind erosion requires detailed data on planting dates, crop development over time, and harvest windows, in relation to the climatologically variations over time. In addition, the risk on erosion is highly affected by the management applied. Therefore, the changes in risk on wind erosion for the two regions, for the two crops under the two scenarios are only described qualitatively and recommendations to reduce the risk on erosion and best practices are provided.

The risk on erosion is high when the soil has a light texture, there is little soil moisture content, when there is a strong wind and there is little or no soil cover. In both regions, the soil texture is sandy loam. This type of soil is not very prone to erosion compared to other soil textures such as sandy, loam sandy or light sand. The precipitation levels the Gaza-Inhumane region are very low, therefore the soil moisture content is low during the year. In Nampula, there are high annual precipitation levels, however, with strong seasonal variations with a high peak in precipitation during the rainy season and a long dry spell during the winter. Therefore, at the end of the summer the soil is very dry and therefore prone to erosion. The wind speed is higher in Nampula compared to the wind speed in the area Gaza-Inhambane. In both regions, the average winds speed is highest in September-October. Therefore, I both regions, the risk on soil loss due to wind erosion is highest in this period. However, if this indeed a risk depends on the soil cover in that timeframe.

It is assumed that swichgrass is sown just before the rainy season. The just sown switchgrass provides little soil cover. However, during these first months, the soil is not very prone for erosion due to the high soil moisture content. After some months it provides full soil cover and avoids erosion. Switchgrass is harvested every year, after which stubbles remain.
Also Eucalyptus is assumed to be planted before the rainy season. It will take some years to reach full soil cover. It highly depends on the management applied if the soil is fully exposed or if the areas between the rows are grown with grass. If there is no soil cover, it is prone to wind erosion.

In the BAUs scenario, it is assumed that shrubland is converted to energy crop production. Shrubland provides generally full soil cover and therefore reduces the risk on erosion. In the progressive scenario it is assumed that agricultural land is converted. As crops are generally harvested in the beginning of the year, there is no soil cover at the end of the dry season. Therefore, cropland can be very prone to erosion in this period. Converting shrubland to switchgrass will not affect the risk on erosion, but converting to eucalyptus the risk on erosion ill increase, especially when there is no cover between the rows. Converting agricultural land to switchgrass will reduce the risk on erosion due to the year round soil cover. Converting agricultural land to eucalyptus will have little effect in the first year after planting and after harvesting, but will reduce the risk on erosion when the trees are more mature.

It is recommended to time the harvest of switchgrass wisely in order to allow for full crop drying in the field before harvest, allow for re-growth of the crop during the rainy season, and prevent soil exposure in the end of the dry season, the most critical period of the year. Also for Eucalyptus it is recommended to harvest after the most critical months for erosion and if possible maintain soil cover (grass) between the row spacing. In addition, differentiating the growth stages of different plots, the length of field and therefore the erosion risk can be reduced by blocking the wind by more mature trees. For both switchgrass and eucalyptus it is wise to sow/ plant perpendicular to the prevailing wind direction in order to reduce the risk on erosion.

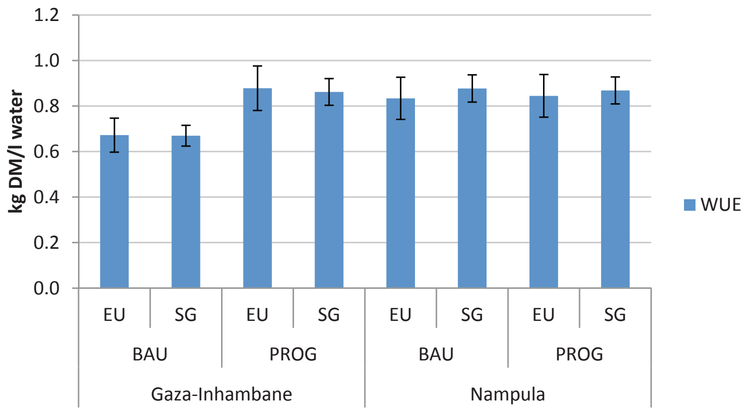
A3.3.1.3 Water

A3.3.1.3.1 Water use

For the water use, two indicators have been selected. The water use efficiency (WUE) and the cumulative water deficit.

In Figure A3.8 the WUE is depicted in amount of biomass

Figure A3.8: Water use efficiency in kg DM_{biomaa} *per liter water for eucalyptus and switchgrass in for the BAU and progressive scenario in Gaza-Inhamabane and Nampual region. The WUE includes the crop and location specific evapotranspiration and the crop and location specific yield.*



produced (DM) per litre water used. The water use is defined as the potential crop and location specific evapotranspiration. The higher the production of biomass per litre of water the better the water use efficiency. The Figure shows that the WUE for all settings are between 0.6 and 1.0 kg/l. The differences are relatively small because the higher crop specific evapotranspiration of eucalyptus are balanced by the higher yield of eucalyptus compared to switchgrass. Similarly, the higher evapotranspiration levels in Nampula are compensated by higher yield levels in this region compared to the Gaza-Inhambane region. The water use efficiencies provide little information, as the evapotranspiration is high in the tropics, the water use efficiencies are relatively low.

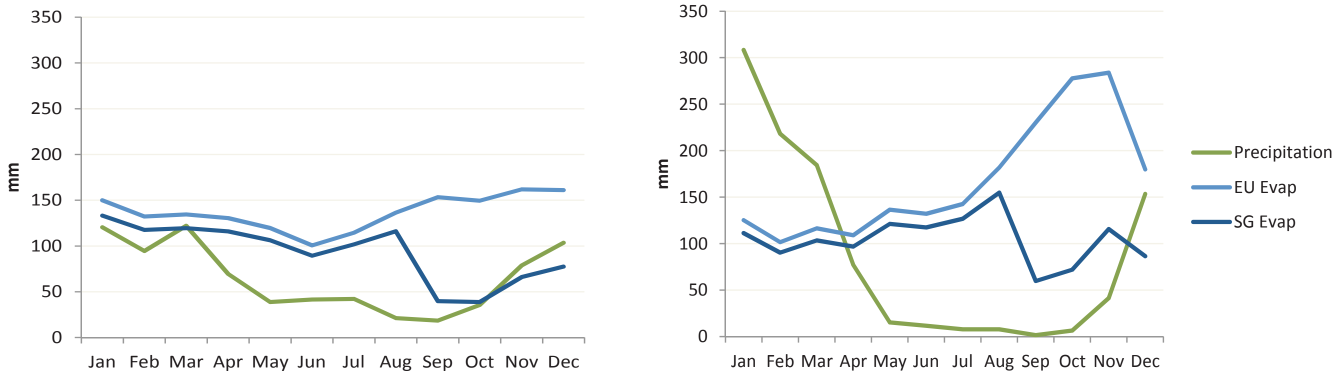
The crop coefficients values applied in this analysis are the Kc values of a stress free environment. When there is stress, such as drought, the Kc values are likely to be lower.

However, to what extent the crop related evapotranspiration of dedicated energy crops lead to changes in seasonal water deficits compared to current land uses need to be determined by a water balance. This includes the monthly precipitation levels, the monthly evapotranspiration and the crop specific-growth stage specific crop-coefficients. This requires detailed information on the timing and development of the growth stages of eucalyptus and switchgrass in the two regions, which is not available yet. For this first order assessment, the growth stage specific Kc values of other perennial grasses and C4 crops have been applied for switchgrass (Based on the figures of Allan *et al.* 1998) and an annual average Kc value is applied for Eucalyptus (Grattan *et al.* 1994).

In Gaza-Inhambane, even the reference evapotranspiration exceeds the precipitation levels. The fast growing eucalyptus and switchgrass increase the evapotranspiration levels significantly, especially eucalyptus. It is likely that a switch towards these fast growing energy crops could increase drought related problems in this region. In the Nampula region, the precipitation levels are much higher but are characterised by high seasonal fluctuations. Also, in this region the evapotranspiration levels exceed the precipitation levels. But this is a limited difference compared to the cumulative water deficit in Gaza-Inhambane region. Also here, the extraction of water by eucalyptus exceeds the water extraction by switchgrass (see Figure A3.9).

Cumulative water deficit it neglects however groundwater level, flow schemes of the water basin and the water tables and hydrological dynamics. To what extent seasonal water deficits causes declining water tables and to what extent that limits the accessibility of the water for the plants depend on many variables such as rooting depth, soil depth, water tables, replenishing options from the surrounding environment etc. It could be that due to the rooting depth of eucalyptus, it may be able to access ground water even in water stress periods. The advantage is that eucalyptus can relatively easily resist periods of drought and maintain relatively high yields even in relative dry areas of areas with a temporal uneven distribution of precipitation. A disadvantage is that eucalyptus is still able to extract water from a water stressed environment which could result in more extensive drought problems. This could have detrimental effect on surrounding agricultural areas but also on nature conservation and ecosystem services in the surroundings of the project.

Figure A3.9: Monthly precipitation and crop specific evapotranspiration levels of eucaluptus (EU evap) and switchgrass (SG evap) in Gaza-Inhambane and Nampula region.



However, to assess this and to include the impacts from water stress on the evapotranspiration levels requires more complex hydrological models and very detailed spatial data on climate, soil, crop and hydrology which are not available for the selected areas. Therefore, water balance provides too little information to assess where actual droughts will occur and if this will result in damage to agricultural land and nature areas in the surroundings. In order to assess the actual effect on water tables it is recommended that more advanced hydrologic models are applied. Due to the limitations of this analysis, the results should be interpreted with care

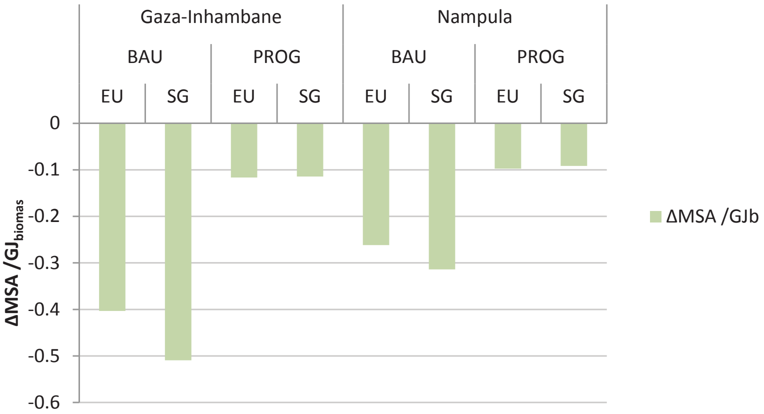
A3.3.1.4 Biodiversity

In the land use modelling step, the conservation areas and the national parks have been excluded. In addition, in the progressive scenario also forest and mangrove areas have been excluded. Therefore, considering these scenario conditions these areas are not affected by the implementation of large scale bioenergy projects. There are no protected areas nearby the selected areas in Gaza-Inhamabne and Nampula. In addition, the protected areas are depopulated in terms of animals and the protection and maintenance levels of these areas are very low.

