Identifying Responsible Cultivation Areas in Mozambique

Guidance for indirect impact assessments on 'unused land' and input for developing a certification module for Low Indirect Impact Bio-fuels for the RES-D

Acknowledgement

We express our gratitude to AgencyNL, from the ministry of Economic affairs, agriculture and innovation for their financial supporting the project Certification System addressing Indirect Impact of Bio-fuels. We also very much appreciated the support of the staff in the Ministry of Agriculture and Forestry in Mozambique for their participation in this project and we thank Ecofys, the Roundtable of Sustainable Bio-fuel our collegues in WWF, in particular, those making a direct contribution to the model: Victoria Junguera, Vivian Schuller, Japer van der Staaij and Ana Robiero.

The authors of the document are: Hans Harmen Smit,
Heko Koster
Gabriel Albano
Joachim Macuacua

The project was coordinated by: Laszlo Mathe
Rito Mabunda
Hans Harmen Smit

Executive Summary

Background

Bio-energy production has seen a sharp growth in recent years. Key drivers include aims for reduction of greenhouse gas emissions, promoting energy security and rural development. Future energy scenarios with high contributions from renewable energy show bio-energy will play an important role. Especially in the transport sector, where few alternatives are available, the use of bio-fuels is stimulated. One of the key challenges of sustainable bio-energy are dealing with indirect effects of bio energy feedstock production, especially Indirect Land Use Change (ILUC). We have put forward four main solutions to expand biomass usage for energy purposes without unwanted consequences from ILUC. For this pilot in Mozambique, we will focus on: Bio-fuel production on land not currently in use, or used with a low intensity. Since 2008, WWF International, Ecofys, Conservation International and Winrock have developed a methodology to identify such areas and/or production models for bio-energy feedstock production with a low risk of indirect effects, also referred to as Responsible Cultivation Areas (RCA's).

Methodology

The RCA concept takes into account the needs of *market players*. This requires it to be feasible at the level of *individual production units*. This is in contrast to methodologies that aim to identify the national or global (sustainable) potential for energy crops or agricultural expansion in general. In the RCA methodology, an area is considered suitable for "responsible cultivation" if it is ensured that the area 1) can be used for environmentally and socially responsible energy crop cultivation, and 2) such energy crop cultivation would not cause unwanted indirect effects. The methodology follows five principles:

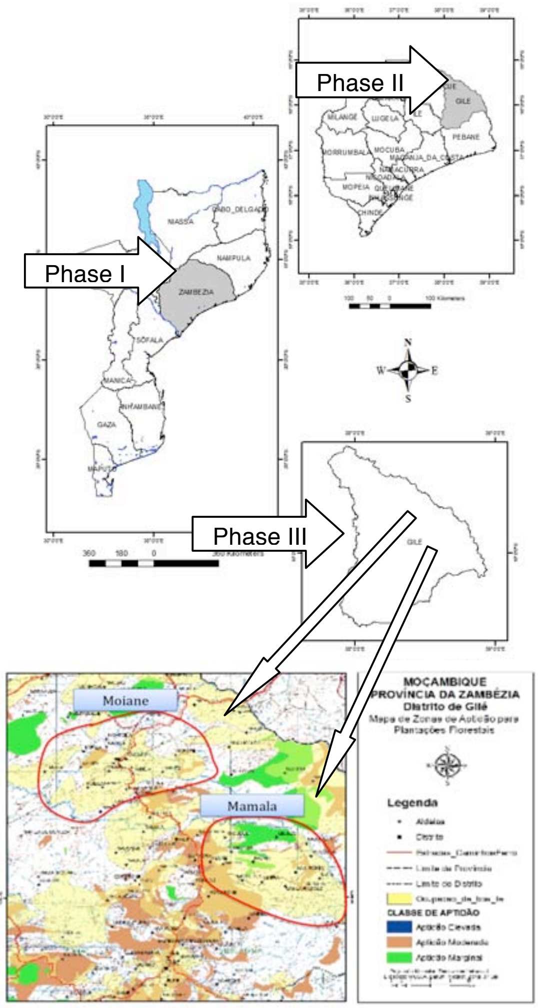
1. High Conservation Values are maintained or enhanced
2. Carbon stocks are maintained or increased
3. Legal claims are respected
4. Unwanted displacement effects are avoided
5. The area is agriculturally suitable

The RCA methodology uses a four-step process to identify RCA's (see also figure 2.1). The process starts on a large scale with coarse and readily available information to quickly identify the most promising areas (Site Pre-Selection). Next, a more detailed assessment is performed on these promising areas to further refine the Pre-Selection of promising areas (Desk-Based Assessment). In the third step, the fieldwork has the purpose to verify the results of the first two steps and to fill all remaining knowledge gaps. In step 4, all of the collected information is evaluated to determine whether (a part of) the area classifies as an RCA

Results

In phase I, we found several species of known high conservation value outside the existing conservation. We therefore recommended that in phase II specific attention should be paid to the distribution of species included in the Red list species of IUCN. It was found that only annual cropland or grassland can be used for *Jatropha* and meet the minimum 35% GHG savings requirement in the RES-D. On land use rights, phase I identified the limited capacity of administrative bodies in performing their statutory functions as root of the conflicts between users. With regards to land use it was estimated that only 10 percent is presently in productive use. Due to application of shifting cultivation practices, it was considered unlikely to find areas that are 'unused', but rather 'underused'. Finally, in phase I it was found that the yield of *Jatropha* shows a wide variation, and that the expectations of *Jatropha* seem to have been overly optimistic, especially regarding the potential production under marginal conditions. The province of Zambezia is considered to contain the most land that is moderately suitable, and therefore the most likely province for finding candidate areas in line with the RCA criteria. Therefore, Zambezia was selected for more in depth analysis for phase II.

In phase II it was recommended to select a research area outside existing conservation areas including associated bufferzones, all riparian zones as well as forest areas (including miombo) and coastal zones. Fort the field assessment the presence of the RED list species has to be assessed based on direct observations in the field and interviews with local communities. Also the carbon stock have to be measured in representative plots on site. Areas with dense populations should be avoided, and specific attention should be paid to the land claims of the communities. Land with relatively long rotation cycles was preferred, to increase the options for additional production. Based on the recommendations of phase II Gile district was selected, due to a relatively low population density is the central east of Gile district, and the expectation that documentation land (use) rights exists.



In phase III we found that HCV values are present in the area, but if appropriate management practices implemented with regards to the identified HCV's the principle 1 could be complied with. Principle 2 can also be complied with if grasslands are used, all other vegetation types were found to have higher carbon stocks that are unlikely to lead to a GHG saving above 35% (the target for the RES-D until 2017).

With regards to land rights, we found a multitude of overlapping claims on the site in Moiane. There are several overlapping claims on the land (forest concessions, mining concessions, immigrants and local communities) in the areas, and it seems that communities are not involved or informed about land use planning decisions. In Mamala overlapping claims also exist, but this is mostly between community members. This has not let to serious conflicts yet, and may be manageable. If people can come to consensus on their claims. We concluded only the area in Mamala can comply with principle 3.

Conclusion

As was expected from the desktop, there is no 'unused land' on the research sites. There are two major constraints on starting with bio energy feedstock production in general by smallholders in Zambezia, the lack of industrial, bio energy generating plant and the low technology level present in the communities. As a result of the increasing population density, fallow periods are relatively short, and are expected to even decrease even more. The communities currently actively use 45%, of their community land and 45% is in fallow, partly covered by re-growth and woodland. By providing the communities with fertilizers and training them in best management practices land use can be optimized, and current production is expected at least to double with moderate input. Unless the local farmers are facilitated implementing better management practices, here is thus a considerable risk for displacement, in particular of food production. Therefore, if and only if yield improvement measures are successfully implemented and food production is increased indirect effects are prevented.

Recommendations

- Based on our findings we recommend to identify future candidate conservation areas, since several areas with important conservation values outside existing conservation areas were found. In the identification of an area suitable for plantation development with regards to GHG emission the focus should be on grassland areas with low biodiversity value and no trees.

- With regards to land rights, interviews and participatory mapping with local communities is strongly recommended, since their rights are unlikely to be registered nationally.
- The land use was found very extensive, and 'unused land' is not likely to be available, rather 'underused land'. Due to the current low level of inputs and technology, the potential for intensification in Mozambique is high. If production can be intensified, it is likely a significant part of the land used can be made available other uses without displacement. It is important to manage the remaining lands sustainably, because even though part of fallow lands could be used, this would reduce the length rotation cycle and result in a increased decline in productivity due to nutrient mining.
- The potential of *Jatropha* as a sustainable bio energy feedstock is questioned by us. Comparing the inputs and production of *Jatropha* with several other potential energy crops let to the conclusion there are more suitable candidates for sustainable bio energy production. Based on the experience and uncertainty regarding *Jatropha* yields, other feedstock should be considered: potentially cassava and coconut. Since *Jatropha* is, like other crops, just as depended on inputs for an economically viable production, it is by no means the ideal candidate.
- In case of certification of ILUC specific attention should be paid to setting the baseline and the expected additional production. Only if the intensification of community land is guaranteed, the production of bio energy feedstock be considered 'additional'.

Content

Figures

§1: General introduction: Background CIIB and objectives study

Background

Indirect effects of bio-fuels form one of the key challenges of sustainable bio-energy. Since 2008, WWF International, Ecofys, Conservation International and Winrock have developed a methodology to identify areas and/or production models for bio-energy feedstock production with a low risk of indirect effects, or Responsible Cultivation Areas (RCA's). The next step is to take the RCA methodology to the next level – that is: to develop the methodology into a certifiable module for bio-fuels with a low risk of causing indirect impacts, including indirect land use change (ILUC) and displacement of food and other provisioning services. This certification module can be incorporated into voluntary schemes, such as the Roundtable on Sustainable Bio-fuels (RSB), as well as into regulatory schemes, such as the bio-fuel and bio-liquids sustainability scheme of the European Renewable Energy Directive (RED). A certification will allow operators to make certain claims with regards to the ILUC risks.

The importance of bio-energy

Bio-energy production (non-traditional uses) has seen a sharp growth in recent years. Key drivers include reduction of greenhouse gas emission, energy security and rural development. In all future energy scenarios with high contributions from renewable energy, bio-energy plays an important role. Especially in the transport sector, where few alternatives are available, the use of bio-fuels is stimulated. Developing a successful and sustainable bio-energy sector is therefore of key importance.

Concerns about the sustainability of bio-energy

The sharp increase in bio-energy production, and especially bio-fuels, has led to concerns about the sustainability of such large-scale production. Key concerns include direct effects such as deforestation, loss of biodiversity and land right conflicts, as well as greenhouse gas emissions resulting from land use change and other emission sources in the bio-energy supply chain. While still in their infancy, an increasing number of voluntary and regulatory initiatives aim to tackle these direct effects. One of the key unresolved sustainability issues around bio-energy are indirect impacts, including indirect land use change (ILUC) and associated effects such as loss of biodiversity and other ecosystem services, as well as effects on food security and rising food prices. Indirect effects can occur when bio-energy feedstock production displaces other land production functions such as food production or cattle farming. For a sustainable and credible future of the bio-energy sector, assuring the sustainability of bio-energy, including direct and indirect effects, is of high importance.

The need for practical solutions to prevent Indirect Impacts

Most of the current work on indirect impacts is focused on 'sizing the problem' – to estimate the amount of indirect impacts from a certain amount of bio-fuels and the GHG-emissions.

Preventing Indirect Impacts at the project level – what companies can do

Four main solutions at the project level have been put forward to expand biomass usage for energy purposes without unwanted consequences from ILUC. In Mozambique, we will focus on: Bio-fuel production on **land not currently in use**, **or used with a low intensity**. Because this does not displace human uses it does not cause an ILUC. Clearly, expanding production on unused land does leads to a direct land use change (LUC). The big difference is that direct LUC is controllable (e.g. through impact assessments and certification) and can be limited to those areas where effects are acceptable, while the effects of indirect LUC are uncontrollable.

Associated with this, several studies have also estimated the effect of bio-fuel mandates on food commodity prices. While understanding the size of the problem is clearly relevant, this should be complemented by an understanding of how bio-fuels can be produced without (or with a minimum risk of) indirect impacts. This is especially relevant as most of the results so far indicate that GHG-effects from ILUC to be significant. What is needed is a certification module that can distinguish and credit bio-fuels with a low risk of indirect impacts. Only then can we continue bio-fuels without the unwanted negative indirect impacts.

§2: Methods: RCA and HCV assessments

Summary of the RCA methodology

The RCA concept takes into account the needs of ***market players***. This requires it to be feasible at the level of ***individual production units***. This is in contrast to methodologies that aim to identify the national or global (sustainable) potential for energy crops or agricultural expansion in general. The RCA concept is also useful for other parties such as (national) governments and NGOs. In the RCA methodology, an area is considered suitable for "responsible cultivation" if it is ensured that the area 1) can be used for environmentally and socially responsible energy crop cultivation, and 2) such energy crop cultivation would not cause unwanted indirect effects. The methodology follows four principles (see also textbox RCA principles and criteria) and adds one additional dimension for practical reasons – agricultural suitability. The agricultural suitability of potential RCAs is taken into consideration throughout the identification process to ensure its suitability for energy crop cultivation. This leads to the following five aspects that are evaluated in the identification of RCAs (see also Appendix 2):

6. High Conservation Values are maintained or enhanced
7. Carbon stocks are maintained or increased
8. Legal claims are respected
9. Unwanted displacement effects are avoided
10. The area is agriculturally suitable

Four step process

The RCA methodology uses a four step process to identify RCAs (see also figure 2.1). The process starts on a large scale with coarse and readily available information to quickly identify the most promising areas (Site Pre-Selection). Next, a more detailed assessment is performed on these promising areas to further refine the Pre-Selection of promising areas (Desk-Based Assessment). In the third step, the field work has the purpose to verify the results of the first two steps and to fill all remaining knowledge gaps. In step 4, all of the collected information is evaluated to determine whether (a part of) the area classifies as an RCA (for more details on the application of the methodology in the context of Mozambique see Appendix 2.0 and 2.1).