However, other high conservation areas, or important habitats of threatened species are other areas that could be of high biodiversity value have not been assessed due to a lack of data.

The Mean Specie Abundance indicator has been used to assess the effect of the LUC from the current land use to energy crop cultivation. The MSA is expressed in a value between 0 and 1 differentiated for different land use types. In this analysis, the current land use (shrubland or cropland), the new land use (eucalyptus or switchgrass), and the amount of hectares required to be converted in order to meet the input requirements of the conversion plant. Figure A3.10 shows the change in MSA per GJ biomass produced. In all settings the conversion from current land use to energy crops result in a negative impact on the Mean Specie Abundance. Figure A3.10 shows that the change in MSA/$GJ_{biomass}$ is more negative in the BAU scenario compared to the progressive scenario. This is the result of the conversion of native vegetation (shrubland) to cultivated land in the BAU scenario (forest plantation and perennial energy crop). In the progressive scenario it is assumed that energy crops are cultivated on land previously in use as agricultural land which is abandoned because of higher agricultural productivity. However, it should be noted that the intensification of the agricultural sector in the progressive scenario will have a potential negative effect on the biodiversity as well. However, these effects are not quantified as this study only includes the direct effects of LUC. In the BAU scenario, the conversion from native vegetation to switchgrass results in a more negative ΔMSA/$GJ_{biomass}$ compared to eucalyptus despite of the lower MSA value for forest plantations compared to perennial energy crops. This is caused by the lower yield levels of switchgrass compared to eucalyptus. In the progressive scenario the ΔMSA/$GJ_{biomass}$ is similar for eucalyptus and switchgrass; here the lower yield of switchgrass is compensated by the higher MSA value for perennial grasses.

Figure A3.10: Change in cumulative mean species abundance per GJ biomass produced for Eucalyptus (EU) and switchgrass (SG) in the Gaza-Inhambane region and the Nampula region for the two scenarios (in Δ MSA value /GJ biomass x100).



The impact of large scale bioenergy production on biodiversity is mainly related to the design and the management of the project. There are many measures that can maintain and enhance biodiversity. The most important ones are:

- Avoid monocultures: scatter bioenergy crop / tree plots within natural areas
- Avoid clearance of native tree species within the bioenergy plots
- Maintain important corridors for key species
- Maintain natural vegetation in riparian areas
- Minimize disturbance within the field
- For forest plantations: maintain different plot in different growth stages to enhance diversity within the landscape.

A3.3.2 Socio-economic impacts

A3.3.2.1 Legality

This aspect cannot be analysed ex-ante, therefore a description is provided of the policy framework of biofuel (investment) in Mozambique.

The government of Mozambique has recently implemented a “Biofuel Sustainability Framework”. This framework aims to contribute to a transparent environment for biofuel investments in Mozambique. Sustainability principles, criteria, indicators and verifiers are designed to fit the Mozambican reality and at the same time consider long-term sustainability requirements by major markets (Republic of Mozambique, 2012).

In 2009, the Government of Mozambique approved the Biofuel Policy and Strategy (Resolution No. 22/2009) which defined the steps that are needed to guide biofuels investment and production. An Inter-ministerial Biofuel Commission (CIB) that is composed of five ministerial subgroups was composed led by four ministries; the Ministry for the Coordination of Environmental affairs (MICOA), the Ministry of Agriculture (MINAG), the Ministry of Energy

(ME) and the Ministry of Planning and Development (MPD). More specifically, the subgroup 'Sustainability Criteria' which is led by MICOA consist of the following ministries and organisations; National Directorate for Environmental Impact Assessment (DNAIA), National Council for Sustainable Development (CONDES), National Directorate of Environmental Management (DNGA), National Directorate for New and Renewable Energies (DNER), Agricultural Promotion Centre (CEPAGRI) and National Directorate for Land and Forestry (DNTF), Investment Promotion Centre (CPI) and National Directorate of Water (DNA).

In November 2011, the council of Ministers approved the Biofuel Blending Regulation (Decree no. 58/2011). This regulation established a mandatory blending of biodiesel with diesel (3% from 2012 to 2015, 7.5% from 2015 to 2020 and 10% from 2021 onwards) and a mandatory blending of anhydrous ethanol with gasoline (10% from 2012 to 2015, 15% from 2015 to 2020 and 20% from 2021 onwards) (Republic of Mozambique 2012).

The Biofuel Sustainability Framework was developed taking several legal instruments that were already used in the country into account (Bossel and Norfolk 2012) and (Republic of Mozambique 2012):

- *Land Law and regulations* (Land law; land law regulations; technical annex to the land law regulations; land planning law).
- *Investment Law and regulations* (Investment law; investment law regulations; code of fiscal benefits; project application form, Procedures for the presentation and appreciation of investment proposals involving extension areas above 10,000 ha)
- *Specific environmental legislation* (Environmental Law; regulation about the environmental impact assessment; general directive for the elaboration of environmental impact studies; manual of procedures for environmental licensing; general directive for the public participation process; Forest and Wildlife law; Regulation about the standards of environmental quality and effluent emission, Water law)
- *Labour law and regulations* (Labor Law No. 23 2007)
- *Specific Biofuel policies* (Biofuels policy and strategy (Resolution no. 22/2009); biofuels blending regulations (Decree no. 58/2011); biofuel technical regulations; regulations for licensing activities of production, storage, export, transport and commercialization of biofuels)

Investment proposals are evaluated by CPI in collaboration with the ministries of MINAG, ME and MICOA. The size of the project determines whether the project is assessed at the national or provincial level. After receiving the investment proposal different ministries and institutions analyse the proposal and provide a written opinion on whether and how the biofuel investor should proceed. After approval it is the responsibility of the government to monitor biofuel investments, inter-ministerial monitoring visits, supervised by CPI, are performed annually after project implementation. Based on the level of compliance with the indicators in the sustainability framework, an additional 6 month monitoring visit can take place.

A3.3.2.2 Land rights

A3.3.2.2.1 Quantitative analysis

The land analysis in section 2.2.1.4 in the final report, provides the total required land, the suitability of the regions and the resulting potential feedstock production per region. All cropland that is currently in use has been excluded. Furthermore all communities that have applied and received land rights (DUAT), and all large scale biofuel investments that have received DUATs are excluded. This means that if the potential feedstock production is 100%, the land availability is no issue in theory, see Table A3.1.

Only in the BAU scenario in Nampula region, the potential feedstock production is below 100%, indicating problematic land availability. Switchgrass has an even lower production potential than Eucalyptus; only 46% of the total feedstock that is required can be produced in Nampula in the BAU scenario. The production in Gaza-Inhambane is never below 100% indicating that land availability is not an important issue in that region (although other problems with land allocation can occur, see qualitative analysis.

Table A3.1: The land requirements in km² to meet the input requirements, the proportion of the feedstock that can be produced in the regions and the potential land right risks for Eucalyptus and Switchgrass in the Gaza-Inhambane and in the Nampual region and the Business as Usual and the progressive scenario in 2020.

🟩 *Positive impact* 🟨 *Neutral or minor impact* 🟥 *Negative impact*

			Gaza-Inhambane				Nampula			
			BAU		PROG		BAU		PROG	
	Impact	Unit	EU	SG	EU	SG	EU	SG	EU	SG
	Land rights									
	Land Area	Km²	2046	3013	1317	1317	826	826	1317	1871
	Conversion plant input requirements	%	100	100	100	100	62	46	100	100
	Land right risk	Qualitative	+	+	+	+	-	-	+	+

A3.3.2.2.2 Qualitative analysis

Land allocation procedures and land laws in Mozambique are often unclear and procedures can be problematic leading to land conflicts. This is amongst other reasons, due to informal customary land-laws that co-exist with formal land title laws, not clearly demarcated boundaries of many properties and generally undocumented land ownership, especially by local communities (Van Eijck et al. submitted).

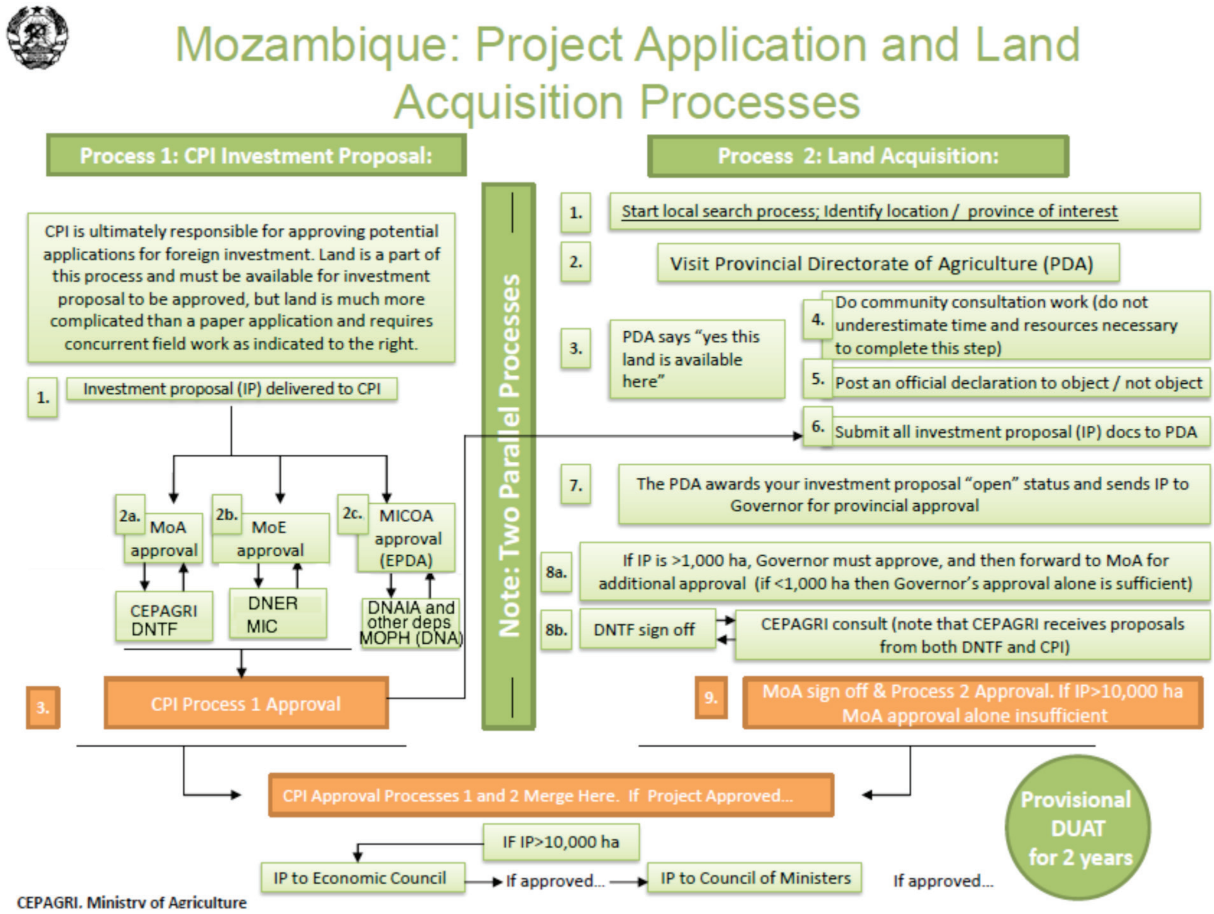
The Mozambique Investment Promotion Center (CPI) is the organization that facilitates foreign investments, while CEPAGRI facilitates investments in agriculture and biofuel. The Biofuel Sustainability framework provides guidelines see Figure A3.11 for all steps in the process of land acquisition. The ambition of the Mozambican government is that all these steps are taken within a timeframe of a few months. For investments that require less than 1000 ha of land, approval is provided by the Provincial Governor. If the requested land is >1000 ha but less than 10,000 ha, approval has to be provided by the Ministry of minerals and agriculture (MINAG). For areas larger than 10,000 ha, approval has to be provided by the Economic council and a council of ministers. After the land title (DUAT) has been provided several evaluation moments (e.g. after two years) are implemented to monitor the implementation (Republic of Mozambique 2012).