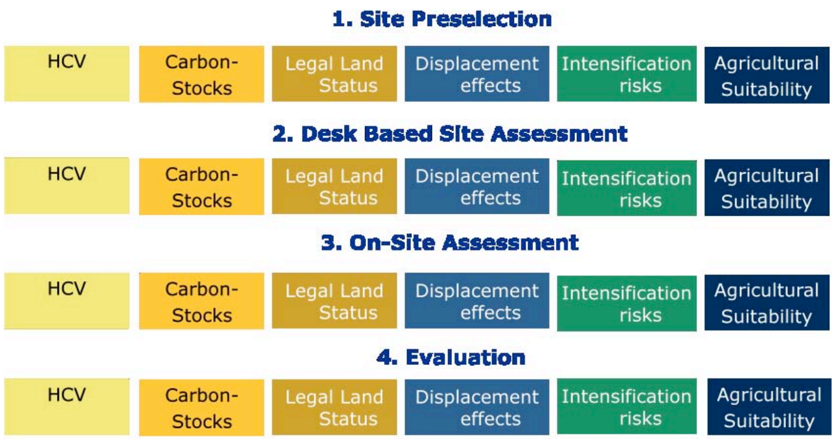


Figure 2.1: Four step process to identify RCAs. Source: Ecofys, 2011

§3: Phase I: National level assessment

Background bio-fuel production Mozambique

Since 2005, there has been a growing interest in bio-fuels production in Mozambique motivated by the rising oil prices, climate change and concerns about future energy supplies. Such interest is also driven by the favorable growing conditions and the availability of land, water and labor. In addition, there is the potential of bio-fuel production to reduce fuel import dependency and create rural employment. As result, in 2009, the government of Mozambique approved the police and strategy of bio-fuels that will enable the large-scale production of bio-fuels feedstock such as sugarcane and sorghum for the production of ethanol and *Jatropha* and coco-nut for the production of bio-diesel (Agro-fuels, 2010).

Large scale production of bio-fuels would need adequate implementation for their sustainability and of the agricultural system. Although there is long term accumulated experiences of large scale production of sugarcane and coconut for sugar and copra production, research on effects and possible impacts of these crops for bio-fuels production is needed to ensure that their production do not result in displacement of food crops or other negative effects on agricultural system. The production of *Jatropha* for commercial purposes is new. The crop has been growing in the country as a live fence or hedge. Commercial production of the crop need clear assessment of its agricultural suitability which includes evaluation of climatic and soils conditions for its production and on its effects and impacts on the production of other crops. Such information would enable designing adequate strategies for its implementation and production of recommendation on how to implement its production for ensuring its sustainability and of the agricultural system.

As a result of agricultural expansion and human activities in general, natural ecosystem/habitat fragmentation has become a major concern in land use planning and decision making in the last decades. The fragmentation of natural habitats into Human impacted land uses has implications to land cover change, biodiversity losses and species extinction. Both natural and human activities contribute for natural habitats fragmentation. In order to withhold the current tendency of natural ecosystem/habitat fragmentation various development initiatives are underway. For instance, the Climate change mitigation initiatives resulting from the United Nations Framework Convention on Climate Change are now managing woodlands to sequester carbon (Silver et al., 2004; Williams et al., 2008) to maximize benefits and minimize negative impacts on biological and social values. To meet that challenge, High conservation Value (HCV) framework has been used to demonstrate that given development has met sound principles of sustainable land management. By identifying the areas and facilitating the evaluation of development plans against environmental and social criteria, the HCV entails those areas are maintained or enhanced.

Objective phase I: To select a candidate area for potential energy crop production, in phase I an analysis is done on the national level. The aim of phase I is a desktop assessment based on readily available information that is used to select a province that has the highest potential for RCAs. That province is then assessed in more detail in phase II. The focus of the analysis of phase I is here on the suitability for *Jatropha* production. Even though in this pilot the focus is on *Jatropha*, the RCA concept is in principle addressing all bio-fuel feedstock. In this chapter first; the context of energy crop production in Mozambique is sketched, second; the RCA analysis is done on a national level, third; a province is selected based on the findings of phase I for a more detailed assessment in phase II.

Expert consultation phase I at WWF Mozambique, from left to right Eng. Macuacua, Albano, Smit, Mabunda, Maula (picture Ana Robiero)

§3.1: Phase I; Principle 1: National parks and conservation network in Mozambique

The vegetation of Africa was mapped by White (1983) and 18 regional centers of endemism, transition zones/mosaics and archipelagos were identified. Three areas for conservation were considered especially important in Mozambique namely; the Zambezian Regional Centre of Endemism (ZRCE), the Tongoland- Pondoland Regional Mosaic (TPRM) and the Zanzibar-Inhambane Regional Mosaic (ZIRM) (see Appendix 3.1.1).

Currently, several areas in Mozambique are protected by law for conservation (see also Appendix 3.1.2). The Forestry and wildlife law regulates the utilization and conservation of forestry and wildlife resources, and defines the basic principles for the establishment of conservation areas as well as exploitation of forestry and wildlife resources. In Mozambique the law recognizes three categories of conservation areas: (i) national parks; (ii) national reserves and (iii) zones for historical and cultural use. The national parks and reserves aim to protect species important for conservation such as rare, endemic, threatened/ fragile ecosystems and high valued scenic landscapes. The zones considered for historical and cultural use include areas of sacred forests and areas of importance for providing traditional medicine for the local communities (see figure 3.1.1 for legally recognized conservation areas in Mozambique).

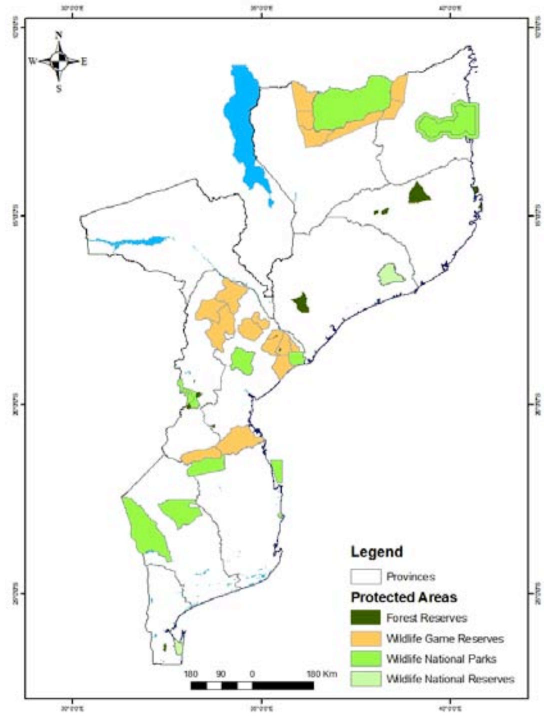


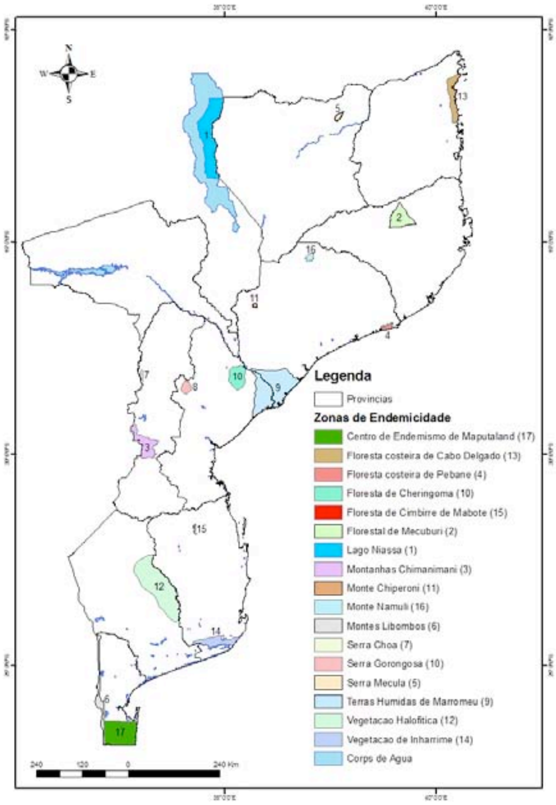
Figure 3.1.1: Legally recognized conservation areas in Mozambique (source ministry of agriculture Mozambique, 2011)

Areas of known high biological value

The conservation area network in Mozambique covers about 16% (ca. 129,803 km^2) of the total land surface (MICOA, 2008) consisting of 6 national parks, 6 game reserves, 14 forest reserves, 3 integral reserves and 12 hunting reserves (see also appendix 3.1.3). Three of these areas belong to Transfrontier Conservation Areas: The Limpopo National Park is adjacent to the Kruger National Park in South Africa and Gonarezhou National Park in Zimbabwe making up the Great Limpopo Transfrontier Park (also Gazaland TFCA). The Maputo Especial Reserve is contiguous with the Tembe Elephant Park and Dumo Game Reserve in South Africa. The Lubombo Mountains at the border with Swaziland form the Lubombos Transfrontier Conservation Area (TFCA). The Chimanimani National reserve is contiguous with the Chimanimani National Park in Zimbabwe forming the Chimanimani TFCA.

The vegetation of Mozambique has been described based on the botanical accounts done for the Flora Zambeziaca Area (comprising Zimbabwe, Zambia, Botswana, Malawi and Mozambique, scale 1:2500.000; Wild & Barbosa, 1967). The map and its supplement provide the distribution of vegetation communities and the description of respective ecological governing factors. The Mozambican component was based on the earlier (1959) broad map produced by J. Gomes and L.A Grandvaux Barbosa for the "Esboço de Reconhecimento Ecológico e Agrícola de Moçambique". The map of Wild & Barbosa (1967) and its supplement were the basis for the last forest inventory in Mozambique. Based on the floristic and physiognomic attributes Marzoli et al. (2007) produced a vegetation classification map (see Appendix 3.1.5).

Most of the conservation areas were established during the colonial period (between 1950 and 1970) motivated by economic interest rather ecological significance. In recent assessments of the conservation areas network using RAPPAM methodology (MICOA, 2008), it was found that the conservation area network is deficient and does not cover the essential elements for the ecosystem functions. This is also confirmed in this study, whereby a number of internationally acknowledged valued areas for biodiversity conservation such as the Ramsar in the Marromeu Complex, the Gorongosa mountain in the Gorongosa National Park as well as the Namuli and Chiperone mountains are excluded from the conservation network (appendix 3.1.6). The current situation of the conservation areas network imposes the need for an integral assessment.



Recent research undertaken in selected areas in Mozambique has shown that there are more species of known high conservation value outside the conservation areas which should be protected (figure 3.1.2 and appendix 3.1.3). The conservation of these species depends entirely on the maintenance of respective habitats. Thus these habitats need to be maintained and should not be converted for energy crop production. Considering these remarks in the context of the HCV criteria, specific attention should be paid to the distribution of species included in the Red list species of IUCN, all areas containing these species should be classified unsuitable for energy crop plantations (see for the Red list species occurring in Mozambique Appendix 3.1.4).

Figure 3.1.2: Spatial distribution of areas of known high biological value as listed in appendix 3.1.3 (source: MICOA, 2008)

§3.2: Phase I: Principle 2: Land use change and GHG emissions

To identify areas with a low risk non compliance with RCA principle 2, spatially explicit data on carbon distribution is required. Unfortunately such spatially explicit data (on carbon stocks in vegetation, or potential emissions related to Land Use Change) was not found. A limited study undertaken on a site in Manica Province, shows that changing annual cropland or grassland into *Jatropha* results in a net build-up of carbon and hence additional GHG savings (Paz and Vissers, 2011). Based on this reference, the conversion of all the other land use types considered would result in significant losses of carbon. From data on vegetation cover and associated carbon stocks (extracted from the literature, Paz and Visser, 2011), a proxy for carbon stocks by province for Mozambique was made (see figure 3.2.1., and table 4.2.1). From figure 3.2.1 it can be concluded that the areas with the highest carbon stocks are located in centre and north of the country, especially in the provinces of Zambezia, Nampula and Niassa. The southern provinces have relatively low carbon stocks (see also Appendix 3.2).

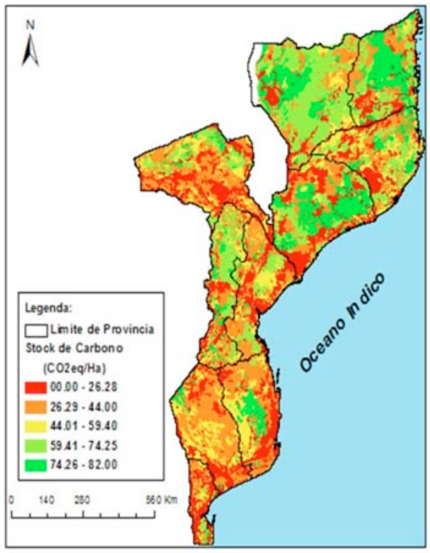


Figure 3.2.1 Distribution of carbon stocks (Mg CO2 eq/ha) in Mozambique (source: ministry of agriculture Mozambique, 2011)

§3.3: Phase I: Principle 3: Land tenure and legal claims

In Mozambique the historical battleground of inclusion-exclusion is land. Land is what Mozambicans identify with and fight over, and it is the issue that most clearly pits the interests of politicians and government officials against those of rural people. Legislators refused to cede state control over land either to private property regime or to community control. Community management was, however conceded under certain conditions, one of which being the recognition by the cadastral agency (Galli, 2003. p.11/2).

In Mozambique all land and its resources are and remain property of the State, land use-right may not be sold, mortgaged or otherwise alienated. This is the main principle as embedded in the Land Law (of) 1997 (GOM, 1997). The Land Law recognizes use-right to land, known by the Portuguese acronym DUAT (direito de uso e approveitamento dos terras). DUATs can be held individually or jointly. They are obtained through:

1. Occupancy of land according to customary norms and practices
2. Good faith occupation of land for 10 years
3. A grant by the State or Province after submitting a request with a specified investment plan for the use and exploitation of the land over a certain period of time (this type of DUAT is generally indicated as a concession.

Most rural land is held by communities, which have perpetual DUATs based on their traditional occupancy. Delimitation and registration of this land is voluntary. Local communities can also grant third parties, such as investors, rights to use the land within their territories. A concise and very informative overview of all requirements and rights of the applicants and owners of DUATs can be found amongst others in a factsheet focusing on these topics prepared by the IS-academie (BuZa, 2011). Relatively few resources are, however, available to help communities to delineate land and prepare for and conduct consultancies with investors. Limited capacity is an issue for Mozambique's land administrative bodies in performing their statutory functions. It is argued that this lays at the root of the conflicts between users (like bio-fuels investors and local communities), and uses (like food production, mining, bio-fuels, etc.). Unfortunately many investment projects are characterized by their lack of knowledge of community rights. As several communities have not registered their rights, outsiders like government and investors often fail to recognize the extent of community land and the nature of community land uses (BuZa, 2011).

§3.4: Phase I: Principle 4: Agricultural land use practices in Mozambique

(based partly on: Ruthenberg, H. 1980. p.14-18; Okigbo, B.N. 1990. p.330-338)

In Mozambique, agriculture constitutes the backbone of the countries' economy, providing employment for over 80% of the workforce (FAO, 2011a; Wikipedia 2008). The country has immense agricultural potential with an estimated 36 million hectares of arable land, of which only 10 percent is presently in productive use (FAO, 2011b). Most of the cultivated area is made by smallholder farmers in small scale production of food crops and some cash crops such as cotton, tobacco, sesame, sunflower and cashew nut. Commercial companies explore the remaining area for large scale production of sugarcane and coco nut. The major food crops in descending order of importance are: maize, cassava, cowpea, groundnuts, sorghum, rice, common beans, pigeon-peas, millets, sweet-potato and bambara groundnut while the major cash crops are: sesame, cotton, cashew nut, sugarcane, coconut, tobacco, citrus, tea and sunflower (INE, 2011; FAO, 2011b).

At present, the agricultural sector is still dominated by smallholder farmers, which account for 90% of the cultivated areas used by over 2.5 million households. The production of this group is associated with 95% to the agricultural GDP, 22% of the gross domestic product and 20% to exports (GDP) (INE, 2011; FAO, 2011). In Mozambique, land use rotation is practiced (see also appendix 3.4.1), with little or no use of biocides and of chemical fertilizer and with more land available than needed for food self-sufficiency. In land use rotation, cultivation is initiated by removal of the natural vegetation after which crops can be seeded. Then after 2 to 4 years the choice is made to shift to another piece of land which subsequently is cleared for cultivation. This is done as after the first years of cropping an increasing damage of crop plants will occur by insects and diseases, as well as a considerable increase of weed growth. Subsequently the cultivated area is given back to nature. First it will be invaded by pioneer species, than secondary vegetation and gradually over some years the natural fallow vegetation. The soil fertility will be restored to the original natural level by the weathering of soil minerals and by the contribution of soil organic matter by the vegetation. It will take generally around 10 or more years to complete this. And then the land is optimal again for arable farming during 2 to 4 years. Thus land has to be fallowed for 10 years or more to attain an optimal and sustainable land use rotation. In most inhabited regions there is not sufficient land for this, and fallow periods are reduced.

Fraction of Land Cultivated (FLC)

The Fraction of Land which is Cultivated (FLC) within a certain area or farm depends on the number of years that once cleared the land is cropped (C), and after the land is given back to nature of the number of years that the land is fallowed (F). FLC can be derived from the following formula FLC = C : (F + C) (For instance F = 10 years and C = 4 years, FLC = 29%; F = 10 years and C = 2 years, FLC is 16%; C = 4 and F = 2, FLC = 66%). Many different land use and farming systems can be distinguished based on FLC (see appendix 3.4.2). In fact in the field the multitude of farming systems is just as large as the number of farms considered. Several of the land use and farming systems distinguished will occur side by side in the same region. However in each region possibly 2 to 4 systems form the majority of all systems present, so some diverse-uniformity occurs in most regions.

Differentiation in cropping is more noticeable with increasing land shortage (LFC > 50%, see appendix 3.4.2) and the higher the degree of commercialization. Larger and smaller farm units, richer and poorer families can be observed in regions dominated by fallow-system farmers. The performance of these farmers under pressure for land differs widely, because here their performance depends more on their effort, drive and ingenuity. Besides agriculture, nature provides in many regions a diverse additional “free” food supply for local people. Thus, nature can be an important factor in the food security of nearby inhabitants.

§3.5: Phase I: Principle 5: Knowledge/experience *Jatropha* Mozambique

Mozambique approved sugarcane and sweet sorghum for bio-ethanol production and coconut and *Jatropha* for biodiesel production (Mitchell, 2011. p.11). Recently cassava is being considered as well (Vries de, et al. 2011). Also sweet potato has potential for bio-energy but has not yet been considered for Mozambique (Ziska, et al., 2009). Probably the grains and beans mentioned above are in Mozambique too valuable economically for food security and self-sufficiency. Oil palm requires year round rainfall, globally it is a major bio-energy source, but it does not fit into the Mozambican climate. Thus for Mozambique’s bio-energy it is sufficient to consider at present the four national approved crops and cassava. For this pilot *Jatropha* was selected, because when the proposals for this projects were developed, the expectations of this plant were high, especially in the context of Mozambique, where large scale *Jatropha* production was proposed as national strategy towards energy security and poverty alleviation. **In the development of this study it became clear that the expectations of the plant have been overly optimistic**. In the next section several limitations of the plant for bio energy production are highlighted.

***Jatropha*: A miracle plant?**

The idea of *Jatropha* curcas being a plant with the capacity to produce its oily seeds for bioenergy on marginal soils led to a hype stirred up by non-agronomists, believing in a miracle-plant. It started with unrealistic expectations about the high production capacity of *Jatropha* under marginal conditions, then after realization that *Jatropha* could not live up to these expectations laymen’s opinion shifted to the extreme opposite *Jatropha* was no good at all. The production of *Jatropha* in Mozambique for commercial purposes started in 2005, and since then it has been increasing significantly and presently it is estimated at about 160,000 hectare (CEPAGRI, 2011). The major producing provinces in order of importance are Sofala, Nampula, Manica, Inhambane and Maputo (see also appendix 3.5.1).

The yield figures for *Jatropha* show a wide range, which can be ascribed of course to the differences in climate, management level, but also to the absence of an accurate census apparatus. Due to this last it is hardly possible to distinguish or single out specific yield-data for a limited number of specific climates, regions or management levels. Climate and soil conditions in Mozambique are in general suitable for the production of most crops. Desktop research indicates that *Jatropha* requires temperature between 20-28˚C, annual rainfall between 300-1000mm and well-drained soils with good aeration (Orwa et al., 2009). These conditions can be met in most of the countries agro-ecologies

Information limits and gaps

Apparently there is an abundance of agronomic information on *Jatropha*, from our review we draw the following conclusions (see also Eijck van, et al. 2010; Brittaine and Lutaladio, 2010. p.24,25):

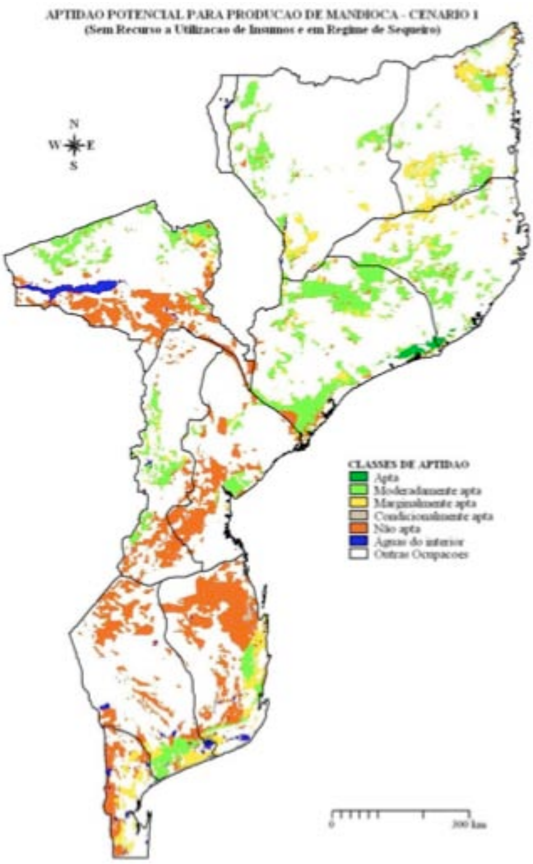
- The agronomy aspects of *Jatropha* production are merely reported for juvenile *Jatropha* plants (seedlings) and relatively young production systems of less than 3 years old. Whereas *Jatropha* takes 3-6 years to reach economic maturity.
- *Jatropha* research has not yet identified varieties that are reliably high yielding.
- *Jatropha* agronomic and production system information is lacking, most importantly for the reliable prediction of yield.
- Only limited experimental fertilization experiments have been presented so far, and recommendations on fertilization and irrigation strategies are lacking, moreover nutrient recycling is not well understood.
- Pruning methods play a very important role in *Jatropha* flowering, seed set and production, but are not well covered in the experimental and industrial production domains.
- Sound reports on the productivity of intercropping and hedge row production are not well represented, but these production systems will become very important in small-scale *Jatropha* production
- In general the comparison between different *Jatropha* curcas genotypes is not available.
- The majority of *Jatropha* stakeholders is not equipped and not educated to produce scientifically sound reports on *Jatropha* growth and production.

Presently realism starts to prevail, *Jatropha* has normal production capacities, requires under most conditions normal care (fertilizers, sometimes biocides) for its production, and might be better suited to some environmental niches than other cultivated plants (which fit better into their specific environments). According to FAO/IFAD "Realizing the true potential of *Jatropha* requires separating facts from the claims and half-truths" (Brittaine and Lutaladio, 2010).

Seed yield in general and in Mozambique

Individual *Jatropha* trees are known to live well over 50 years. The economic life of *Jatropha* plantations is expected to range from 30 to 50 years. Systematic recording of yields started, however, only relatively recently, and there is little data available of seed yields of mature stands. Under optimal growth and management conditions, there are reported yields of 5-8 ton seed/ha/yr. In India spacing experiments with 1.700 – 10.000 trees per hectare showed 1,5 year after planting a negative effect of denser planting on fruits/tree 64 decreasing to 24 fruits, and on seed yield/tree 94 to 32 gram seed, but a positive effect on yield 157 – 319 kg seed/ha. It is clear that yields per ha can show a wide variation. In addition *Jatropha* shows often a high variability in yield among individual trees. The yields of 16 individual trees over a period of 4 years ranged from 10 – 880 gram seed/tree/year, with an average of 250 g seed/tree/year, this in an area of poor soils with no inputs. The variation in production is ascribed to differences in hereditary characteristics of the seeds linked to sexual cross-pollination (Brittaine and Lutaladio, 2010. p.40; Eijck van, 2010. p.28) For more details on biophysical suitability requirements for *Jatropha* see appendix 3.5.4.

Studies in Cabo Degado, Mozambique, during three years upon the planting of *Jatropha*, and extrapolating further *Jatropha* development resulted in the following long term productivity estimates: at 3 years after planting 64 kg dry seed/ha/yr, at 6 years 360 kg and at 8 years onwards a stable production of 800 kg dry seed/yr. This on unfertilized, well-drained soil, without pests or plagues and an annual precipitation of 800 mm in a wet season of 6 months. The potential yield on



this location is theoretically estimated at 4.000 kg seed/ha (Nielsen, 2009a). From the data available it is clear that the yield of *Jatropha* shows a wide variation, and that presently knowledge is insufficient to predict yields for specific situations. The first three to six years after planting yields will be in the range of 50 – 1.000 kg seed/ha/yr, and stabilize after 4 – 8 years at a level ranging from 500 – 3.500 kg seed/ha/yr. The yields will depend on: the yet not identified hereditary characteristics of *Jatropha* plant material (seeds or stem cuttings); the management; and (as in appendix 3.5.4) on: climate, soils, fertilization, pests and plagues.

Based on a agricultural suitability assessment of the ministry of agriculture, Mozambique was zoned on *Jatropha* production potential (see figure .3.5.1). Based on this assessment it was found that Zambezia has the most land that is moderately suitable (1,5 million hectare, see also appendix 3.5.2) The focus on 'moderately suitable was made considering the limitations of *Jatropha* production on marginal soil, and the high risk for competition with food on 'suitable' land).

Figure 3.5.1: Biophysical suitability zoning Mozambique (green: suitable, light green; moderately suitable, yellow: marginally suitable, orange: unsuitable (Source: Ministry of agriculture, Zonemento Agrario, 2011 scenario 1)

Summary Phase I

- **P1:** There are several species of known high conservation value outside the existing conservation areas which should be protected. Specific attention should be paid in phase II to the distribution of species included in the Red list species of IUCN, all areas containing these species should be classified unsuitable.

- **P2:** The quality of spatially explicit data on carbon stocks in vegetation, or potential emissions related to Land Use Change is limited. It is estimated in case of conversion to *Jatropha*, only annual cropland or grassland savannah results in a net build-up of carbon and hence additional GHG savings. The conversion of all the other land cover types is expected to exceed the 35% GHG savings requirement in the RES-D.

- **P3:** Although most rural land is held by communities, which have perpetual DUATs based on their traditional occupancy, all land and its resources are and remain property of the State. As several communities have not registered their rights, outsiders like government and investors often fail to recognize the extent of community land and the nature of community land uses. The limited capacity of administrative bodies in performing their statutory functions is considered at the root of the conflicts between users. There will therefore be a focus on registered DUAT's in the selection of the research area in phase II, so at least basic information on land rights distribution is available.

- **P4:** Land use rotation is commonly practiced, with more land available than needed for food self-sufficiency. Agriculture constitutes the backbone of the countries' economy, the agricultural potential is considered immense, with an estimated 36 million hectares of arable land, of which only 10 percent is presently in productive use. At present, the agricultural sector is still dominated by smallholder farmers, which account for 90% of the cultivated areas used by over 2.5 million households. Besides agriculture, nature provides in many regions a diverse additional "free" food supply for local people. In selecting a research area in phase II, it is unlikely to find areas that are 'unused', but rather 'underused'. It is thus recommended to focus on areas with low productivity.

- **P5:** From the data available it is clear that the yield of *Jatropha* shows a wide variation, and that presently knowledge is insufficient to predict yields for specific situations. The expectations of *Jatropha* seem to have been overly optimistic, especially regarding the potential production under marginal conditions. *Jatropha* has normal production capacities, requires under most conditions normal care for its production, and might be better suited to some environmental niches than other cultivated plants. The province of Zambezia is considered to contain the most land that is moderately suitable, and therefore the most likely province for finding candidate areas in line with the RCA criteria. Therefore, Zambezia was selected for more in depth analysis for phase II.

§4: Phase II; Provincial Level Assessment

In phase I, we selected Zambezia province for a more detailed analysis in phase II and research site selection due to the limited conservation values, priority for economical development, and its high agricultural potential for *Jatropha* Zambezia is also considered by the government as a priority area for *Jatropha* development, due to the high potential for *Jatropha* production, but also due to its access to infrastructure (personal communication: head spatial planning ministry of agriculture). In phase II, a research site in the target province is selected. The aim is to identify a district where *Jatropha* is likely to have a positive impact on the production potential of the district by additional production on un(der)used land, as well as a minimum risk for displacing conservation values. For background information on Zambezia province see appendix 4.0.

Figure 3.6.1: Political map Mozambique

§4.1: Phase II: Principle 1: Identification of 'go' and 'no go' areas in Zambezia

HCV 1.1: Protected and conservation areas
In order to assess the potential presence of HCV 1.1, both conservation areas and the areas of high biological value have to be considered (see also phase I). The protected areas or conservation areas in Zambezia that formally recognized are Derre and Gile National Reserves (see also appendix 3.1). In addition, three areas of known biodiversity values are present in the province: the northern extension of the Marromeu Complex area), the eastern coastal forests (Moebase/Pebane) and the Inselbergs (comprising the Namuli and Chiperoni Mountains, see appendix 3.1). For any developments proximate to these conservation areas buffer zones should be delineated (see Jennings *et* al. (2003). In addition to considering these areas, a specific assessment has to be made of endangered species present (see HCV 1.2 and 1.3 below).