Community consultations are part of the land acquisition process. In practise, several NGO's are active in Mozambique that can assist with these consultations. Also the provincial government should be included in this process; in case of land disputes it is important to have assistance. Other recommendations for the land acquisition process during project implementation include: provide documents in the local language and document all steps in the community consultation process (Van Eijck et al. submitted).

A3.3.2.3 Food security

The food basket in Mozambique consists of sorghum, cassava, maize and rice. Since 2000 the production of the main staple crops, maize, cassava, sorghum and rice has hardly increased. Except for fluctuations in cassava yield, the yields have also remained almost at the same level. From 2000 to 2010, the prices of all four main staple crops, maize, cassava, sorghum and rice, in Mozambique have increased. Even when the strong inflation is taking into account, the real price increase is still strong. Therefore there is a price risk, and food security in Mozambique is an important issue.
Also in the two regions, food security is important and is currently not achieved for the entire population. In Nampula there is a higher mean calorie intake per person per day Gaza-Inhambane region. Furthermore the harvested area with maize

Figure A3.11: Project application and land acquisition process in Mozambiqiue (Republic of Mozambique 2012)



Mozambique: Project Application and Land Acquisition Processes

Process 1: CPI Investment Proposal:

CPI is ultimately responsible for approving potential applications for foreign investment. Land is a part of this process and must be available for investment proposal to be approved, but land is much more complicated than a paper application and requires concurrent field work as indicated to the right.

1. Investment proposal (IP) delivered to CPI

2a. MoA approval

2b. MoE approval

2c. MICOA approval (EPDA)

CEPAGRI DNTF

DNER MIC

DNAIA and other deps MOPH (DNA)

3. CPI Process 1 Approval

Note: Two Parallel Processes

Process 2: Land Acquisition:

1. Start local search process; Identify location / province of interest

2. Visit Provincial Directorate of Agriculture (PDA)

3. PDA says "yes this land is available here"

4. Do community consultation work (do not underestimate time and resources necessary to complete this step)

5. Post an official declaration to object / not object

6. Submit all investment proposal (IP) docs to PDA

7. The PDA awards your investment proposal "open" status and sends IP to Governor for provincial approval

8a. If IP is >1,000 ha, Governor must approve, and then forward to MoA for additional approval (if <1,000 ha then Governor's approval alone is sufficient)

8b. DNTF sign off

CEPAGRI consult (note that CEPAGRI receives proposals from both DNTF and CPI)

9. MoA sign off & Process 2 Approval. If IP>10,000 ha MoA approval alone insufficient

CPI Approval Processes 1 and 2 Merge Here. If Project Approved...

IF IP>10,000 ha

IP to Economic Council

If approved...

IP to Council of Ministers

If approved...

Provisional DUAT for 2 years

CEPAGRI. Ministry of Agriculture

(one of the staple crops) has increased over the years 2003-2010 in Nampula but decreased in Gaza-Inhambane. Therefore, the situation in Nampula is slightly better, although both regions need improvement in the food security situation. In the land availability assessment the increase in food production as a result of the increase in population and in dietary intake per capita, has been taken into account. In this analysis it is assumed that the average caloric intake per capita increases 2100 Kcal per capita per day to 2400 Kcal/ cap/ day, which is a considerable increase but still low compared to developed countries. Only in the BAU scenario in Nampula, land availability is a limiting factor, therefore there is a risk that land currently in use for food production is taken into production which would negatively impact food security. Although, the land availability assessment takes into account the population density and the distance to markets in claiming land for food production, it provides too little information on the local food security conditions. In the progressive scenario, it is assumed that the productivity of the agricultural sector increases significantly. This will have a significant positive impact on the food security situation. However, this impact is the result of the assumed scenario conditions and not of the implementation of the bioenergy production project. However, the bioenergy production project could contribute in the development of the agricultural sector and therefore food security in many ways. Because the current food security is very low, the implementation of a biofuel project in the two regions can impact food security in a positive way.

A few examples are:

- Providing storage facilities, enabling the storage of food crops to balance seasonal fluctuations in food availability, both for own consumption for farmers but also maintain the quality of seed material for the succeeding season. Moreover, storage can prevent temporally flooding of the market resulting in low prices and therefore low farmer's income.
- Improving infrastructure, enabling access to markets and therefore famer's income and incentives for higher production.
- Providing extension services to the surrounding farmers and employees of the energy plantation, to let them benefit from agricultural knowledge and skills available on the bioenergy plantation
- Enabling a market for agricultural inputs. Currently there is no market for fertilizers and other agricultural inputs.
- Allow employees that have their own plots, time to work on their food crops in addition to the work they provide for the bioenergy plantation
- Facilitate a renting system for agricultural machinery and tools that enable employed substance farmers and farmers in the surroundings of the bioenergy plantation to rent equipment to improve their farming practices.
- Use part of the land of the plantation premises for food crop production to provide food for employees.
- Employment generation by the project will likely increase household income and therefore food security. The prices of staple crops have increased over the years, therefore wages should be high enough to overcome this risk.

Table A3.2 summarises the impact of large scale bioenergy production from the two crops on food security in the two regions for the two scenarios in 2020.

A3.3.2.4 Economic viability

For the two selected regions in Mozambique, the economic viability is assessed by calculating the net present value of the cultivation cost and the net present value of the cost of the entire supply chain up to plant gate. The distribution of biofuels within the country or the export of biofuel to other countries is not included.

In Figure A3.12 the disaggregated net present values of the cultivation cost of Eucalyptus and switchgrass in the Gaza-Inhambane and Nampula region for the BAU and progressive scenario are depicted. The cost in the progressive scenario are much lower compared to the BAU scenario as it is assumed that in the progressive scenario the cultivation of energy crops takes place on abandoned agricultural land which is no longer in use as the agricultural sector has become more efficient resulting in lower land requirements. In this case, no land clearing is required. In the BAU scenario, no agricultural land becomes available. In this scenario, the cultivation of energy crops takes place at the cost of shrubland. The clearance of shrubland is a costly and time consuming process.

In both regions in both the BAU and the Progressive scenario, the discounted costs for switchgrass are lower than for Eucalyptus. This is mainly caused by the lower cost for planting as for switchgrass only seeds are required and for eucalyptus plantlets need to be planted. In addition, as the harvest of eucalyptus is only harvested every 7 years, compared to annual harvesting of switchgrass, the discounted yield of eucalyptus is relatively lower. In both scenarios, the cultivation cost of both switchgrass and eucalyptus is lower in Nampula compared to the Gaza-Inhambane region because of the higher agro-ecological suitability of the land available in Nampula.

Table A3.2: The impact of large scale bioenergy production from Eucalyptus and switchgrass on food security in the Gaza-Inhambane and Nampula region for the Business as Usual and the Progressive scenario in 2020.

🟩 ***Positive impact*** 🟨 ***Neutral or minor impact*** 🟥 ***Negative impact***

			Gaza-Inhambane				Nampula			
			BAU		PROG		BAU		PROG	
	Impact	Unit	EU	SG	EU	SG	EU	SG	EU	SG
	Food security									
	Food security	Qualitative	+/-	+/-	+	+	-	-	+	+

In Figure A3.13 the disaggregated cost of the entire supply chains of second generation ethanol from eucalyptus and switchgrass in the Gaza –Inhambane and Nampula region are depicted for the two scenarios. The cost of sizing and storage and conversion are independent form the location and are therefore the same for the two regions. The costs of transport are lower in the Gaza-Inhambane region because of a higher biomass density related to the higher concentration of available land. Although the costs of the feedstock are lower for switchgrass, the total cost of the supply chain is slightly higher compared to ethanol from eucalyptus because of the higher cost for primary transport and handling and storage of swichgrass compared to eucalyptus. This is mainly related to the lower density of switchgrass. The cost of the entire supply chain are lower in the Nampula region because the feedstock cost have a significant contribution to the total cost and the cost of feedstock are lower in Nampula because of the better agro-ecological conditions of the available land.