HCV 1.2: Critically Endangered Species
Areas that are important for the survival of the critically endangered species (as listed in the IUCN RED List and the Appendix 1 of the CITES) are considered HCV 1.2. The species in these lists have a high risk of becoming extinct and, therefore very vulnerable for changes in their remaining habitats (see appendix 4.1.1). Unfortunately, no comprehensive data or studies were found on the distribution of these species in Zambezia, we therefore had to rely on expert judgement of our ecologist (Gabriel Albano). Based on his knowledge, for Zambezia, some of these species do occur in the province. Large mammals (elephant and lion), for instance, are known to occur in the Gile National Reserve (see appendix 4.1.2). Other IUCN and CITES species described for the province occur in the far northern and western parts of the province. Due to the limited data available, the presence of the RED list species has to be assessed on a site level.

HCV 1.3: Habitats for viable populations of endangered, restricted range of protected species
Habitats that have sufficient concentrations of populations of protected, endangered, or restricted range species qualify for HCV 1.3. Generally, such concentrations can be the result of habitat loss/ fragmentation. Most of the habitat losses around biodiversity concentration areas in Zambezia Province are the result of antropogenic activities (agriculture and expansion of settlements) (Timblake *et al*. 2009). As more land is cleared for agriculture, the more animal and plant communities are confined to small areas to sustain their which limits options for viable populations. We assume that areas with large intact forest cover contain natural ecosystem that can support viable populations of the listed species (see HCV 1.2). Given that the species vary in terms of space requirements, it is a challenging exercise to define the extension of such area to support viable populations (see also

appendix 4.1). Based on the spatial data available, it is expected that HCV 1.3 is present in the mount Namuli (inselbergs area), the coastal area including Moebase forest, and the extension of the Marromeu complex area on the northern side of the Zambeze delta (Chinde area) (see appendix 4.1.4). In line with the precautionary approach recommended (Jennings *et* al. 2003), we recommend selecting an research area remote from these areas, outside the boundaries of the respective buffer zone as proposed in HCV 1.1.

HCV 1.4: Areas that Contain Habitat of Temporary Use by Species or Congregations of Species
The HCV 1.4 identifies areas or habitats temporarily used by species in a landscape, and includes those habitats which accommodate concentrations of migratory species or important migration routes. Relevant in Zambeziain this context are riparian forest (for example for *Cercopithecus albogularis* survival in the Gile Reserve). For Zambezia the key habitats include all extensive mangrove, freshwater swamps, and riparian forest. Areas where these habitats are present are:

- The mangrove and wetlands (grassland) along the Zambezi Delta; the mangrove and wetland on the Zambezi delta and the surrounding vegetation are habitats for migratory birds.
- The riparian forest along the main rivers (e.g. Molocue, Zambezi and Licungo rivers

In addition,the western, southern and, probably, the Eastern side of the Gile Reserve is also expected to classify as HCV 1.4, due to elephant movement there (DNAC, 2010). In addition to these specific areas, we recommend all riparian zones to be assessed for potential presence of HCV 1.4.

HCV 2.1: Large Natural Landscape with Capacity to Maintain Natural Ecological Processes and Dynamics
The objective of HCV 2.1 is to identify and protect core areas of the landscape responsible for ensuring natural ecological processes can take place without negative influence of fragmentation and edge effects. The definition of HCV 2.1 is a landscape with core area of a forest block (or a natural landscape mosaic) with larger than 20.000 ha surrounded by a natural vegetation buffer of at least 3 km from the forest edge (HCV Consortium, 2008). Based on the land cover data, large continuous tracts of forest areas of about 20.000 ha with a buffer zone of about 3 km are not found in the Zambezia Province. Possibly HCV 2.1 is present in the Inselbergs and the coastal forests along the Zanzibar-Inhambane coastal mosaics (see also appendix 4.1.4 and 4.1.5). Considering the precautionary principle, we recommend to select a research location outside the Inselbergs and the coastal forests to minimize the risk violating HCV 2.1. requirements.

HCV 2.2: Areas that contain Two or More Contiguous Ecosystems
The maintenance of ecosystem types co-occurring within a landscape remains a major challenge for conservation. Under these conditions, connectivity between habitats/ecosystems is critical (Kimmins, 1999) to ensure movement of species, flow of material and energy among different ecosystems in face of environmental changes. The transition areas tend to contain relatively high number of species. Therefore, HCV 2.2 aims to identify landscapes that contain multiple ecosystem/habitats types to protect their core areas and maintain connectivity among these types. From the GIS analysis, it was difficult to identify clearly the ecosystem transition zones or *ecotones*. The maps are presented on 1:1.000.000 scale which hardly can be used to depict the extension of the ecotones. It is expected that areas remote from forest areas and main rivers do not contain important ecotones. To ensure the research site does not contain HCV 2.2 forest areas should be avoided, but the land use/cover maps need to be verified on the ground.

HCV 3: Rare or Endangered Ecosystems
Ecosystems can be classified as rare or threatened based on their natural distribution or as a result of the impact of anthropogenic factors. Thus, rare and endangered ecosystems are targeted for protection as they inhabit a diversity of plant and animal species. To preserve the variety of environmental services, representative samples of these ecosystem types should be maintained. The HCV 3 aims to identify rare and endangered ecosystems in a landscape for maintenance. These ecosystems include rare forests as well as those ecosystems which were once known to be continuous and nowadays only small patches are left. We found there is insufficient historical land cover data available (the existing information about the biogeography of the ecosystems is based on general descriptions done for the entire region, or phytochoria as in Wild & Barbosa 1967; White 1983; Burgess and Clark, 2000). From the regional assessments it was found that the rare and

endangered ecosystems include the coastal forests of eastern Africa, ecosystem described under the Inhambane-Zanzibar Regional Mosaics (White, 1983; Burgess and Clark, 2000). The coastal forests were once known to be continuous throughout eastern Africa coastal zone, but due to various factors, nowadays are fragmented in the Zambezia Province. These coastal zones should therefore be avoided, but since the available data to assess the presence of HCV 3 is very limited, field verification on the presence of HCV 3 is necessary.

HCV 4.1: Areas or Ecosystems Important for the Provision of Water and Prevention of Floods for Downstream communities

Land use activities or forest degradation in a watershed often disturb the water cycle affecting the communities downstream. The forests found on water catchment areas help to regulate water cycle and ensures resource availability downstream. All the forests that are known to play a role in hydrological functions (such as, production of clean water or to control flooding in downstream communities) qualify as HCV 4.1. (HCV Consortium, 2008). To identify potential presence of HCV 4.1 in the Zambezia Province, experts were consulted to assess the presence of water catchment (see appendix 2.1). The experts identified most of the mountains in the province as potential water catchment areas. In addition, the river banks from the local basins are also likely to qualify as HCV 4.1. The precautionary principle should be applied to whole of these areas and an integrated model based on mosaic representation of the ecosystems and plantations should be adopted in case energy crop plantation is to be developed.

HCV 4.2: Areas prone to erosion (based on Micoa, 2007)

Areas that are prone to high levels of erosion (above 180 Mg/y), are considered HCV 4.2. In Mozambique soil erosion affects many parts of the country, resulting in huge economic damage as a result of degradation of social infrastructure , loss of soil fertility and loss of ecosystems services. The impact of erosion is exacerbated by high levels of poverty in which the majority lives in rural and peri-urban country. The combined effect of lack of resources and the need to meet the basic requirements for survival leads to overexploitation or misuse of available resources with serious implications for the environment.

Due to a lack of reliable information on the scale of the problems caused by erosion makes it impossible to understand the seriousness of the problem. In addition, there is a lack of mechanisms for identifying appropriate solutions as well as a lack of plans for concrete actions and responsibilities. These factors led to the preparation of the draft Program and Action Plan for Prevention and Control of Erosion Soils. This document constitutes support of the Laws of the Land and Environment, and proposes on the one hand to: provide information on the situation of erosion resulting from the action of man and secondly, proposes ways to minimize the risks associated with the misuse of Natural Resources. This Plan suggests the basis for systematization and structuring actions to prevent, control and combat soil erosion in Mozambique over a period of 11 years. It clearly defines the responsibilities of each stakeholder in the process of mitigating the effects caused by erosion

Several actions have been carried out in isolation, aimed at controlling soil erosion in the province by the various stakeholders in environmental management for sustainable development. The corrective measures are, however, usually only implemented in emergency situations. Currently, much of the country faces serious problems of erosion in a particular coastal area. Due to the seriousness of this issue in Mozambique, we recommend to take no risks and avoid all areas that may result in increasing erosion upon conversion to bio energy plantations. Thus all areas close to rivers, and areas containing forests (like miombo), should be avoided. Considering the limited quality of spatial data available to assess this, field verification of the absence of these systems is necessary.

§4.2: Phase II Principle 2: Land cover/use types and carbon stocks

A recent study undertaken on miombo woodland in Mozambique (Williams et al., 2008) emphasizes the importance of measuring and monitoring ecosystem carbon stocks when assessing the potential for Carbon sequestration. Based on a literature review of the above mentioned studies, it was found that the above ground carbon stocks in the miombo vegetation can be as high as 33 t C ha^{-1} (after

Williams *et al*., 2008) as compared to about 18 t C ha-1 for perennial *Jatropha* plantation (Paz and Vissers, 2011) (see also Table 4.2.1). It follows, that carbon stocks in the natural miombo vegetation are higher and conversion of these lands to *Jatropha* plantation should not be encouraged in line with to RCA principle 2. Carbon stocks in grassland vegetation can be up to 8 t C ha-1 which is lower than estimated for a *Jatropha* plantation. In the context of RCA principle 2, the grassland is thus suitable for conversion. It should be noted that these values should be considered with care as the carbon stocks will depend on various factors including soil type, rainfall, etc..

It has been postulated that conversion of 'marginal land' into energy crop plantation will enhance carbon sequestration reducing thus, the net carbon emissions. Therefore, for the land cover of the proposed land use types it has to be assessed whether or not the carbon stocks will be significantly reduced in case conversion to a energy crop plantation. The above ground carbon stocks in each vegetation type will be assessed using literature review. Above ground carbon stock studies have been undertaken in miombo vegetation from the neighboring Sofala Province (Williams *et al*., 2008) and calculations of biomassa from the Gile National Reserve (RNG, 2010). Moreover, assessments of the impact of land use change on the GHG performance has also been undertaken in Manica Province (Paz and Vissers, 2011). This approach is in line with the IPCC guidelines in tier 2.

Land cover/ use type	**Above ground Carbon stock in vegetation (t C/ha)**	**Soil organic Carbon in top layer (t C/ha)**	**Total Carbon Stock (t C /ha)**
Perennial *Jatropha* plantation	18	47	65
Grassland	8	46	54
Forestland (canopy < 30%)	30	47	77
Scrubland	46	46	92
Forestland (Canopy > 30%)	156	47	203

Table 4.2.1: Carbon stock values (t C/ha) for vegetation and soil in Manica province (after Paz and Visser, 2011).

The carbon stocks in the districts in Zambezia range from an average of 18 ton / ha (Cases to 82 tons / ha. In relative terms, the districts of Morrumabala (20%), Pebane (19%), Mocuba (10%) and Gile (12%) have the largest stocks of CO2 equivalent in Zambezia province, and with lower stocks stand out from the districts of Quelimane, Inhassunge Chinde and Namacurra with a ratio of carbon dioxide equivalent for all districts of the province of 0.09%, 3.4%, 1.94% and 1.46 respectively (see also appendix 4.2). Considering that the above findings were drawn from coarse landcover data, and comparative figures are partly from outside the study area, it is strongly recommended that the different land types are assessed for above ground carbon stocks in the field.

§4.3: Phase II Principle 3 Land claims in Zambezia

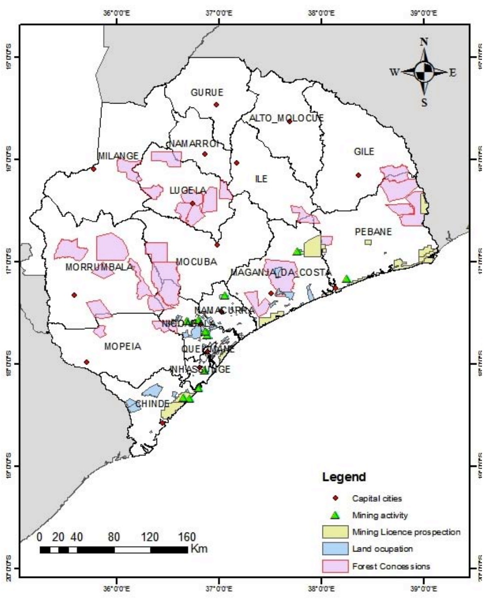


Figure 4.3.1: Forestry concessions in Gile (source: ministry of agriculture, 2011)

In Zambezia requests at provincial level for forestry concessions exceeded one million hectares (out of a total of three million hectares of forest land). These applications were for short term licenses, which meant that investors were not likely to be interested in investment and rational exploitation of these resources (Galli, 2003. p.238). Possibly the most successful support to farmers in Mozambique were the concessionaire schemes of cotton and tobacco (Coughlin, 2011. p.318/9,345/6).

In some areas of Zambezia persists in what may be termed quasi-feudal vestiges, resulting from the creation of a mixed-race caste of powerful landowners, dating from early Portuguese settlement. There occurs a process of land grabbing which is led by the elite and investors. It is highly likely that the province may attract farmers from South Africa and Zimbabwe, wishing to resettle and either to use the land for agriculture or as game reserves (NRI, 1996. p.39). Presently the Ministry of Agriculture still excludes small-scale rural producers from major agricultural development programs, such as those involving irrigation works. In figure 4.3.1 the distribution of concessions in Zambezia is presented. It is known that much illegal activity occurred in regard to granting of concessions and the unauthorized exploitation of natural resources, it is thus important to assess in the field whether any additional concessions exist that are not included in this map.

Considering the vulnerable position of smallholders in the province and the lack of documentation on customary land rights, areas with dense populations should be avoided and specific attention should be addressed to the land claims of the communities present. This should be done through interviews with the both the head of the district, as well as the leaders of the villages in the research area.

§4.4: Phase II Principle 4: Smallholders and shifting cultivation

Blessed with abundant land but squeezed between low farm-gate prices and high input costs, practically all farmers in Zambezia remain subsistence farmers, selling nothing or little to the market (Coughlin, 2011. p.317). The lack of stable marketing outlets within has generally discouraged producers from expanding production beyond what donors, institutions, and the government term “subsistence”. Nevertheless, people do not see themselves as subsistence producers. The increasing amount of crops brought to the market since the late 1990’s is ample proof of this situation. The general state of low accumulation has mainly to do with the lack of credit and productive investments in their vicinity, such as access roads, marketing outlets, rural industry, such as in packaging and processing.

The majority of Mozambican producers do not fall neatly either into the categories of subsistence farmers or small commodity producers. All who can, market what they can (Galli, 2001. p.257). This is confirmed for Zambezia, where the family sector produces about 60% of the total marketed output of copra. Smallholders sell to local traders or directly to large companies. Though with respect to the future, the competition with cheaper palm-oil limits medium-term prospects for copra (NRI, 1996. p.26). In view of the commercial classification of the smallholder farmers in Zambezia it seems likely that most belong to the category of “partly commercialized farming, selling some of their produce but less than 50%”.

Agricultural land use by smallholders at present

The Zambezia province is estimated to contain nearly a quarter of all small holders in Mozambique. The population density in Zambezia is in the upper category 33 inhabitants per km^2. The increase in population density in Zambezia is striking; in 1980 it has been recorded as being between 10 - 20 persons per km^2 (NRI, 1996. p.22). In Zambezia the average holding size per family is 0,8 ha, ranging from 0,5-1,5 ha per family. The average is lower than in other provinces because large areas near the coast are irrigable and are not fallowed (NRI, 1996. p.5,26, see also figure 4.4.1 for the distribution of the population). Most smallholders produce without the benefits and risks of modern technological inputs (as mentioned above: low farm-gate prices and high input costs). Fallowing and crop rotation are common, and improved varieties (e.g. for maize, cassava, sweet potato) are used where available. Some pre-industrial methods of intensification are applied, such as composting, manuring, small-scale irrigation, use of nitrogen fixing crops or green manure, integration between land and animal husbandry, and animal traction, but to a limited extend (Coughlin, 2011. p.317).

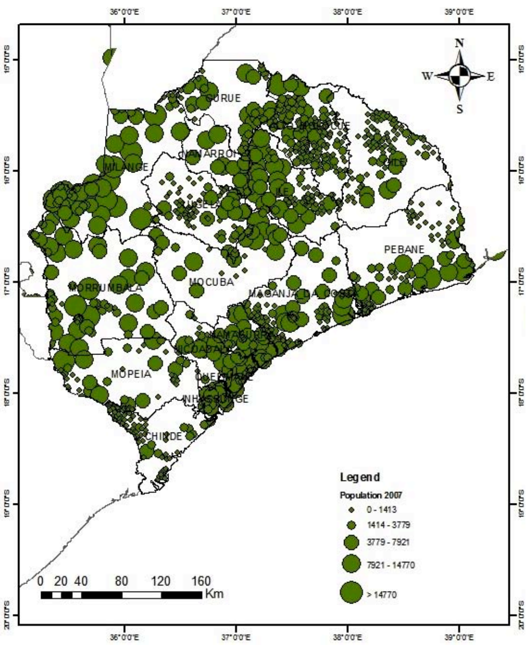


Figure 4.4.1: Population distribution Zambezia (source; ministry of agriculture, 2011)

On a modest scale, most agricultural intensification takes place in contract-farming schemes, providing extension, credits and guarantee prices for produce. Under these conditions smallholders benefit from the use, and use fertilizers, biocides and hybrid seeds (Coughlin, 2011. p.317).

Population growth results in a larger demand agricultural land and wood for charcoal. It is the main factor causing deforestation in Mozambique. In Zambezia the mean rate of deforestation over the period of 1990-2002 was 0,71% per year of the existing forest. Slightly higher than the national average 0,58%, the highest rate 1,67% was in the province Maputo. (Marzoli, 2007. p.59,62). Thus part of the agricultural land is obtained by deforestation of virgin forest (NRI, 1996. p.21). Another part is obtained by cultivating shrub vegetation and pastures/grassland either virgin or re-growth on fallowed land, and from land classified as wooded shifting cultivation.

Shifting cultivation

It was estimated that in 2005, 49% of the province is covered with forest. Apart from the tree plantations (coconut, cashew) totaling 1,3%, (Marzoli, 2007. p.9,15,61), practically all agricultural land in the province is probably under shifting cultivation by smallholder households/families (Coughlin, 2011. p.317, see also figure 4.4.2). From the Zambezia land-cover inventory of 2004/5 the following land use data were obtained (Marzoli, 2007. p.9):

- Pastures/grassland 3%
- Wooded shifting cultivation 13%
- Shifting cultivation wooded 9%
- Cultivated fields 9%

Total fallow land is at maximum the sum of all Pastures + Wooded shifting cultivation + Shifting cultivation wooded = 3% + 13% + 9% = 25%. Total cultivated fields = 9%. Assuming that all or the majority of this land is part of the shifting cultivation cycle, then the fraction of land cultivated (FLC) in all land used for shifting cultivations is 9% : (9% +25%) = 26% (see also appendix 3.4). The actual traditional practice is to fallow the land during 3 to 5 years. It indicates that the average intensity of the shifting cultivation in Zambezia is probably causing some nutrient mining. Causing a slow gradual decline of the yields per ha (NRI, 1996. p.5,25,26, see also appendix 4.4.1). This indicates that the land is already overused, and it is unlikely that 'unused land' is available for *Jatropha* production (also considering that plantations are not viable under marginal conditions).

The potential for increasing production through improved agricultural practices is therefore crucial. Therefore, only if additional production can be realized, land may be freed up for other uses, like bio energy feedstock production. It is therefore recommended areas with large areas of shifting cultivation are selected, that have a low population density as well as low population growth, in order to minimizing the (future) risk of displacing current land use and especially food production

§4.5: Phase II Principle 5: Agricultural suitability *Jatropha* in Zambezia

People in Zambézia province have experience with production of commercial crops such as cotton in the districts of Morrumbala and Mopeia, tea in Gurue, coconut and cashew nut, tobacco and paprika in Morrumbala and sesame and sunflower around all province. Compared to most provinces in Mozambique, Zambézia has a relatively good agricultural suitability for the production of food crops. The soil types and fertility of Zambézia province are variable ranging from sandy soil with poor fertility mainly in coastal areas to clay and clay loam with moderate to good fertility mainly in interior and along the Zambezi river. The rainfalls in the province are also variable ranging from 850mm in Mopeia to 1450mm in Namacurra. In the regions in Mozambique below 1.300 m a.s.l., with a precipitation between at least 800 and at maximum 1.500 mm/yr, and with well drained not-marginal soils (sandy or not) *Jatropha* can produce normal quantities of seed. That is to say some 4 to 8 years after its establishment 800 – 2.000 kg seed/ha/yr (more extremely the range can be set at 500 - 3.500 kg seed/ha/yr). Or from individual trees 50 - 400 g/tree/yr (more extremely 10 – 900 g/tree/year) Regrettably, it is not yet possible to predict the future production of the *Jatropha* on any site. Considering the many uncertainties, such as the (hereditary) production potential of the plant material used, pests and plagues, need for fertilizers, etc. *Jatropha* can be planted as: a monoculture;

rows with intercropping; hedges (land demarcation, livestock barriers); spot wise for instance for erosion control; and as singular trees.

Selected crop products their characteristics and bio-fuel yield on smallholder farms

Based on the above yield estimates per hectare on smallholder farms in Zambezia, with no or very limited use of fertilizer, the yield per hectare has been estimated and is presented in table 4.5.1. Due to the limitations of *Jatropha* (as addressed in phase I) four other crops are selected (sugarcane, cassava, sweet sorgum and coconut), to extend the scope and potential application of the findings in this study. In table 4.5.1 some aspects have been included of the five crops considered. For instance the need to harvest, potential uses of the crop product and possible uses of the byproduct(s) obtained after use of the crop product for bio energy. These factors may play a role in choosing another crop than *Jatropha* for bio energy production. But this choice is in the first place dependent of the nearby presence of a crop-processing plant for bio energy, the distance of the farm to the plant, and the transportation costs per unit of bio-fuel obtained from the crop product. The last cost will be low for copra and *Jatropha*, and high for sugarcane and sweet sorghum. The transportation costs for fresh cassava will be relatively high, they can be considerably reduced by drying the cassava.

The production in areas remote from the coast and rivers, the yields are in general expected to be low on smallholder farms. This is because crop production is constrained by not using fertilizers, apart from the occurrence of pests, diseases and exceptional dry years (see appendix 4.5.1). Probably on many farms a considerable, economically justified, increase of the yield can be obtained by moderate use of fertilizer, eg. 50 kg N, 50 kg P_2O_5, and considering the soil either or not with K_2O (Anonymus, 2010b; Euroconsult, 1989; Kelly, 2000 and 2002; Köster, 2010. p.75; Wairegi et al., 2010). This is, however, still a rate far below the rates calculated for agronomical maximum production. Economic considerations are expected to fix maximum fertilizer application rates at best to a point where fertilizer costs to produce one product unit more (so called marginal costs, MC) are equal to the money farmers receive from that one unit more produced (so called marginal returns, MR). Possibly the point at which MC=MR will be at a production level of around 80% of the maximum agronomically achievable production; which 80% level might be achievable with 40-60% of the fertilizer rate required for maximum production.

Crop, plant part used	**Delay of harvest when mature**	**Yield ton/ha/yr**	**Other uses**	**Durability when stored after harvest**	**Byproduct Type; and use**	**Bio-fuel; Conversion efficiency liter/ton**	**Bio-fuel yield liter/ha /yr**	**Industrial high technology**
sugarcane, stalks	no problem	14-30	sugar, rum, juice	medium	bagasse; fuel	ethanol; 80 *	1.130-2.430 *	well developed (>20 years)
sweet sorghum, stalks	problem	8-10	grain, juice?	poor-medium	bagasse; fuel	ethanol; about 100**	800-1.000 **	Similar to sugarcane
cassava, tuber ("root")	no problem	5-10	food, beer	perishable; when dried medium/good	fiber?; fuel	ethanol; 180 *	900-1.800 *	limited experience (<5 years)
coconut, copra	no problem	0,6-0,7	food, oil, wine	good	cake; feedstuff	bio-diesel; 400 **	240-280 **	no info retrieved
***Jatropha*, seed**	problem (?)	0,8-2	soap, fuel for cooking	good	press cake; fertilizer with some N	bio-diesel; about 340 * (estimate 30% oil in seed)	270-280 *	no info retrieved

Table 4.5.1:. Selected crop products (feedstocks), their characteristics and bio-fuel yield per ha. on smallholder land, generally not fertilized and of low to medium soil fertility.

* conversion rate crop product to bio-fuel conform p.17 Mitchell, 2011.

** conversion rate crop product to bio-fuel estimated from p.17 Mitchel, 2011.

Note: Depending on the feedstock and technology used the bio-fuel is either ethanol or biodiesel. Their properties, application-uses and their energy content differ. Expressed as Lower (net) Heating Value (LHV) this is respectively for: 1 liter ethanol 21,1 MJ, and for 1 liter biodiesel 32,6 MJ (Hofstrand, 2008).

Based on the information above, it can be concluded that compared to the current situation, a significant part of the land can be 'freed up' in case the local farmers get access to fertilizers necessary to increase production. Assuming that most of the land is currently used (either in fallow or actual production), implementing the recommended management practices is crucial for preventing indirect impacts on land use. Since collaboration with local farmers will be crucial in this respect, it would be wise to find a group that is interested in such collaboration. The group that is likely to be most interested are farmers that are experiencing declining yields, and appreciate the benefits fertilizer application can bring. Land in currently existing shifting cultivation systems that has been used for an extended period, and is likely to show a decline in production potential. Such areas are likely to demonstrate significant increase in yield improvement upon fertilizer application, and thus maximize the amount of land 'freed up' for other uses.

Summary Phase II

- P1: The research area must be selected outside: Derre and Gile National Reserves, the northern extension of the Marromeu Complex, the eastern coastal forests (Moebase/Pebane), the Inselbergs as well as the associated buffer zones (see appendix 4.1.4). All riparian zones should be treated with care, and assessed on presence of HCV's. Forest areas (including miombo) and coastal zones should be avoided.

- Buffer zones for conservation areas have to be designed
- The presence of the RED list species has to be assessed on a site level, based on:
    - Direct observations in the field;
    - Interviews with local communities

- P2: Required field data: Grassland vegetation is the only class with stocks lower than the *Jatropha* plantation, selection of the research area should be in this land cover type. Carbon stock measurements should be done in the field.

- P3: Areas with dense populations should be avoided (see figure 4.3.1) and specific attention should be addressed to the land claims of the communities present by interviewing both the head of the district, as well as the leaders of the villages in the research area.

- P4: The average fallow period of the land in Zambezia is estimated 3 to 5 years. Considering a *Jatropha* plantation is not economically viable on marginal land, and fertile land is scarce, selecting a research area should focus on moderately fertile areas (with relatively long rotation cycles), likely to be present in areas with a relatively low population and growth.

- P5: Assuming that most of the land is currently used (either in fallow or actual production), areas that are likely to significant increase in yield upon fertilizer application should be the focus. Communities interested in intensification of current production should be identified.

One of the areas showing such moderately fertile areas, and relatively low population density is the central east of Gile district. There are also several registered DUAT's in this area, potentially an indication that documentation land (use) rights exists. In this area conservation values are also expected to be minimal outside Gile National Reserve. We therefore select this area as the research site and verify our findings from the desktop in the field in phase III.

§5: Phase III; District Level Assessment

Objectives phase III

In phase II we found that in the northeast of Zambezia province there are a number of areas expected to be degraded to bush or scrubland, that are part of landscape mosaic with shifting cultivation systems. Conservation values in this area are expected to be low or absent, and the land use intensity is expected to be relatively low, due to shifting cultivation practices. Based on these findings we select Gile district as a target area, with a focus on the north east for phase III (see figure 5.0.1). In phase II, Gile district was selected for further RCA analysis due to the expected absence of conservation values, the low intensity land use, and presence of marginal land (not suitable for food crops, but potential for *Jatropha*). Due to the size of the district, two regions were selected in the northeast; Moiane and Mamala (see also figure 5.0.1).

In phase III, a number of findings from the desktop analysis have to be checked and gaps filled. Based on the desktop assessment in phase II, we have listed for each principle what data has to be obtained in the fieldwork, how this must be done and which expertise is needed (see appendix 5.0.1).