A3.3.2.5 Local prosperity

Mozambique is one of the poorest countries of the world and is ranked 184 out of 187 (in 2011) on the Human Development Index (UNDP). Within Mozambique there is a difference between the two chosen regions. Nampula is the most densely populated region of the two (and the second most densely populated province of Mozambique) and also has the lowest incidence of poverty, mainly due to the presence of its large harbour. The city of Nampula is the provincial capital and 12% of the population is concentrated in this city. In addition to agriculture, fishery is an important source of income for the population. Tourism is concentrated on Ilha de Mozambique, an UNESCO world heritage site, but there is potential for the sector to be developed further especially along the coastline. The port of Nacala is the deepest natural port of south and eastern Africa and is the starting port of the Nacala development corridor and services most of the land locked SADC countries. It has an installed capacity of 2.4 Mton and a terminal handling capacity of 45.000 TUEs3F[2][1] (Governo da Província de Nampula 2009). In addition, there are 3 very small ports in the Nampula province; Angoche, Moma and Ilha de Mozambique. In both provinces, the majority of the houses are thatched roofed huts made from reed, wood or bamboo. 60% of the households use paraffin, petroleum or kerosene for their energy supply (mostly in and around cities). In rural areas households generally rely on firewood. The region Gaza-Inhambane is much less developed and has higher poverty levels. The population density in Gaza and Inhambane is very low, especially in Gaza where villages are scattered. Gaza Province (together with Zambezia Province) have the highest rates of poverty incidence (59% - 70.5%)(UNADF 2012). The largest reduction in poverty rates from 2002/03 to 2008/09 was found in Cabo Delgao (-26%) and Inhambane (-23%) (DNEAP 2010).

A3.3.2.5.1 Direct impacts

Taking the amount of land that is required and available per region and the amount of jobs generated per hectare, the total number of jobs is calculated, see Table A3.3.

Figure A3.12: Net present value of feedstock cultivation cost for Eucalyptus and Swithgrass in the Gaza-Inhambane and Nampula region for the BAU and the progressive scenario, desaggregated for various cost items.

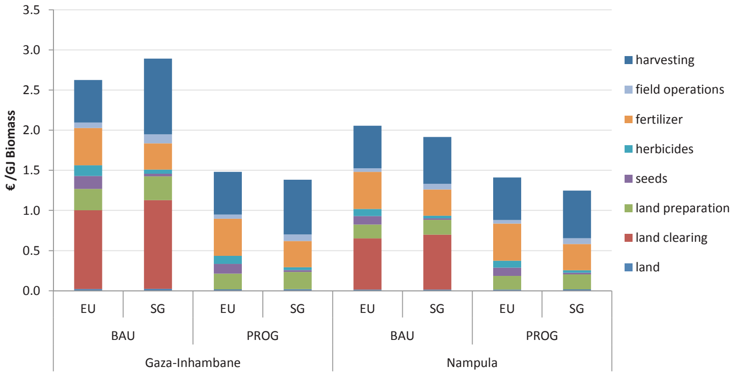
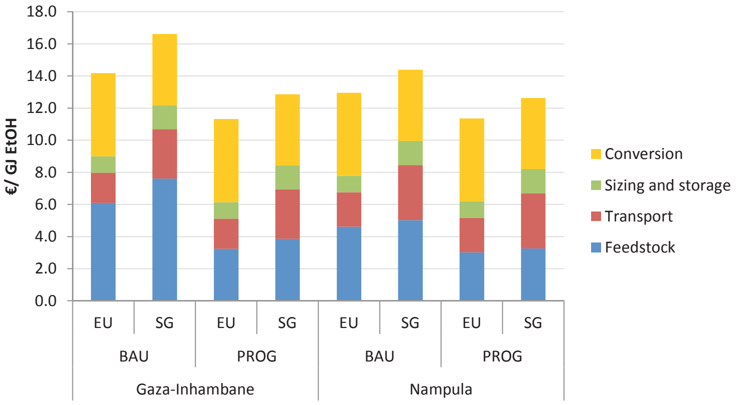


Figure A3.13: Cost of total supply chains (plant gate) of second generation ethanol from eucalyptus switchgrass in the Swithgrass in the Gaza-Inhambane and Nampula region for the BAU and the progressive scenario, desaggregated for various cost items. Distrbution or export of biofuel is not included.



In the progressive scenario, the amount of jobs and total investment in Gaza-Inhambane is lower than in the BAU scenario, even more than 50% in the case of Switchgrass. This is due to the higher yields and therefore reduced land requirements. However, this also means that multiple projects could be developed. In the Nampula region, the amount of jobs is higher in the progressive scenario, this is due to the fact that in the BAU scenario not enough land is available to obtain a 100% feedstock production. The total investment and total wages will have a great positive effect on regional GDP. This would even be larger if indirect employment effects would be taken in to account. These effects would have to be calculated by input-output analysis, but this was not possible for Mozambique due to lack of data. See for an example of an input-output analysis for Mozambique (Arndt *et al.* 2009) and (Arndt *et al.* 2011b). The total unemployed labour force in the region is much larger than the amount of jobs generated. However, labour migration might still occur because the labour figures do not reflect the large part of the population that consist of subsistence farmers, who may not be looking for employment labour. The total amount of wages

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[2] [1] Twenty foot equivalent unit

Table A3.3: The impact of large scale bioenergy production from eucalyptus and switchgrass on the local prosperity in the Gaza-inhambane and the Nampula region for the Business as Usual and the Progressive scenario in 2020.

🟩 ***Positive impact*** 🟨 ***Neutral or minor impact*** 🟥 ***Negative impact***

		Gaza-Inhambane				Nampula			
		BAU		PROG		BAU		PROG	
Impact	**Unit**	**EU**	**SG**	**EU**	**SG**	**EU**	**SG**	**EU**	**SG**
Local Prosperity									
Total jobs	X 1000 jobs	9.7	6.9	8.0	5.9	4.8	2.3	7.1	4.7
Local labour	%	100	100	100	100	100	100	100	100
Total investment	M€	260	297	208	230	157	127	201	226
Total wages	M€	10.1	7.1	8.3	5.8	4.9	2.4	7.4	4.9

Table A3.4: The impact of large scale bioenergy production from eucalyptus and switchgrass on the social well-being in the Gaza-Inhamban and Nampula region for the Business as Usual and the progressive two scenarios in 2020, based on the people directly affected by the project.

🟩 ***Positive impact*** 🟨 ***Neutral or minor impact*** 🟥 ***Negative impact***

		Gaza-Inhambane				Nampula			
		BAU		PROG		BAU		PROG	
Impact	**Unit**	**EU**	**SG**	**EU**	**SG**	**EU**	**SG**	**EU**	**SG**
Impacts									
Social well-being									
Total no of people affected[1]	X 1000 people	49	34	40	28	24	12	36	24

[1] It is assumed that the number of dependencies per employee is equal for both regions.

Table A3.5: Recommendations for best practice to enhance the labour conditions for a large scale bioenergy production project.[1]

	Recommendations for best practise
Child labour provisions (children in employment and hazardous work)	No children should be employed (farmers might ask their children to help)
Discrimination	Selection of employees should be based on skills and talent, tot on tribe or gender. Employees from all tribes should preferably be employed. Attention should be paid to employ a substantial number of female employees
Forced and compulsory labour	None should occur
Disciplinary practices	A warning system should be in place before dismissing
Safety	Safety regulations should be in place and communicated clearly to employees. Furthermore, protective wear should be provided to factory employees.
Freedom of trade union organisation	There should be freedom of association and right to organise; also contacts with labour unions should be facilitated.
Education/training	Courses can be provided depending on skills (e.g. computer skills, human resource, HIV/AIDS etc.)
Working hours	Working hours in Mozambique should not exceed 48 hours per week and 9 hours per day. Furthermore overtime should not exceed 96 hours per quarter, not more than 8 hours per week or 200 hours per year (Republic of Mozambique 2012)
Secondary benefits	Several secondary benefits can be provided such as: provision of meals, coverage of medical cost, provision of education for employee's children, provision of housing for staff living far from the workplace etc.

[1] Based on van Eijck *et al.* (2013)

is based on 1.5 times the minimum wage and only includes feedstock cultivation. This figure can potentially be much larger if conversion and transport is also taken into account and if higher wages are paid than 1.5 times the minimum agricultural wage (which is 32 €/month).

A3.3.2.6 Social well-being

Although both regions have very low enrolment in secondary education, the Nampula region is slightly better off since the number of students per teacher is lower. Nampula also has a higher number of healthcare centres and has much better transport facilities due to the presence of airport, ports and railways to Malawi (and in the near future to Tete province). This means however that a biofuel project in Gaza-Inhambane can potentially have a larger positive impact on social well-being if measures are in place to increase social well-being. Measures to increase social well-being can cover different aspects, for example: investment in education, health care, sanitation or infrastructure, furthermore services such as the provision of land clearing or ploughing equipment for private use by communities, providing fertilisers for a reduced price and so on, see e.g. (Van Eijck et al. 2013).

If it is assumed that five people depend on one employee, the total number of people that are impacted is shown in Table A3.4.

A3.3.2.7 Labour conditions

Labour conditions relate specifically to the implementation of a project, in Table A3.5 recommendations for project implementations are provided.

A3.3.2.8 Gender

Possible gender problems that can be associated with the production of liquid biofuels in general are often due to the lack of access to resources for women. Land ownership is often more difficult for women, and related to this, access to credit, because women do not have land that they can offer as collateral. Furthermore, if energy crops are planted on marginal land, this has a greater risk of pushing out women, since they are mostly the ones who collect commodities such as firewood from these grounds (Rossi and Lambrou 2008). Increasing land pressure increases the risk that women as well as other vulnerable groups (non-founding families and younger members of the community) lose their land access rights (Salfrais 2010). It is often women who cultivate food plots and have domestic tasks. Working as an employee on a plantation reduces the time available for these tasks, which still need to be fulfilled (Mota 2009; Arndt *et al.* 2011b). If plantation owners pay on a piece-rate basis, this can discriminate against women if the job requires physical strength. Plantation owners sometimes tend to prefer women workers because they feel they can pay them less (Rossi and Lambrou 2008). The study by Arndt et al. (2011b; Arndt *et al.* 2011a) showed that skills-shortage among female workers limits poverty reduction, and policy should therefore be addressed to increasing women's education.

Despite the fact that gender induced risks influence the sustainability of biofuel production, all biofuel strategies have to be gender sensitive. GEF should be ensure that women and female headed households have the same opportunity as men and men headed households to engage in and benefit from the sustainable production of biofuels. Especially for the growing number of households headed by women (42% in Africa), particularly in food insecure countries, the access of women to land must be ensured. This would improve the welfare of families and increase the agricultural productivity (FAO 2011) (Franke et al. 2012).

Favourable working hours at a plantation can enable women to keep tending their household food plots (Peters 2009). Other positive effects are related to increased energy access, which reduces women's tasks, such as collecting firewood and milling maize (Van Eijck *et al.* 2013).

A3.4 Detailed results for Argentina

A3.4.1 Environmental impact

A3.4.1.1 GHG emissions

A3.4.1.1.1 GHG emissions life cycle cultivation

The GHG emissions during the cultivation include the emissions from the diesel usage, the production of seeds, pesticides, herbicides and fertilizers and the direct N_2O emissions from nitrogen fertilizer application. In Figure A3.14, the GHG emissions in kg CO_2-eq per /GJ feedstock of switchgrass and soy care depicted for the two selected regions and for the two scenarios.

The GHG emissions related to the cultivation of switchgrass are in both regions under both scenario conditions almost all the same (3.7-3.9 kg CO_2-eq / $GJ_{Biomass}$) because in all settings almost the same maximum yield is achieved. The emissions for soy cultivation are much higher and also more variable for the two regions and for the two scenarios.. Cultivation of soy in the BAU scenario and especially in the Santiago del Estero region results in high GHG emissions (11.5- 21.9 CO_2-eq / $GJ_{Biomass}$) due to the relative low yields that are achieved. In the progressive scenario more suitable land for soy cultivation becomes available. Due to the higher yields per hectare, the GHG emissions per GJ biomass are lower (5.4 – 10.5 kg CO_2-eq / $GJ_{Biomass}$) . The GHG emissions of switchgrass cultivation are dominated by nitrogen related emissions, whereas the GHG emissions of soy cultivations have very low nitrogen related emissions (due to the N-fixation capacities of the crop). The emissions of soy cultivation are dominated by the emissions related to diesel usage. The GHG emissions are relatively uncertain, however, the uncertainties cannot be quantified because of a lack of information

Figure A3.14: GHG emission related to the cultivation of switchgrass and soy in in Buenos Aires and in Santiago del Estero for the BAU and the PROG scenario.

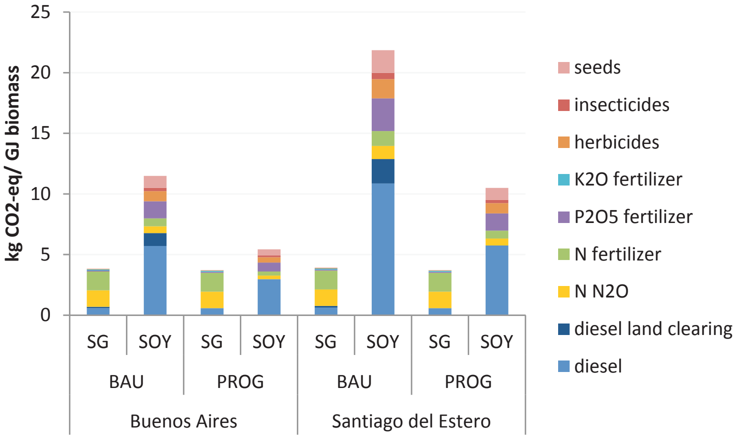


Figure A3.15: GHG emissions of switchgrass ethanol production and soy biodiesel in Buenos Aires and Santiago del Estero for the Business as Usual and the progresisve scnario including the emissions related to LUC and production chain (AGB = above ground biomass, BGB= Below ground biomass, SOC = soil organic crabon, LCA = lifecycle emissions). Ref depeics the GHG emissions of the fossil diesel / petrol reference.

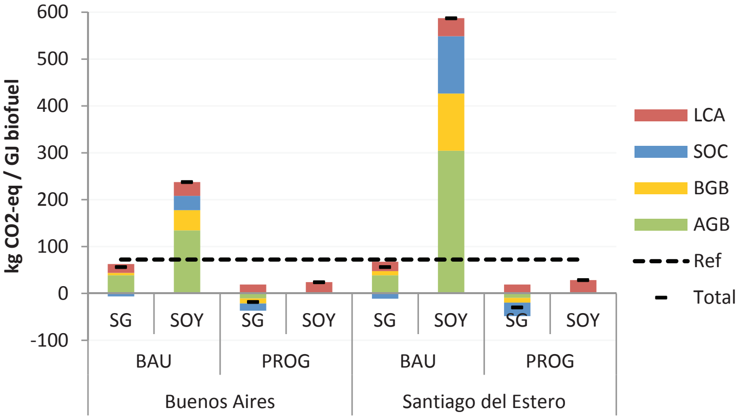
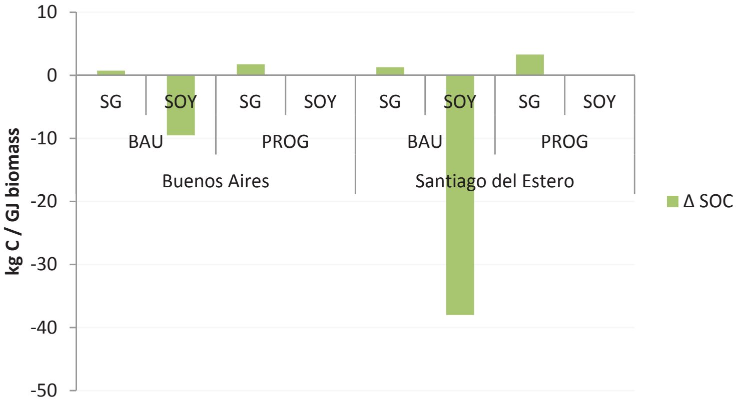


Figure A3.16: Change in soil organic carbon in kg C/ GJ$_{biomass}$ due to the conversion from current land use to switchgrass and soy cultivation.



A3.4.1.1.2 Total GHG impact

The total GHG emissions of the total lifecycle of bioethanol production form switchgrass and biodiesel production from soy including the GHG emissions are depicted in Figure A3.15. It includes the emissions related to LUC (changes in above and below ground biomass and in soil organic carbon) and emissions over the lifecycle (cultivation, transport and processing). In line with the IPCC (2006) and EU RED (EC 2009) a time horizon of 20 years is assumed. Consequently, the changes in carbon stocks are allocated to total biofuel production of 20 years. In Figure A3.15, the GHG emissions per GJ of the fossil reference is also depicted (±72 kg CO$_2$-eq / GJ).

The GHG emissions of soy biodiesel are very high in the BAU scenario (238 kg CO$_2$-eq / GJ biodiesel in Buenos Aires and 587 kg CO$_2$-eq / GJ biodiesel in Santiago del Estero). This is due to the high LUC related emissions. In the BAU scenario shrubland is cleared for the cultivation of soy which results in high losses of above and below ground biomass stocks and soil organic carbon. In Santiago del Estero, the soy yields per hectare are relatively low. Therefore, the GHG emissions LUC related GHG emissions per GJ biodiesel are very high. Also the emissions of switchgrass ethanol are high in the BAU scenario. Although the GHG emissions are still lower than GHG emission of petrol, little emission reduction is achieved in this scenario (22% in both regions. This is mainly related to the high carbon stock loss of above ground biomass when shrubland is converted to switchgrass.

In the progressive scenario, large GHG emissions reductions are achieved. The abandoned cropland is converted to switchgrass results even in a net carbon sequestration in above and below ground biomass and in soil organic carbon. The conversion of cropland to soy had no net effect on carbon stocks. The emission reduction in the progressive scenario is 125-141% for switchgrass ethanol and 60-67% for soy biodiesel.

A3.4.1.2 Soil

A3.4.1.2.1 Soil organic matter

The change in soil organic carbon is used as a proxy indicator for the change in organic matter content of the soils and therefore as an indicator of the quality of the soil. The change in soil organic carbon as a result of the conversion form current land use to energy crop production is calculated yet in order to assess the total GHG balance of bioenergy production. The change in soil organic carbon is expressed in Δkg C/ GJ biomass produced and is depicted in Figure A3.16. These figures are highly uncertain because of the high spatial variation in soil characteristics and the uncertainties in the interactions between crop and soil over time under different conditions. The change in soil organic carbon is discounted for 20 years: the total expected change in carbon is divided over the yield obtained in 20 years. The low soil disturbance and to the fertilizer use during switchgrass cultivation results in gains in soil organic carbon (0.74 and 1.17 kg C/ GJ$_{Biomasss}$ in the BAU scenario and 1.76 - 3.31 kg C/ GJ$_{Biomasss}$ in the Progressive scenario). In the BAU scenario when shrubland is converted to soy, soil organic carbon is lost (1.02 and 2.14 kg C/ $GJ_{Biomasss}$) due to the soil disturbance related to the cultivation of annual crops. In the progressive scenario there is no net change in SOC when cropland is converted to soy cultivation.

A3.4.1.2.2 Soil erosion

The soil losses due to water erosion are not included. The steep slopes which are prone to water erosion are already excluded for LUC in the land availability modelling. In addition, the regions assessed in this study have relatively flat landscape characteristics. The risk on soil loss due to wind erosion requires detailed data on planting dates, crop development over time, and harvest windows, in relation to the climatologically variations over time. In addition, the risk on erosion is highly affected by the management applied. Therefore, the changes in risk on wind erosion for the two regions, for the two crops under the two scenarios are only described qualitatively and recommendations to reduce the risk on erosion and best practices are provided.

The risk on erosion is high when the soil has a light texture, there is little soil moisture content, when there is a strong wind and there is little or no soil cover. In both regions, the soil characteristics are heterogeneous. The dominating soil classes in Buenos Aires and Santiago del Estero are Phaeozems, which are sandy loam soils which can be prone to erosion. In Buenos Aires the precipitation levels are relatively high (814 mm/year) and more equally distributed over the year. Therefore, periodic droughts and risk and therefore risk on erosion are relatively low. In Santiago del Estero the precipitation levels are lower (667 mm/year) and unevenly distributed over the year, with higher levels in the month November until March and low levels during the months April-October. Therefore, at the end of the dry season the soil is very dry and therefore more prone to erosion. In Buenos Aires, the monthly average wind speed varies between 4.1 and 5.6 m/s which is 3-4 Beaufort. The highest wind speeds are achieved in September. In Santiago del Estero, the average monthly wind speed varies between 2.6 and 3.6 m/s (2-3 Beaufort). As the higher wind speed do not coincides with the end of the dry season the risk on erosion is not very significant.

It is assumed that swichgrass is sown just before the rainy season. The just sown switchgrass provides little soil cover. However, during these first months, the soil is not very prone for wind erosion due to the high soil moisture content. After some months it provides full soil cover and avoids erosion. Switchgrass is harvested every year, after which stubbles remain which provide protection for wind erosion.
Soy is planted before the rainy season (October-December) and harvested in March –June. This means that the soil is bare during the dry season and that soil preparation takes place in the dry season. Therefore the conversion to soil increases the risk on erosion.