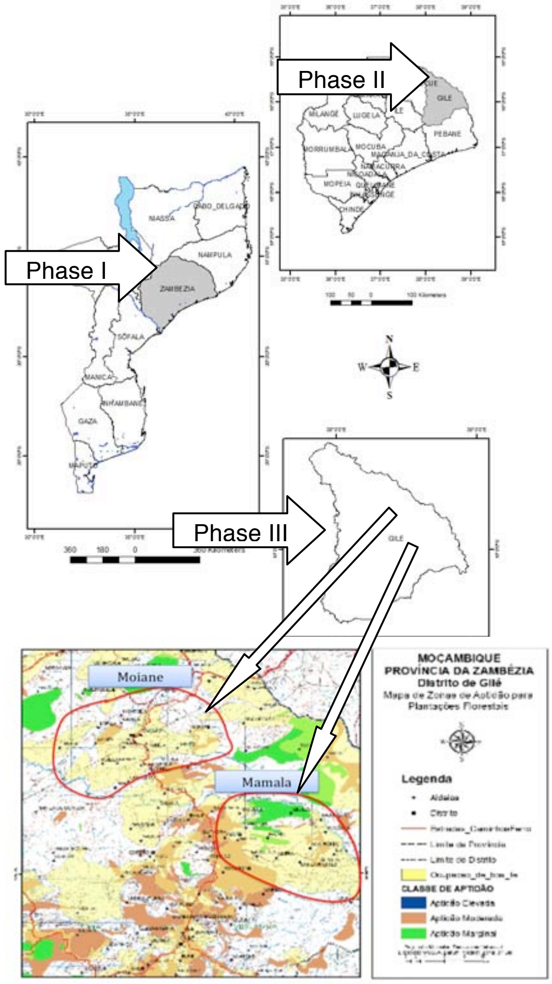


Figure 5.0.1: Target research area for phase III

§5.1: Phase III: Principle 1: Buffer-zones to be implemented

HCV 1.1: Based on the desktop study, it was indicated that HCV 1.1 is potentially present in the proximity of Gile Special Reserve, and bufferzones have to be delineated. In addition, we found that the Gile National Hunting Reserve (5,000 km ²) has potential 67 species of mammals, 114 species of birds and 253 species of plants with good conservation of vegetation (Source Management Plan Reserve 2010). Formally, the buffer zone for the Gile Reserve is still to be approved by the Council of Ministers (eng. Buramuge, Provincial Directorate of Tourism, per. comm.), but in setting the system boundaries, the site the proposed bufferzone has been avoided, as well as the Hunting Reserve (see mapping appendix 5.1.1).

HCV 1.1: In Mamala area, the area most proximate to the Gile National Reserve we found that the natural vegetation has been cleared for agriculture and settlements. The remaining forest cover is located to the eastern side (figure 8) where there is a forest concession (see also principle 3). The establishment of the concession with approved management plan seems good approach to delineate a buffer zone, however, the development of energy crop plantation can have implications to the forest conservation as this may trigger encroachment (indirect effect) by local communities.

HCV 1.2: Since no spatial data on critically endangered species (HCV 1.2) in Gile was found, it was recommended that the presence of these species should be assessed through field surveys and interviews. We found no critically endangered species, both in Mamala and Moiane. According to local communities the areas were once rich in wildlife but most of it has disappeared due to human activities in the area (i.e. hunting and conversion of the natural habitat).

HCV 1.3 : As we recommended in phase II, the presence of HCV 1.3 was assessed in the field. It was found that HCV 1.3 is not present since most of the natural habitat is converted into anthropogenic vegetation, and almost no biodiversity is left.

HCV 1.4: In phase II an assessment of the riparian vegetation along the Molocué River was recommended, since these constitute HCV 1.4. The Molocue River is, however, far from the research area, and no migratory species were found to be present (see also HCV 2).

HCV 2.1: Based on the Phase II study it was realized that HCV 2 was unlikely to be found near to the proposed sites. Guided on the precautionary principle it was recommended that this assumption should be verified onsite during the Phase III. We found that the natural vegetation (forest) had been cleared. The existing area is not in, or part of a large natural ecosystem. The two sites are dominated by cultivated areas with fallow lands of different ages. The Mamala vegetation is composed of a mixture of crops and scattered native trees. In Moiane, however, the active cultivated lands are more to the northern side of the village as most of the southern, eastern and western areas were found to be part of a mining concession (see also principle 3). Within the concession there was, however, a significant recovery of the natural vegetation as a result of less intensive use for agriculture (see appendix 5.1.2).Under the current ecosystem condition, however, it is unlikely that wide range species such as elephants and other large herbivores be present in the area, since there is no suitable habitat.

HCV 2.2: The phase II emphasized the need for a field assessment to identify connectivity of co-occuring ecosystems within a landscape. We found that the mountains and other hilly elevated areas tended to show a change in vegetation along an altitudinal gradient. More interesting still was the connectivity exhibited by the forest (mostly miombo) at the base. A narrow strip of miombo vegetation appears as ecotones between two adjacent mountains. It is recommended that these ecotones, linking two adjacent mountains are maintained.

HCV 3: The desktop study indicated that the existing rare and/or endangered ecosystem is very far from the research site. The sites are, however, partly located in a miombo vegetation, but based on our survey and interviews, it was concluded for both sites that HCV 3 is not present.

HCV 4.1: The desktop study indicated a potential presence of HCV 4.1 proximate to mountains or rivers. Regarding the supply of clean water, there is a large imbalance in its distribution to the villages, in the Mamala area, water is much less accessible then in Moiane. The majority of the population uses water from rivers and lakes as well as the springs in the mountains. We found that the areas around most of the mountains in Mamala and Moiane form the water source network, and are considered HCV 4.1. This doesn t mean the whole site cannot be used, but in the management plan for any bio energy feedstock plantation, buffer zones have to be delineated around these mountains to avoid any negative impact on the water supply and quality (see also HCV 1.4).

HCV 4.2: It was recommended that all areas close to rivers, and areas containing forests (like miombo), should be avoided. Based on this recommendation, all the woodland areas are considered unsuitable for development (see also principle 2).

§5.2: Phase III: Principle 2: Only grasslands?

From the desktop analysis it was found that the above ground carbon stock of grassland is relatively low compared to that of perennial. In order to verify these estimations, above ground carbon stocks were measured in the field (see appendix 5.2.1 for methods used for carbon stock measurement).
The vegetation distribution on the two study sites follow a similar pattern, characterized by a gradient from agricultural lands, close to the village centre, to native vegetation, in the interior. The vegetation types include different aged fallow lands, dominated by a mixture of cashnut/mango trees and regrowth of miombo species (*Brachystegia* spp. and *Julbernardia globiflora*). In the miombo woodland trees above 12 m are rarely found, and the dbh was mostly below 20 cm. These are indications that the vegetation is in a development stage and has not reached its climax stage.

The proportion of miombo and cashew nut trees on depends on the age of the fallow and distance from the village. In Mamala site, for example, about 80% of the study area is characterized by young fallow lands composed of a mixture of cashnut trees and regrowth of miombo species closed to homesteads. In Moiane, however, most the fallow lands in the eastern, southern and western sites are covered by stands of even age miombo regrowth species. The grassland is dominated by *Imperata* sp. with scattered shrubs and/or small tree species of *Annona senegalensis*, *Strychnos* spp., *Antidesma venosum* and *Albizia* spp. Most of tree species rarely exceed 05 meters high.

MSc. Gabriel Albano setting sample plots in Mamala (Picture: Hans Harmen Smit)

Above ground Carbon Stocks: The current assessment shows that the miombo established woodland has the highest above ground carbon stocks followed by the riparian vegetation, young fallow lands and the grasslands. There is a high contribution of above ground carbon stock from trees on the miombo woodland compared to other vegetation types (table 5.2.1). In the grassland however, most of the carbon stock is in the understory stratum.

Vegetation type	Tree carbon stock (t C/ha)	Understorey Carbon stock (t C/ha)	Total carbon stock
Miombo woodland	48	1	49
Riparian miombo vegetation	37	1	38
Fallow land	27	3	31
Grasslands	7	9	16

Table 5.2.1: Mean carbon stock values for each vegetation types considered for the study sites (*Number of samples)
Note: The results presented in this study should be used with caution as the data used for the analysis is not from a randomized sampling. Further studies using randomized sampling strategy based on a larger sample should be considered.

Based on the above findings it can be concluded that land cover/use types of miombo woodland, riparian miombo vegetation, mixed fallow and even grasslands contain higher carbon stocks as compared to *Jatropha* plantations (of 8 t C/ha based on Paz and Visser, 2011). Considering the RCA principle 2, the sites surveyed are not suitable for conversion to *Jatropha* plantation.

§5.3: Phase III: Principle 3 Overlapping claims and risks for conflicts

According to the 2007 population Census, the Gile district had approximately 171.000 inhabitants, distributed over an area of 8875 km² (population density of 14.3 persons per km ²). In 2011, the population is estimated to be 28 /km² inhabitants, which is likely mostly the result of migration. There has thus been a strong increase in population, which resulted in more intensive land use.

This was also true for the pilot areas and land conflicts exists and are likely to become more frequent and intense. It was found the concessions overlap with areas currently used (both for food and income). This is mostly the result of poor land use planning. Communities are not aware of the existing concessions on their land, and have not been consulted in the process. In the two research areas, the situation regarding land use right issues is quite different. In Mamala area land has become scarcer as a result of population growth (Personal Comm. Village head Mamala). Currently the population in Mamala area consists of +/-28,000 inhabitants, out of which +/- 15,000 in the research area, and +/-13,000 in Moiane (see also Appendix 5.4). At the time of the field assessment, community members mentioned to be self sustaining, and were able to live from the production of the land. In case of increasing population, this may change if production levels remain the same.

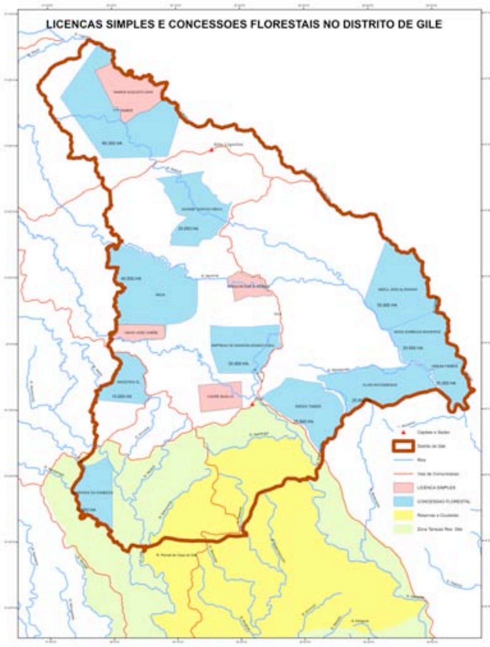
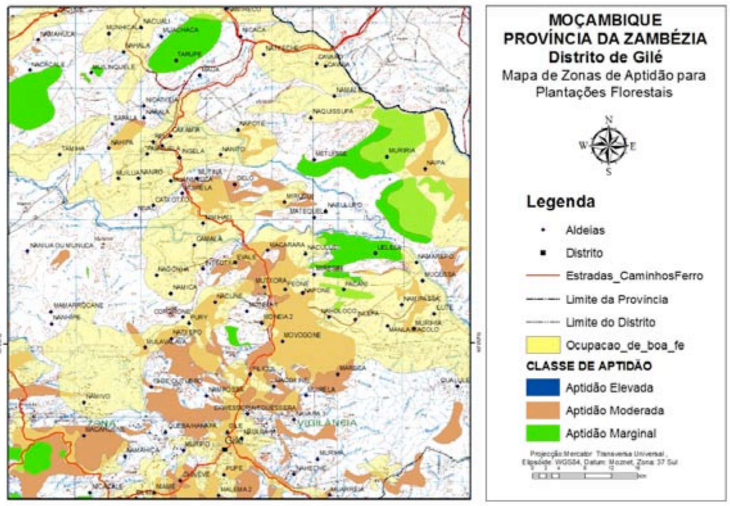


Figure 5.3.2: Existing concessions in Gile district (source, district government, dept forestry Gile (May 2011))

Like most districts in Zambezia, the government endorses mining as a means of economic development, but do often does not consult nor consider local communities. It is estimated that currently over 80% of Moiane is part of concessions (see also figure 5.3.2). In Moiane land conflict(s) are caused by conflicting interests of mining and forestry, but also between concession holders and the local community. Even though the community holds a certificate of own-use and exploitation (DUAT), their legal rights are ignored. Some stakeholders even complain that the miners are now occupying land previously used for food production as well as historical sites (burial grounds) and places used for traditional worship (HCV 6). As a result land conflicts between concession holders and the local community members occur more frequently.

Eng. Daniel Maula interviewing community of Mamaly (picture:Ana Robeiro)

§5.4: Phase III: Principle 4 Current land use



As was expected in phase II, the land use in the pilot areas is dominated by smallholders growing crops in a shifting cultivation system (see figure 5.4.1). The production from the land is in both communities the only source of income. The Gile people are very poor, which severely limits the options for sourcing provisioning services other than those from local agriculture. This is especially true for Mamala. In Moiane people economically benefit from the mining in the area.

Figure 5.4.1: Illustration of the land use and suitability for agricultural production in Gile, shifting cultivation systems in yellow (source: ministry of agriculture Mozambique (May 2011))

Considering the population in the research areas (approximately less than 3000 families in the research area in Mamala and less then 2000 families in Moiane) the land needed 2400 hectare and 1600 hectare in Mamala and Moiane respectively (assuming a land use of 0,8 hectare per family, see also P4 phase II). Since each research site is over 15.000 hectare, one would expect to find a substantial amount of 'unused land', this was, however, not the case.

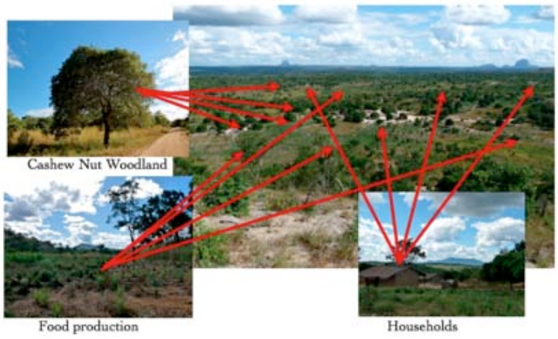


Figure 5.4.2: Typical situation sketch of the different types of land use in Mamala area (Picture: Hans Harmen Smit (May,2011))

Most of the land in Mamala is part of a shifting cultivation system approximately 80% and about 20% covered with woodland/cashew (see also figure 5.4.2). In Moiane approximately 45% of the land is used for agriculture, the remaining fraction is woodland, mostly consisting out of cashew nut trees. The land use system is classified as bush fallowing in Mamala and Rudimentary sedentary agriculture in Moiane (shifting cultivation phase 2, and phase 3 respectively, see appendix 3.4). In general land use is scattered, and used in a low intensity. 'Unused land' doesn t seem to exist though, even land that is at this point in time not used, is likely to be used in the (near) future. Increasing food production would decrease the amount of land needed for providing the provisioning services for the community. As a result of low inputs, yields are currently declining, and with a growing population the production potential with currently applied management practices is likely to be insufficient to provide for future needs. We will further address this potential in the next section on agricultural suitability.