A3.4.1.3 Water

For the water use, two indicators have been selected. The water use efficiency (WUE) and the cumulative water deficit.

In Figure A3.17 the WUE is depicted in amount of biomass produced per litre water used. The water use is defined as the potential crop and location specific evapotranspiration. The higher the production of biomass per litre of water the better the water use efficiency. The water use efficiency expressed in a mass base is much higher for switchgrass. Although the water use over the year is much higher because of the ling growing season, the high yields of switchgrass results in relative high water use efficiency. The growing season of soy is relative short, but because of the relative low yields the water use efficiency is low. In Santiago del Estero, the WUE is somewhat lower compared to Buenos Aires because of the relative high evapotranspiration rate and the somewhat lower biomass yields.

However, to what extent the crop related evapotranspiration of dedicated energy crops lead to changes in seasonal water deficits compared to current land uses need to be determined by a water balance. This includes the monthly precipitation levels, the monthly evapotranspiration and the crop specific-growth stage specific crop-coefficients. This requires detailed information on the timing and development of the growth stages of eucalyptus and switchgrass in the two regions, which is not available yet. For this first order assessment, the growth stage specific Kc values of other perennial grasses and C4 crops have been applied for switchgrass (Based on the figures of Allan *et al.* 1998) and the crop and growth stage specific Kc values are applied for soy (Allan *et al.* 1998).

Figure A3.17: Water use efficiency in gram biomass per liter water for switchgrass and soy for the BAU and progressive scenario in Buenos Aires and Santiago del Estero. The WUE includes the crop and location specific evapotranspiration and the crop and location specific yield.

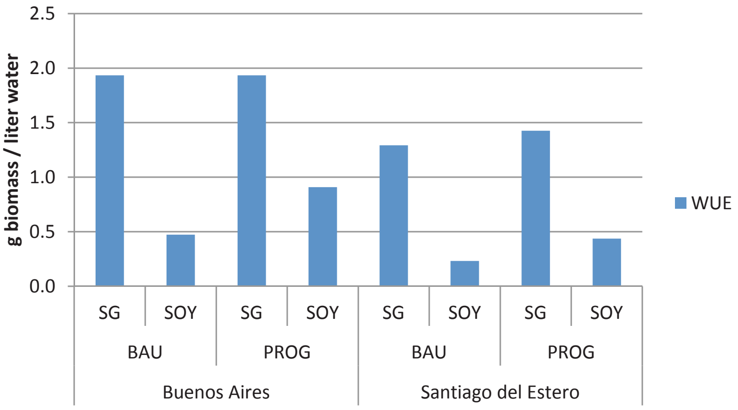
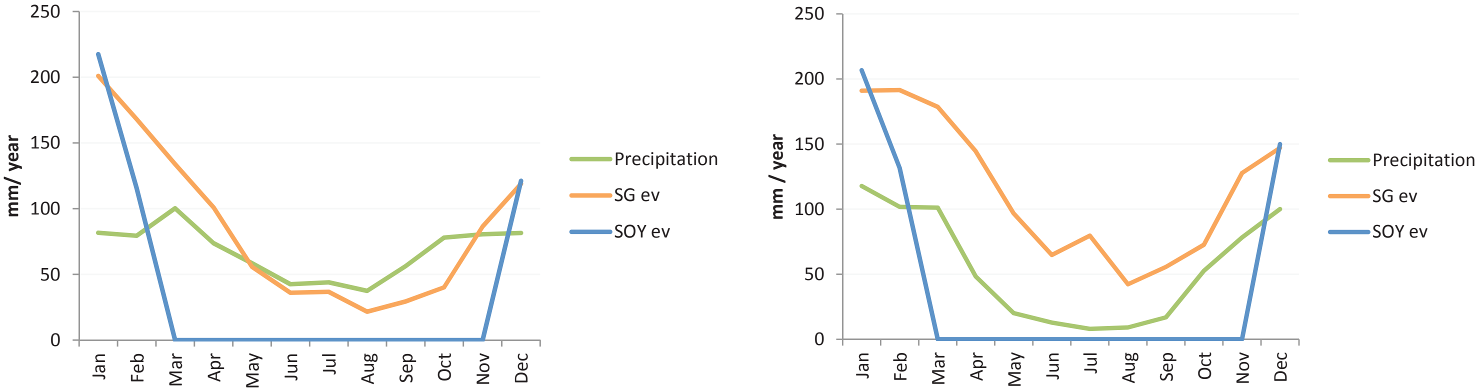


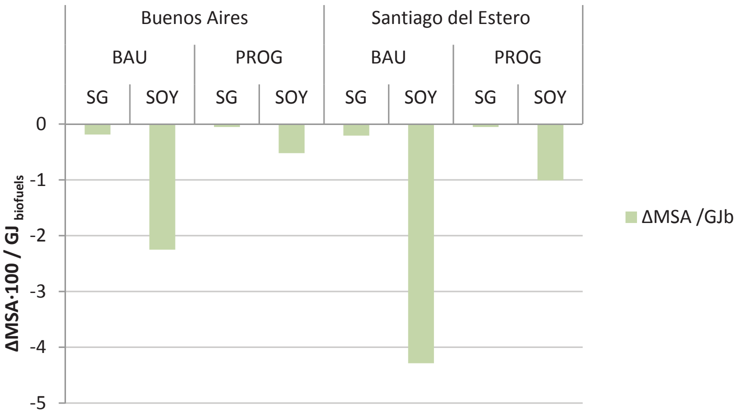
Figure A3.18: Monthly precipitation and crop specific evapotranspiration levels of switchgrass (SG ev) and soy (SOYev) in Buenos Aires (left) and Santiago del Estero (right).



The growth season of soy is only 3 months a year. Therefore only the water evapotranspiration in the growing season is taken into account. The evapotranspiration of soy exceeds the precipitation in the rainy season. However, as there is not evapotranspiration outside the growing season, the water shortage can be replenished. To what extent soy cultivation leads to draughts and to what extent these can be replenished depend on the excess of soy roots to ground water and the evaporation levels of the bare soil outside the growing season. However, there is little risk that the cultivation of soy will lead to increased droughts. The risk on crop failure when there is to sufficient access to water during the growing season is more significant. This risk is greater in Buenos Aires due to the lower precipitation levels during the growing season of soy compared to Santiago del Estero.

Because of the long growth stage of switchgrass and its high kc values, the evapotranspiration levels of switchgrass are high compared to soy. Especially in Santiago del Estero, cumulative water deficits can be significant as evapotranspiration continues during the dry months. Switchgrass is relatively drought tolerant. Therefore, the risks on crop failure due to water deficits are lower compared to soy. However, limited access to water will result in lower yields.

Figure A3.19: Change in cumulative mean species abundance per GJ biomass produced for switchgrass (SG) and soy in Buenos Aires and Santiago del Estero for the two scenarios (in Δ MSA value /GJ biomass x100).



Cumulative water deficit it neglects however groundwater level, flow schemes of the water basin and the water tables and hydrological dynamics. To what extent seasonal water deficits causes declining water tables and to what extent that limits the accessibility of the water for the plants depend on many variables such as rooting depth, soil depth, water tables, replenishing options from the surrounding environment etc. However, to assess this and to include the impacts from water stress on the evapotranspiration levels requires more complex hydrological models and very detailed spatial data on climate, soil, crop and hydrology which are not available for the selected areas. Therefore, water balance provides too little information to assess where actual droughts will occur and if this will result in damage to agricultural land and nature areas in the surroundings. In order to assess the actual effect on water tables it is recommended that more advanced hydrologic models are applied. Due to the limitations of this analysis, the results should be interpreted with care.

A3.4.1.4 Biodiversity

In the land use modelling step, the conservation areas and the national parks have been excluded for LUC. In addition, in the progressive scenario also forest and mangrove areas have been excluded. Therefore, considering these scenario conditions these areas are not affected by the implementation of large scale bioenergy projects. However, other high conservation areas, or important habitats of threatened species are other areas that could be of high biodiversity value have not been assessed due to a lack of data.

The Mean Specie Abundance indicator has been used to assess the effect of the LUC from the current land use to energy crop cultivation. The MSA is expressed in a value between 0 and 1 differentiated for different land use types. In this analysis, the current land use (shrubland or cropland), the new land use (switchgrass or soy), and the amount of hectares required to be converted in order to meet the input requirements of the conversion plant. Figure A3.19 shows the change in MSA per GJ biomass produced. In all settings the conversion from current land use to energy crops result in a negative impact on the Mean Specie Abundance. However, the impacts of the conversion from natural vegetation to soy have the most severe impacts on biodiversity. The impact of the conversion of extensive managed cropland to intensive cultivated switchgrass is only minor. This is also the result of the high switchgrass yields per hectare which results in low impacts per GJ biomass produced.

In the progressive scenario it is assumed that energy crops are cultivated on land previously in use as agricultural land which is abandoned because of higher agricultural productivity. However, it should be noted that the intensification of the agricultural sector in the progressive scenario will have a potential negative effect on the biodiversity as well. However, these effects are not quantified as this study only includes the direct effects of LUC.
The impact of large scale bioenergy production on biodiversity is mainly related to the design and the management of the project. There are many measures that can maintain and enhance biodiversity. The most important ones are:

- Avoid monocultures: scatter bioenergy crop / tree plots within natural areas
- Avoid clearance of native tree species within the bioenergy plots
- Maintain important corridors for key species
- Maintain natural vegetation in riparian areas
- Minimize disturbance within the field
- For forest plantations: maintain different plot in different growth stages to enhance diversity within the landscape.

A3.4.2 Socio-economic impacts

A3.4.2.1 Legality

Argentina has a supportive policy climate for liquid biofuels since late 1990. In 2001, a ‘Competitiveness Plan for Biodiesel’ was formulated, which allows for tax exemptions for 10 years on the fuel transfer tax on the national level, as well as for revenues and property to biodiesel producers on a provincial level. This policy shaped the biodiesel market until 2004/05 together with other legislative efforts. In 2006 a new law was approved that involved a regulatory and promotion regime for sustainable production and use of biofuels. It included a tax exemption of 15 years if certain criteria are met such as a certain ownership structure and quality and efficiency requirements by conversion plants. In 2008, the government approved four resolutions known as the “Law for Sustainable Use of Biofuels.” In essence the resolutions meant that all gasoline must have a 5% bioethanol mix (and diesel with biodiesel by an earlier law), by 2010. The main aim of this law was to increase attention and investments into ethanol production, diversifying the energy matrix of the country (J. A. Hilbert *et al.* 2011). Table A3.6 summarizes the legal framework.