§5.5: Phase III: Principle 5: Baseline production levels & potential for additional production

In the current situation, there seems to be no land left for bio energy production. In the research site, no records on current production exist. Based on expert estimations (Prof. Rogério Marcos Chiulele) current production can be tripled even with fairly low fertilizer inputs (see also appendix 3.5.4). As mentioned in phase II, production of *Jatropha* on sandy/marginal soil is not economically viable, and fertilizer application will be necessary. *Jatropha* can invade and persist on degraded soils as in the

research area, but its seed production will just be as marginal as the soil. The same applies to disturbed or man-made soils, such as mine tailings, many road sides, etc. If care is taken these marginal soils can be improved, e.g. by first planting (invasive) creeping legumes or leguminous trees with possibly a light dressing of P (either or not with some light grazing). At the same time *Jatropha* can be planted in plant holes filled with normal or fertilized marginal soil, with precautions for its survival during establishment. In addition to this, there are two major constraints on starting with bioenergy feedstock production in general by smallholders in Zambezia:
- At present there is no industrial, bioenergy generating, plant in Zambezia which can process the feedstock of any crop.
- With respect to smallholders in Mozambique is remarked: “the majority is impoverished and largely isolated from the benefits of policy, good advice and improved technologies”; a mere 4% of them used fertilizers in 2007 (Coughlin, 2011. p.321, 345).

Considering the above, it may be wise to wait with *Jatropha* plantation development until cultivars are available with a guaranteed high production potential. It is advised not to plant this tree on a large scale in the research site. Other crops/production models should be considered, since increasing production on these areas is very feasible, will benefit the communities, and is likely to be needed in the future to supply future demand. Mozambique approved sugarcane and sweet sorghum for bio-ethanol production, and coconut and *Jatropha* for biodiesel production (Mitchell, 2011. p.11). Recently cassava is being considered as well (Vries de, et al. 2011). Here we assess a few candidate crops on their suitability for the research site from an agricultural viewpoint and will be considered individually below for the region:

- **Coconut:** The relief of the province 0 m a.s.l. along the coast increases regularly going land inward. The altitude-zone from 0 to 300-400 a.s.l extends, parallel to the coast line, 150 km land inward, and covers around 50% of the surface area of Zambezia (NRI, 1996. Map 3). Here coconut will thrive. For optimum growth it needs: high humidity > 70-80%; mean annual temperature of 27 ^{o}C; regular rainfall >1.000 mm/yr; full sunlight no shade. Coconut can stand fluctuating high water tables with saline water in sandy beaches along the coast (Wikipedia, 2011). It can be recommended to each smallholder to have at least 1-10 coconut on his property. Possibly this is the existing situation in Zambezia. One tree can produce about 50 nuts/yr, which corresponds to 10 kg of copra. Presently the copra is sold for domestic and other uses, not for bioenergy. The energy yield per ha is rather low, but the durability of harvested products is high, and transportation costs of stored copra (6% moisture; oil content up to 60%) are low.
- **Sugarcane:** Sugarcane requires at least soils of low-medium soil fertility. The feedstock(stalks)-energy yield per ha is high, but the transportation costs are high (60-70% moisture, 15% sugar). Harvesting can be postponed and can be extended over long periods. Labor requirement for the harvest is rather low. The durability of harvested cane is low, processing preferably within 24 hours after cutting. Generally speaking it is a crop for at least medium intensive farming systems, not a good choice for the majority of smallholders. Unless they are supported by credit facilities, crop insurance, efficient extension services, etc. Food value of cane practically nil, its juice can serve as a sweet drink.
- **Sweet sorghum:** Sweet sorghum can grow reasonably well on soils of low fertility. The feedstock(stalks)-energy yield per ha is medium-high. It has a short growing season 4-5 months, is rather well adapted to dry spells and years with low rainfall. It has to be harvested within a short time upon maturing. Labor requirement for the harvest peaks, but is rather low in total. For smallholders it is to be preferred over sugarcane, though it is even more critical to process it within 24 hours after cutting. An advantage is its production of edible grains, under poor conditions probably 0,5-1 ton/ha/yr (one crop per year). Grains are and can be used as food. Its juice may contain cyanogens and may be toxic. Well adapted and reasonably producing cultivars have yet to be identified and/or bred.
- **Cassava:** Cassava can grow reasonably well on soils of low fertility. The feedstock(roots)-energy yield per ha is medium-high. The durability of the roots in the soil is permanently good. So for its harvest there is no time-pressure. Once harvested, the roots are very perishable and drying has to start within 48 hours. Harvesting and drying is very laborious.
  Roots are and can be used as food. Precautions have to be taken with respect to their cyanide (cyanogens) content (Cardoso et al.,2005; Anonymous. 2010a).

§6: Conclusions & Recommendations

§6.1: Conclusions

It was concluded that on the research site, there are potential conflicts with regards to principle 1, most importantly, development in the buffer zones around the Gile Reserve should be prevented (see analysis HCV 1.1 and 1.3). Along the rivers and the mountains on site, areas important as a temporal habitat (HCV 1.4) were identified. Considering that the local communities are dependent on the water sources (HCV 4.1), the riparian zones, and buffer zones around the mountains have to be maintained. According to the Mozambican land Law all the land within the width of about 100m is part of the riparian forest and should be protected. In the mountain ranges (9% of the community land), ecotones (HCV 2.2) were also identified. These areas need to be preserved as these have a supporting function in the migration of species and as seed bank for the re-colonization of the surrounding fallow lands. The mountain ranges and rivers are also considered HCV 4.1, since the areas provide important water catchment services. It was concluded that HCV values are present in the area, but if appropriate management practices implemented with regards to the identified HCV's, the remaining area can be converted based on principle 1.

Although in general the carbon stocks in this area are relatively low compared to forest areas, most vegetation cover types have a higher carbon stock than is expected in a *Jatropha* plantation. The only vegetation type with a carbon stock that is low enough avoid net emissions upon conversion are grasslands. Considering the relatively low carbon stock in Jatropa, the presence of a few trees can already affect the net emissions, even when the displacement of fossil fuel is taken into account the displacement of fossil fuel. This will strongly depend on what is displaced though, if for example the seedcake can be used to displace charcoal, the carbon saving can amount to above 35% in the grasslands, and potentially over 50% as well (the target for the RES-D for 2017). For the other vegetation types then grassland, this is unlikely.

On the site we found a multitude of overlapping claims. Some of these claims (from mining for example), did not show up in earlier stages of the analysis, but only in phase III. Currently there are several overlapping claims on the land (forest concessions, mining concessions, immigrants and local communities) in the areas, and it seems that communities are not involved or informed about land use planning decisions. Land conflicts currently exist and will remain potentially. Especially in Moiane, we found that forestry, mining and community land use rights overlap to such an extend that the risk for future conflicts is too high, and therefore this area is unsuitable as an Responsible Cultivation Area. In Mamala overlapping claims also exist, but this is mostly between community members. This has not let to serious conflicts yet, and may be manageable. If people can come to consensus on their claims, Mamala can qualify as RCA based on principle 3.

As was expected from the desktop, there is no 'unused land' on the research sites. Due to poverty, and the limited access to fertilizers and current production levels are very low. As a result of the increasing population density, fallow periods are relatively short, and are expected to even decrease even more. This will result in a further depletion of the soil nutrients, and speed up the trend of declining production. The communities currently actively use 45%, of their community land and 45% is in fallow, partly covered by regrowth and woodland. By providing the communities with fertilizers and

Childeren of Moiane with Hans Smit (picture; Gabriel Albano) training them in best management practices land use can be optimized, the production can be significantly increased. The current production is expected at least to double with moderate input of fertilizers. If this increase in production is realized, less land is needed for providing provisioning services to the communities. Unless the local farmers are facilitated implementing better management practices, here is thus a considerable risk for displacement, in particular of food production. Therefore, if and only if yield improvement measures are successfully implemented and food production is increased the site can qualify as RCA based on principle 4.

Based on climatic and soil conditions, the study area has potential for the production of *Jatropha*. The *Jatropha* can be planted on non-marginal soil, at an altitude below 800 m a.s.l., with an average precipitation of about 1.200 mm/yr, and a dry season of 6 months. Normal conditions for *Jatropha* production in the two administrative posts apply. Mamala has sandy soil with fertility ranging from poor to moderate. In Moiane soil varied from sandy to clay loam with fertility ranging from moderate to good). The production of *Jatropha* in the area at large scale, however, would be constrained by availability of land given that most the land is currently being cultivated for the production of field crops. Under these circumstances, the production of *Jatropha* would be possible through shifting some of the land currently used to produce field crops for the production of *Jatropha*. This indicates that the production of *Jatropha* at large scale or even at small scale would result in food insecurity in the district. There are two major constraints on starting with bioenergy feedstock production in general by smallholders in Zambezia, the lack of industrial, bioenergy generating plant and the low technology level present in the communities. These constraints can be addressed and can be overcome, but would require significant (financial input). A major constraint in assessing the indirect impact is the absence of yield data in the current situation. Establishing a baseline, and measuring additional production will be challenging.

§6.1: Recommendations

Conservation Values: In this study we found that the data required to make an HCV assessment (land cover, ecosystem/species distribution, social values) is either coarse or absent. Although it is considered possible to avoid areas with HCV's in case of plantation development, considering the presence of several rare /threatened species in the country, additional work is specifically recommended on identifying future candidate conservation areas. With regards to displacement of provisioning services (HCV5), several limitations were identified, we address these this in principle 4 and 5.

Carbon: The lack of reliable data on carbon distribution is a major limitation, but since we aim to avoid sites with high carbon stocks, this is manageable as long as the on-site verification is done thoroughly. In the case of *Jatropha*, carbon stocks have to be low for an area to be a suitable candidate, and identifying suitable areas with regards to this principle can be done in a time efficient manner if there is a focus on grassland areas with low biodiversity value and no trees.

Land rights: Assessing the distribution of land rights was found to be challenging, and is likely to be complicated in most cases in Mozambique due to limited availability of documentation as well as lack of transparency in the process of land use planning. This situation is likely to result in cases where several land claims overlap. Especially the rights of local communities are not considered in the process and they nor are they consulted in giving out new concessions. In the current situation, conflicts on land rights is expected to be common and the risks for violating this principle are considered high. In assessing land (use) right distribution, a thorough investigation on land use planning in government (especially provincial and district) offices is required. In addition, interview and participatory mapping with local communities is strongly recommended, since their rights are unlikely to be registered.

Land use and displacement: Due to the low inputs in terms of fertilization and management, land use is in general very extensive. Most people rely on their land for provisioning services and are sensitive to disturbances that affect their production. Even though a substantial part of the land may not be used at a specific point in time, it is likely to be fallow, and should not be considered unused. Using such fallow lands will reduce the length rotation cycle resulting in a decline in productivity and likely to lead to nutrient mining. If production can be intensified, it is likely a significant part of the land used can be made available other uses without displacement. This potential will be mostly determined by the access to fertilizers and application of best management practices regarding land use.

Agricultural suitability: The potential of *Jatropha* as a sustainable bio energy feedstock has been questioned on several occasions in this document. Comparing the inputs and production of *Jatropha* with several other potential energy crops let to the conclusion there are more suitable candidates. Based on the experience and uncertainty regarding *Jatropha*, other feedstock should be considered. We have assessed the suitability for smallholders for four other feed stocks below from an agronomical perspective.

Little or no potential for feedstock production

- **Sugarcane;** It is not fit for most smallholders, considering the constraints by low-medium soil fertility, no use of fertilizer, and in addition the rather long (6 months) dry season.
- **Sweet sorghum**; Well adapted and reasonably producing cultivars have yet to be identified and/or bred. This may take 3-7 years.

Medium potential for feedstock production

- Cassava. Advantages, low-medium productivity on soils of low-medium fertility without use of fertilizer. No time pressure on its harvest, roots durable in the soil. All farmers have ample experience with this crop. Disadvantages, once harvested fresh roots very perishable. Harvesting and drying of roots very laborious. Medium-high transport costs of fresh feedstock, and medium of dry feedstock to bioenergy processing plant.

Good potential for feedstock production by smallholders in Zambezia:

- Coconut in the regions below 300-400 m a.s.l., covering 50% of the land surface of Zambezia. Advantages harvest can be postponed, harvested nuts durable. Disadvantage opening the nuts, grinding and drying the endosperm for copra production all require a lot of labor. Other advantages dried copra durable, low transport costs.

Since *Jatropha* is, like other crops, just as depended on inputs for an economically viable production, it is by no means the ideal candidate. Thus other options for bio energy production, besides *Jatropha* should be considered. Considering unused land is not likely to be available, or unsuitable for economically viable plantation development, in meeting the requirements for certification of low indirect impact, the key is to prevent displacement of current land use is through intensification. Due to the current low level of inputs and technology, the potential for intensification in Mozambique is high. With regards to the aim of this project, the major challenge was found to be establishing a baseline of current production levels. By leaving this to 'expert judgment' this uncertainty could be managed. It is, however, likely that such (gu)estimations range significantly. Considering the high potential for yield increase, the significance of this uncertainty may be significantly reduced. A challenge is then addressing this in the application requirements for certification. Another challenge is to ensure intensification of the land use of the communities, assistance has to be provided by the company. In the certification it should be specifically addressed what production levels are expected in the production of the community, as well as processes and safeguards to achieve this. Only if the intensification of community land is guaranteed, the production of bio energy feedstock be considered 'additional'.

References

Agro-fuels, 2010. The *Jatropha* trap? The realities of farming *Jatropha* in Mozambique. Friends of the earth international.

Albeniz Larrauri, J.M. 2011. *Jatropha* curcas L. development explained by soil nutrient status. MSc thesis WUR.
https://sites.google.com/site/mozambique*Jatropha*/

Anonymous. Not dated < 2010. *Jatropha*. www.biozio.com/sou/jat/jat.html

Anonymous. 2010a. Australian government sponsors cassava research in Mozambique. pp. 2 Phoebe, 25-10-2010.

www.clubofmozambique.com.

Anonymus. 2010b. Moderate fertilizer use could double African banana yields, study shows. www.sciencedaily.com/releases/2010/02/100210164714.htm

Bassam, N.E. 2010. Handbook of Energy crops: a complete reference to species, development and applications. pp. 516. EarthScan.

Batidzirai, B., Faaij, A.C.P., Smeets, E.M.W. 2006. Biomass and bioenergy supply from Mozambique. Energy for sustainable development, X (1): 28.