The tax export rates of Argentina are also a significant factor in the development of the biofuels infrastructure. As the above described policy environment encourages competitiveness, the export tax of Argentinean are found to be 23.5 and 20 percent (as of 2006) for soybean and its byproducts respectively. Due to this export tax, the internal price of soybeans is 23.5% less than its international price. This means the competitiveness of Argentina’s soybean products is increased as a result of the comparatively lower internal prices (Costa *et al.* 2009).

Table A3.6: Legal and regulatory framework forethanol and biodiesel in Argentina.[1]

Resolution	Description
Resolution 120/01	Defines biodiesel.
Law 26.093/06:	Biofuels law. Biodiesel and ethanol mandates. Participating enterprises. Application Authority.
Decree 109/07:	Regulations for Biofuels Law.
Law 26.334/08:	Promotional law for ethanol.
Resolution 266/08	Registry of universities authorized to perform technical, environmental, and safety audits on biofuels plants.
Resolution 1293/08:	Mechanism for the selection and approval of ethanol production projects.
Resolution 1294/08:	Procedure and formula to determine the wholesale price of ethanol.
Resolution 1295/08	Quality specifications for ethanol.
Resolution 1296/08:	Fire safety requirements for biofuels plants.
Resolution 698/09:	Determination of the companies that are allowed to sell ethanol and their required volumes for 2010.
Resolution 733/09:	Establishes monthly capacity additions committed to by companies participating in the ethanol mandate.
Resolution 3/10:	Correction to Resolution 733/09.
Resolution 6/10:	Quality specifications for biodiesel.
Resolution 7/10:	Announces the list of producers that comprise the domestic mandate during calendar 2010, as well as the formula used to determine the wholesale price.

[1] The texts of each of the above legal framework can be found on CADER’s website at www.argentinarenovables.org/leyes.php in Spanish only.

Table A3.7: Land requirements and land right risks for Buenos Aires and Santiago del Estero in the Business as Usual and the Progressive scenario

		Buenos Aires				Santiago del Estero			
		BAU		PROG		BAU		PROG	
Impact	**Unit**	**SG**	**SOY**	**SG**	**SOY**	**SG**	**SOY**	**SG**	**SOY**
Land area required	Km^2	313	2835	313	1475	128	117	313	2856
% of required production	%	100	100	100	100	37	2	100	100
Land right risk		+	+	+	+	-	-	+	+

A3.4.2.2 Land rights

This analysis has both a quantitative and qualitative analysis.

A3.4.2.2.1 Quantitative analysis

The land analysis in the earlier section provides the % of required production that can be achieved in the regions per scenario. All land that is currently in use has been excluded. This means that if the potential feedstock production is 100%, the land availability is no issue in theory, see Table A3.7.

Only in the BAU scenario in Santiago del Estero, the potential feedstock production is below 100%, indicating problematic land availability. Soy has a lower production potential than Switchgrass in this scenario, only 2% of the total feedstock that is required can be produced in this region. The production in Buenos Aires is never below 100% indicating that land availability is not an important issue in that region (although other problems with land allocation can occur, see qualitative analysis).

A3.4.2.2.2 Qualitative analysis

The most important issues with land and land rights in Argentina stem from the massive purchases of land by urban and external investors, the increase of land prices due to amongst others, soy cultivation, the displacement of small producers in agricultural areas and new models of agricultural management with emphasis on leasing (Sbarra and Hilbert 2011; Sili and Soumoulou 2011). Because of the emphasis on leasing, land ownership is more and more separated from companies that use the land for production and companies that coordinate financial capital. Per type of player there are several issues that are specific for Argentina. Small-scale producers for example face structural difficulties when attempting to continue productive development due to their inability to improve production conditions. Medium-scale producers face fierce completion for land from external investors while issues surrounding large-scale producers or investors range from violent evictions, unsustainable use of natural resources (including impacts on biodiversity) and illegal control of water (Sili and Soumoulou 2011).

Furthermore, there are also institutional, legal and regulatory issues around land management. A lack of transparency in the land acquisition process is apparent. There have also been reports on irregular land administration processes by national and provincial agencies, and there is a lack of appropriate policies and instruments. Many provinces for example lack systemized information on land which contributes to an informal market for land (Sili and Soumoulou 2011).

Argentina's situation regarding land ownership concentration is quite remarkable. According to the 2008 agricultural census, more than 60,000 farms shut down between 2002 and 2008, while the average size of farms increased from 421 to 538 hectares (Sbarra and Hilbert 2011). The Buenos Aires region (Pampa region) is a core region for soy production while the Santiago del Estero region was historically not a location for soy until the introduction of technologically improved (RR) soy. In the Pampa region, the expansion of soy lands took place through the rent of land by different producers. In the case of Santiago del Estero the land expansion has been, on average, through the acquisition of lands by producers. This has been possible because of the lower prices of lands in this region at the beginning of the 2000s. This expansion means that most of the producers that own land in the Santiago del Estero province are from the Pampean Region (Sbarra and Hilbert 2011).

A3.4.2.3 Food security

Argentina does not have a widespread food security problem. Historically, in 2002, Argentina encountered a detrimental economic crisis resulting in a 57% of the population living below the poverty line (Sbarra and Hilbert 2011). Since then, the situation has improved with 6.5% living below the poverty line in 2012, compared with 38.3% the year before the crisis (CEDLAS 2012). Also, in 2009, the government intervened with a variety of measures e.g. a monthly sum of US$ 63 per child to working families under the poverty line (Sbarra and Hilbert 2011). Also the percentage of undernourishment of the population is <5 which is equal to developed countries (FAOSTAT 2012).

Pesticide use during cultivation of soy (and Switchgrass) can contaminate the land of small-scale farmers, including their water supply. This could pose a risk for them.

The land analysis excludes the amount of land in use for the cultivation of food crops, so the cultivation of soy and switchgrass should not lead to a decrease of food security. Since the current situation is already positive (people are food secure) employment in the sector can lead to an increased household income and thus increased food security. Therefore

Table A3.8: The impact of large scale soy and switchgrass production on food security in Buenos Aires and Santiago del Estero for the Business as Usual and the Progressive scenario.

		Buenos Aires				Santiago del Estero			
		BAU		PROG		BAU		PROG	
Impact	**Unit**	**SG**	**SOY**	**SG**	**SOY**	**SG**	**SOY**	**SG**	**SOY**
Food security	Qualitative	+	+	+	+	+-	+-	+	+

in Table A3.8 all scenarios except the BAU scenario in Santiago del Estero, have a positive impact on food security.

Even in the BAU scenario for Santiago del Estero, wages can compensate for any loss of food production.

A3.4.2.4 Economic analysis

For the two selected regions in Argentina, the economic viability is assessed by calculating the net present value of the cultivation cost and the net present value of the cost of the entire supply chain up to plant gate. The distribution of biofuels within the country or the export of biofuel to other countries is not included.

In Figure A3.20 the disaggregated net present values of the cultivation cost in euro per GJ biomass of switchgrass and soy in Buenos Aires and Santiago del Estero for the BAU and progressive scenario are depicted. The costs for soy are much higher compared to switchgrass due to the lower yield (in GJ biomass /ha / year) of soy and the relative intensive management in terms of inputs and field operations. The costs for soy are especially high in Santiago del Estero in the BAU scenario; this is due to the very low yields that are achieved here. In general the costs are higher in the BAU scenario compared to the progressive scenario because in the BAU scenario, the cost of land clearing are included and in less suitable areas are available for energy crop production.

In Figure A3.20, the cost of switchgrass ethanol and soy biodiesel (in €/ $GJ_{biofuel}$ at plant gate) are depicted for the two regions and the two scenarios. The cost of sizing, storage, crushing and conversion are assumed to be equal for the two regions. The cultivation costs of soy are allocated based to soy biodiesel based on the energy content. The costs for soy biodiesel production in Santiago del Estero in the BAU scenario are very high, because of the high feedstock cost (see Figure A3.20). The cost of switchgrass ethanol and soy biodiesel per GJ end product are almost equal when the suitability for the cultivation of switchgrass and soy are similar, for instance in Buenos Aires in the progressive scenario where both crops achieve maximum yields. However in all other settings, the suitability of the available land is much higher for switchgrass compared to the suitability for soy. Therefore, the overall costs of switchgrass ethanol production are lower compared to soy biodiesel.

Figure A3.20: Cultivation cost of Swithgrass and Soy in Buenos Aires and Santiago del Estero for the Business as Usual and the Progressive scenario, desaggregated for various cost items.

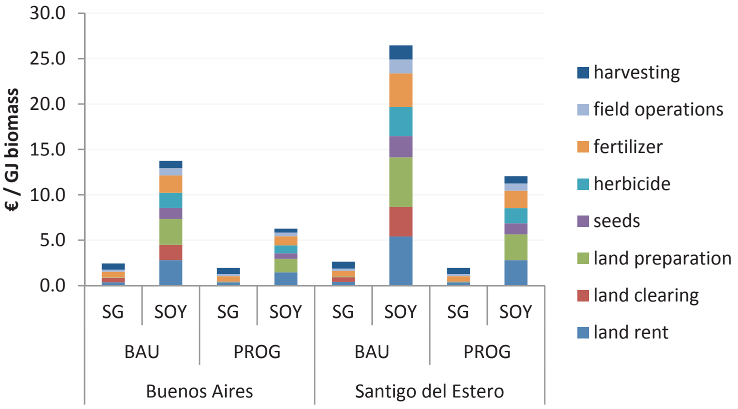
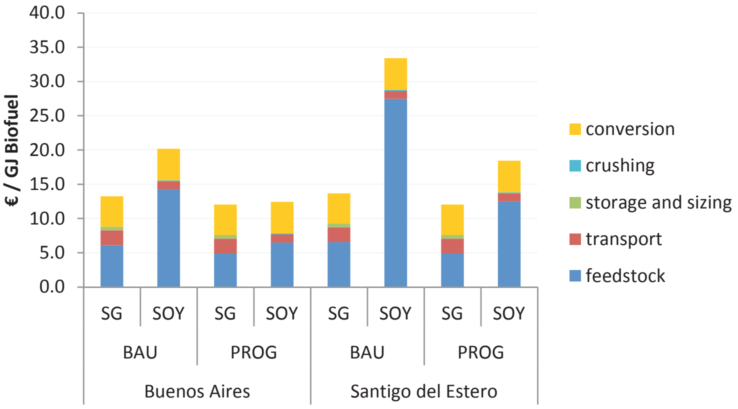


Figure A3.21: Cost of total supply chains (plant gate) of second generation ethanol from switchgrass and biodiesel from soy in Buenos Aires and in Santiago del Estero for the Business as Usual and the progressive scenario, desaggregated for various cost items. Distrbution or export of biofuel is not included.



A3.4.2.5 Local prosperity

Argentina is relatively wealthy, with per capita income estimated at U.S. $ 15,800 (at purchasing power parity) by 2010, reaching place 52 on a total of 178 countries surveyed by the International Monetary Fund. Poverty has declined since the economic crisis of 2001, while the Gini index declined from 0.541 in 2003 to 0.442 in 2010. In terms of production structure, the agricultural sector represents 10% of GDP, industry 20.7% and services 60%, measured at current prices. Other important sectors are construction and mining, representing 5.7% and 3.6% respectively. During the last twenty years Argentina's economy went through a series of reforms that allowed it to modernize its production equipment (J. A. Hilbert *et al.* 2011). The unemployment rate is 8.2% in Argentina (2010). But unemployment is rising in the whole of Argentina (personal communication INTA, Argentina).

Santiago del Estero is in one of the most marginalised regions of Argentina. The total population is 874,000 (2010). The main crops are soy (>800,000 ha planted and 3M ton production), maize (>130,000 ha planted and 600,000 ton production) and wheat (>130,000 and >200,000 ton production). In Santiago del Estero, 21 259 people out of the total population are unemployed (INDEC 2010). In 2012 10% of the people in Santiago del Estero are unemployed (personal communication INTA Argentina).

In the region of Buenos Aires, the unemployed population is 489 510 people (INDEC 2010). The official rate in 2012 is almost 7% and 8% for the first half of 2013 (personal communication INTA Argentina). The amount of jobs generated in feedstock production differs per crop. The average per hectare is 0.03 for switchgrass and 0.005 for soy or one job per 200 ha (J. M. Dros 2004). The impacts on local prosperity are summarised in Table A3.9.

In both regions there is enough local labour available to fulfil labour requirements, so no labour migration is required. The total employment, investment and total wages will have a great positive effect on regional GDP. This would even be larger if indirect employment effects would be taken in to account. Furthermore, only feedstock production is included, the total amount of jobs is larger if also transport and conversion is taken into account.

A3.4.2.6 Social well-being

Santiago del Estero is a more marginal area of the country compared with Buenos Aires. It is the least urbanized and one of the poorest. The cultivation of soybean has increased over the years and is now the driving force in this region (and others), leading to expansion of the agricultural areas into previously marginal areas. These areas are often occupied by peasants (known as 'campesinos'), with precarious land tenure (see section land rights). They have already experienced forced evictions by powerful landowners and companies (Wald and Hill 2011).

Further evidence of the negative impact that can be introduced by large-scale farming on small-scale farmers is also seen in a study done by Arza et al. (2012) on how technological change benefits (and disadvantages) farmers in Argentina. Small-scale farmers are negatively impacted by the shift towards genetically modified technologies. These technologies require more advanced inputs that most small-scale farmers do not usually have. While at the same time, the technical assistance for non-GM seeds is reduced and those seeds are less and less available (Arza *et al.* 2012).

These issues could present a problematic issue for the sustainability of large scale production of biofuels, particularly in Santiago del Estero. The high unemployment rate in the province, however, could benefit from the introduction of supply chains.

A3.4.2.7 Labour conditions

In Argentina many labour conditions are regulated by laws and regulations. Section 14 of the constitution is responsible for establishing worker's rights, such as equitable working conditions, limited working hours, paid rest and vacation, fair remuneration, minimum vital and adjustable wage, equal pay for equal work, participation in the profits of businesses and enterprises, protection against dismissal given with no reason, and democratic labour unions. The workers also have a right to strike, to enter collective bargaining, and union's representatives are protected.

Table A3.9: Impact of large scale biofuel production on local prosperity in Buenos Aires and Santiago del Estero in the Business as Usual and the Progressive scenario.

		Buenos Aires				Santiago del Estero			
		BAU		PROG		BAU		PROG	
Impact	Unit	SG	SOY	SG	SOY	SG	SOY	SG	SOY
Total jobs	jobs	940	1417	940	738	384	59	940	1428
Local labour	%	100	100	100	100	100	100	100	100
Total investment	M€								
Total wages [a]	M€	10	15	10	8	4	1	10	15

[a] based on 57 $/day (Sbarra and Hilbert 2011) and 240 days/year

A3.4.2.7.1 Wages and labour contracts

In the soy sector a lot of the work (feedstock production, conversion, transport) is seasonal. The non-registered salaries reflect the salary of seasonal workers (mainly in agriculture) and they have increased considerably since 2005 (CEDLAS database (Sbarra and Hilbert 2011). The contract of employment is usually seen to be concluded for an unlimited period of time. Fixed-term contracts of employment are permitted to be concluded, in writing, as long as they are not concluded after more than 5 years. A contract for casual work can also be concluded if exceptional and temporary requirements are met. Part-time work and apprenticeship contracts can also be concluded. The first three months of a contract are a probation period during which both parties can terminate the contract at any time, as long as the contract has been registered with the authority in charge. Probation can be extended to 6 months by way of collective agreement. The contract of employment can also be suspended on grounds such as illness, maternity leave, holding of public or trade union office, and military service. Lack of work due to decreases in demand are also grounds for suspension, as well as disciplinary reasons (ILO 2013).

A3.4.2.7.2 Health insurance

In Argentina also access of workers to health insurance is registered. In 2010 nearly 65% of the workers had access to this type of insurance, which was around 56% in 2003 (CEDLAS database (Sbarra and Hilbert 2011).

A3.4.2.7.3 Pension

In 2007 the pension system has changed in Argentina, from being both private and public to only public. From this period onward the percentage of workers that have a right to receive a pension later has increased from around 56% to around 65% (INDEC, (Sbarra and Hilbert 2011).

A3.4.2.7.4 Working hours

Legal working time in Argentina is eight hours a day and forty-eight hours per week. The regular working week does not exceed 44 hours for daily work, 42 for nightly work, and 36 hours in hazardous conditions. Saturday afternoon and Sunday are not typically permitted days for work (ILO 2013). The primary law is the Employment Contract Law No 20,744 ("LCT"). The Law No 11,544 is also significant and regulates matters such as working hours (Sbarra and Hilbert 2011).

Union agreements

The Law No 14,250 (1953) regulates all matters concerning Union Agreements, i.e. agreements entered into between entities representing the relevant workers and businesses. The law is still in force to date, but with amendments, the latest of which is the Law No 25,877 (2004). Law No 23, 551 provides legislation in relation to trade unions. Finally, the Law No 14.786 regulates union disputes and the Government's role therein (Sbarra and Hilbert 2011).

A3.4.2.7.5 Occupational health and risks

Law No 24,557 refers to occupational accidents and professional diseases. The Laws Nos 24,013 and 25,323 provide increases to labour indemnities in the event of labour fraud, and also –in the former case– it regulates various matters on the subject of employment. In terms of risk law , the Occupational Risk Law No 24,557 (LRT), as regulated, provides the regulatory environment for an occupational accident and certain professional illnesses included in a list prepared by the National Executive (Sbarra and Hilbert 2011).

A3.4.2.7.6 Secondary benefits

The law provides a system of payments in kind (medical and pharmaceutical assistance; prostheses and orthopedic items; rehabilitation; professional re-qualification and funeral services) and money payments (as a lump-sum or in instalments; referring to temporary or permanent disability to work; which may be temporary or final, in whole or in part; gross disability; death) for the benefit of a worker (or its successors), which contemplates any contingencies sustained by the worker, and the subsequent rehabilitation and occupational re-insertion thereof (Sbarra and Hilbert 2011).

A3.4.2.8 Gender

Maternity leave is regulated by law. It is not permitted to employ female workers 45 days before and after they have given birth to a child. The worker can request this period to be reduced to 30 days before childbirth – hence lengthening the post birth leave to 60 days. During her leave, she is to receive cash benefits from the Social Security funds. The employer also cannot terminate the worker's contract during her pregnancy and maternity leave related to her pregnancy. The employer is responsible for proving that this termination is unrelated to the pregnancy. Any dismissal within a period of 7.5 months before and after her childbirth is presumed to be related to her pregnancy provided that the worker has submitted a certificate of proof that she is pregnant. If the employer is not able to prove that their dismissal is unrelated to the pregnancy, they are required to pay the worker one year's worth of salary in addition to severance pay and notice that are typically due for regular termination. The worker is also entitled to receive two daily breaks in order to breastfeed her child (ILO 2013).

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Abbreviations

AGB	Above Ground Biomass
BGB	Below ground Biomass
BAU	Business as Usual
CA	Cellular Automata
CLUE	Conversion of Land Use and its Effects
CO_2-eq	Carbon dioxide equivalent
DUAT	Direito de Uso e Aproveitamento da Terra (land Use Right)
EF	Emission Factor
EU	Eucalyptus
ET	Evapotranspiration
EtOH	Ethanol
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GI	Gaza-Inhambane
GIS	Geographic Information System
GJ	Giga Joule
Ha	Hectare
HAZ	Homogeneous Agro-economic Zones
HHV	Higher Heating Value
IIAM	Instituto de Investigação Agrária de Moçambique
iLUC	Indirect Land Use Change
INTA	Instituto Nacional de Tecnologia Agropecuaria
Kc	Crop Coefficient
km	Kilometre
LCA	Lifecycle assessment
LHV	Lower heating Value
LU	Land Use
LUC	Land Use Change
m	meter
m^3	Cubic meter
M	Million
MC	Monte Carlo
Mha	Mega hectare
Mm	Millimetre
Moz	Mozambique
MSA	Mean Species Abundance
Mt	Megaton
MW	Mega Watt
N	Nampula
NPV	Net Present Value
NUTS	Nomenclature of Units for Territorial Statistics
Odt	Oven Dried Tonne
O&M	Operations and Maintenance
PLUC	PC Raster Land Use Change
PPP	Purchasing power Parity
PROG	Progressive
RUSLE	Revised Universal Soil Loss Equation
SD	Standard Deviation
SEC	Scientific Engineering Centre
SG	Switchgrass
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SRC	Short rotation Coppice
SSR	Self Sufficiency Ratio
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
WEQ	Wind Erosion Equation
Y	Year

ENERGY AND CLIMATE CHANGE BRANCH

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