Berkum, S.van, Tabeau, A., Arets, E., Bindraban P.S., Jongschaap, R., Verhagen, J. 2011. Competing claims on land for food and biodiversity. pp.78. LEI report 2111-049. LEI/WUR. The Hague. The Netherlands.

Bijman, J., Slingerland, M., Baren S. van. 2009. Contractual arrangements for smallholders in bio-fuel chains; A case study of *Jatropha* in Mozambique. pp. 14. "Competing Claims"; Policy Brief. DGIS-BuZa and WUR. Wageningen, The Netherlands.

Bos, S., Leonardo, W., Lerner A., Schut, M.P.W. 2010. Assessing the potential of bio-energy production in smallholder farming systems: The case of Nhambita community. pp. 47. GTZ-PROBEC and Wageningen University Research Centre. Maputo, Mozambique

**Boughton, d., Mather, D., Barrett, C.B., Benfica, R., Abdula D., Tschirley D., Cunguara, B. 2007. Market participation by rural households in a low-income country: an asset-based approach applied to Mozambique. Faith and economics, 50: 64-101.

www.aec.msu.edu/mozambique/market_participation

Bourdeix, R., Correia, A.M., Tomo, L., Konan, J.L. >2000. Mozambique Tall (MTZ). p.168. In: Bourdeix, R., Batugal, P., Oliver, M.T., George, M.L. (eds.). >2000. Catalogue of conserved coconut germplasm. pp. 421.

www.inibap.org/cogent/images/publications/catalog/intro_ld.pdf

Bourdeix, R., Batugal, P., Oliver, M.T., George, M.L. (eds.). >2000. Catalogue of conserved coconut germplasm. pp. 421.

www.inibap.org/cogent/images/publications/catalog/intro_ld.pdf

Brittaine, R. and Lutaladio N., 2010. *Jatropha*: a smallholder bioenergy crop. The potential for pro-poor development. (based on: Proceedings of International consultation on pro-poor *Jatropha* development. Nov. 2008. Rome Italy). pp. 118. FAO/IFAD. Rome, Italy.

Brown, H.C.P. and Thomas, V.G. 1990. Ecological considerations for the future of food security in Africa. pp. 353-378. In: Edwards, C.A., Lal, R., Madden, P., Miller, R.H., House, G. (eds). 1990. Sustainable agricultural systems. pp. 696. Soil and Water Conservation Society. USA.

BuZa. 2011. Mozambique, food security and land governance for equitable and sustainable development factsheet. pp. 7. LANDac IS-academie. Ministry of Foreign Affairs. The Hague, The Netherlands.

Burgess, N.D. and G. P. Clark, 2000. Coastal Forest of Eastern Africa. The World Conservation Union –IUCN. Gland , Swaziland and Cambridge, UK.

Brown S (2002) Measuring carbon in forests: current status and future challenges *Environmental Pollution* 116: 363–72

Brown, S.,; A.J.R. Gillespie; A.E. Lugo (1989). Biomass estimation methods for tropical forests with application to forest inventory data. For Sci. (35) 881-902.

Callé, F.R. 2007. The biomass assessment handbook, bioenergy for a sustainable environment. pp. 269. Earthscan

Cardoso, A.P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J., Haque, M.Z., Bradbury, J.H. 2005. Processing of cassava roots to remove cyanogens. Journal of food composition and analysis, 18: 451-460.

CEPAGRI, 2011. Data on *Jatropha* production in Mozambique.

Clark, G.P. (2000) Defining the eastern African Coastal Forests. In: Burgess & Clark (eds). Coastal Forest of Eastern Africa. Pp 9-26. The World Conservation Union –IUCN. Gland , Swaziland and Cambridge, UK.

Coughlin, P.E. 2011. Focusing on the majority – rethinking agricultural development in Mozambique. pp. 316-353. In:

De Boer, W.F. and C. M. Bento 1999. Birds of Inhaca Island, Mozambique. Birdlife South Africa.. Mondi BLSA Guide 22.

De Jongh, J. 2006. State of art *Jatropha* development in Mozambique.

DNAC [Direcção Nacional de Áreas de Conservação] (2010) Reserva Nacional do Gilé - Plano de Maneio 2010-2020. Fundação IGF. Maputo.

Djurfeldt. G., Aryeetey, E., Isinika A.C. (eds). 2011. African smallholders: Food crops, markets and policy. pp.386. CABI. Oxfordshire, UK.

Duke J.A. 1988. Handbook of energy crops. Glycine max (L.) Merr. Fabaceae. Soybean. http://www.hort.purdue.edu/newcrop/duke_energy/Glycine_max.html

Edwards, C.A., Lal, R., Madden, P., Miller, R.H., House, G. (eds). 1990. Sustainable agricultural systems. pp. 696. Soil and Water Conservation Society. USA.

Eijck, J.A.J. van, Smeets, E., Romijn H.A., Balkema A.J., Jongschaap R.E.E. 2010. *Jatropha* assessment. Agronomy, socio-economic issues, and ecology. Facts from literature. Report. pp. 157. Utrecht University; Technical University Eindhoven; Plant Research International, WUR. Wageningen, The Netherlands. http:\edepot.wur.nl\163388.pdf

Euroconsult. 1989. Agricultural compendium – for rural development in the tropics and subtropics. pp. 740. Elsevier. Amsterdam. The Netherlands.

FAO-Unesco. 1977. Volume VI Soil Map of the World 1: 5.000.000: Africa. pp. 299 and Maps. Unesco. Paris, France.

FAO. 2008. The state of food and agriculture – Bio-fuels: prospects, risks, opportunities. pp.

FAO. Rome, Italy.

http//:tinyurl.com/3c2drph

Fermont A.M. 2009. Cassava and soil fertility in intensifying smallholder farming systems of East Africa. pp. 197. PhD thesis. WUR. Wageningen, The Netherlands.

http://edepot.wur.nl/7784

Fermont A.M., Tittonell, P.A., Baguma, Y., Ntawuruhunga, P., Giller K.E. 2010. Towards understanding factors that govern fertilizer response in cassava. Nutrient cycling in agroecosystems, 86 (1): 133-151.

Galli, R.E. 2003. People's spaces and State spaces. Land governance in Mozambique. pp. 315. Lexington Books. Lanham, USA.

GOM. 1997. Land Law; Law 19/97of 1 October. Government of Mozambique (GOM). Maputo, Mozambique.

GTZ. 2009. *Jatropha* reality check. A field assessment of the agronomic and economic viability of *Jatropha* and other oilseed crops in Kenya. pp. 146. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Gmbh-Regional Energy Advisory Platform (East Africa). Nairobi, Kenya.

Hairiah, K; Dewi, S., van Noordwijk,M. and Rahayu, S. (S/d). Measuring Carbon Stocks Across Land Use Systems: A Field Manual. Draft version. The World Agroforestry Centre, ICRAF.

Hilst, F. van der., Karssenberg D., Verstegen, J.A., Faaij, A. Forthcoming. Spatio-temporal land use modelling to assess land availibility for energy crops illustrated for Mozambique.

Hofstrand, D. 2008. Ag Decision Maker; liquid fuel measurements and conversions. pp.4. File C6-87. University Extension, Iowa State University.

www.extension.iastate.edu/agdm

Jongschaap, R.E.E., Montes Osorio, L.R., Ruiter, F.J. van, Loo, E.N. van. 2011. Highlights of the *Jatropha* curcas Evaluation Programme (JEP): crop management and the fate of press-cake and other by-products with its effects on the environment and sustainability. Presentation on: International conference on *Jatropha* curcas. ICJC-2010. Groningen, The Netherlands.

Jongschaap, R.E.E., Corré W.J., Bibdraban, P.S., Brandenburg W.W. 2007. Claims and facts on *Jatropha* curcas L. Plant Research International/WUR. Wageningen, The Netherlands.

ICRISAT. >2007. The sweet taste of success. pp. 4. GT crop improvement – sweet sorghum.

http://test1.icrisat.org/get-ci/whatsnew.htm

Kalk, M. 1995. A Natural History of Inhaca Island. Johannesburg: Witwatersrand University Press.

Kelly V. and Murekezi A. 2000. Fertilizer response and profitability in Rwanda: a synthesis of findings from Minagri studies conducted by the Food Security research Project (FSRP) and the FAO Soil Fertility Initiative. Minagri. Rwanda.

Kelly V. and Nyirimana J. 2002. Learning from doing: using analysis of fertilizer demonstration plots to improve programs for stimulating fertilizer demand in Rwanda. pp. 20. FSRP Research report. Minagri. Rwanda.

Kimmins, J.P 2004. Forest Ecology. A Foundation for sustainable Forest Management and Environmental Ethics in Forestry. 3rd edition. Pearson Prentice Hall. USA.

Köster, H.W. 2011. Personal communication based on literature retrieval and review.

Köster, H.W. 2010. Feed, animal and food production, land and fertilizer requirements of smallholders in the Great Lakes Region of Central Africa. pp. 173. IFDC. Muscle Shoals, Alabama, USA.

report available at http://ifdc-catalist.org/rwanda.php

Marzoli, A. 2007. Inventario florestal nacional, avaliacao integrado de florestas em Mozambique (Draft). pp. 82. Departemento de inventario de recursos naturais. Direcao Nacional de Terras e Florestas. Maputo, Mozambique.

Mitchell, D. 2011. Bio-fuels in Africa: opportunities, prospects, and challenges. pp. 250. The World Bank. Washington, D.C., USA.

http://africaknowledgelab.worldbank.org/akl/

MICOA, 2007: Ministry for Coordination of Environmental Affairs] 2008. Relatório do Estudo de Avaliação da interacção entre a Biodiversidade e Pobreza em Moçambique. Report. Maputo. Action Plan for 2008 – 2018 to Prevent and Control Soil Erosion, approved at 32th session of the council of the Ministers December 4th, 2007

Natural Resources Institute. 1996. Zambézia Province Mozambique – Renewable natural resources profile. pp. 45. NRI. Chatham Maritime, UK.

Nielsen, F. 2009a. *Jatropha* yield forecasting. Research Activity 11.

http://sites.google.com/site/mozambique*Jatropha*/research-program/research-activities/06-*Jatropha*-yield-forecating-1

Nielsen, F. 2009b. *Jatropha* harvesting labour requirements. Research Activity 16.

http://sites.google.com/site/mozambique*Jatropha*/research-program/research-activities

Nielsen, F. and Jongh, J. de. 2011. End report FACT pilot project "*Jatropha* oil for local development in Mozambique 2007-2010". pp.57. https://sites.google.com/site/mozambique*Jatropha*/

Öhman, J. 2011. Cultivation and management of *Jatropha* curcas L. by smallholder farmers in the Kenyan regions of Baringo and Koibatek. pp. 66. BSc thesis. Esbo, Finland.

Okigbo, B.N. 1990. Sustainable agricultural systems in tropical Africa. pp. 323-353. In: Edwards, C.A., Lal, R., Madden, P., Miller, R.H., House, G. (eds). 1990. Sustainable agricultural systems. pp. 696. Soil and Water Conservation Society. USA.

Orwa et al., 2009. *Jatropha* curcas. Agro-forestry database 4.0.

Paz, A & P. Vissers (2011) Greenhouse gas calculations *Jatropha* value chain Sun Bio-fuels Mozambique SA. Sun Bio-fuels Mozambique SA. Amesterdam. The Netherlands . 35pp

Ruthenberg, H. 1980. Farming systems in the tropics. 3rd. ed. pp. 424. Oxford University Press. New York. USA.

Schut, M., Slingerland, M., Locke A. 2010. Bio-fuel developments in Mozambique. Update and analysis of policy and reality. Energy Policy, 38: 5151-5165.

Timberlake, J.R., Jeevanda Reddy, S. 1986. Potential pasture productivity and livestock carrying capacity over Mozambique (+ 3 maps). Serie Terra e Agua. Comunicacao no. 49. INIA. Maputo, Mozambique (available at http://library.wur.nl/isric).

UNECA. 2011. Critical issues in bioenergy for Africa: exploring the opportunities, constraints and trade-offs. pp. 44. Working paper 11.

www.uneca.org/acpc/publications

USDA. 2011. Mozambique, Sugar Annual Report. pp. 4. Date: 26-05-2011. Global Agricultural Information Network (GAIN). USDA Foreign Agricultural Service. Washington, DC. USA. http://static.globaltrade.net/files/pdf

Vries, S.C. de., Ven, G.W. J. van de., Ittersum, M.K. van., Giller K.E. 2010. Resource use and environmental performance of nine major bio-fuel crops, processed by first-generation conversion techniques. Biomass and Bioenergy, 34 (5): 588-601

Vries, S.C. de., Ven, G.W. J. van de., Ittersum, M.K. van., Giller K.E. 2011. The production ecological-suatainability of cassave, sugarcane and sweet sorghum cultivation for bio-ethanol production in Mozambique. GCB Bioenergy, doi: 10.1111/j.1757-1707.2011.01103.x

Van Wyk, B & P. van Wyk 1997 Field Guide to Trees of Southern Africa. STRUIK Cape Town. South Africa. 536 Pp.

Wairegi L.W.I., Asten P.J.A. van, Tenywa M.M., Bekunda M.A. 2010. Abiotic constraints override biotic constraints in East African highland banana systems. Field Crops Research, 117: 146-153.

White, F. (1983). The vegetation of Africa. A Descriptive Memoir to Accompany the UNESCO vegetation Map of Africa. UNESCO Paris.

Wild, H. & G. Barbosa (1967) Vegetation Map of the Flora Zambesiaca Area. Descriptive memoir. Salisbury . Harare.

Wieringa, J., (1999). Monopetalanthus exit. A systematic study of Aphanocalyx, Bikinia, Icuria, Michelsonia and Tetraberlinia (Leguminosae, Caesalpinioidae). Wageningen Agricultural University 99 – 4, 1 -320.

Williams, M.; C.M. Ryan, R.M. Rees, E. Sambane, J. Fernando, & J. Grace (2008). Carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique. Forest Ecology and Management (254) 145–155.

Ziska, L.H., Runion G.B., Tomecek, M.B., Prior S.A., Torbert III, H.A., Sicher Jr, R.C. 2009. An evaluation of cassava, sweet potato and field corn as potential carbohydrate sources of bioethanol production in Alabama and Maryland. Biomass and bioenergy, 33: 1503-1508

Websites:

DGIS www. dgis.wur.nl/NR/rdonlysres/www.dgis.wur.nl

INE, 2011. Evolução da produção agrícola das culturas alimentares básicas [Online]. Available on http://www.ine.gov.mz:82/pxwebine/pxweb/temp/agricult_produc_culturas2007525152248.xls. Accessed on 20/7/2011.

INE, 2011a. Mozambique GDP [Online]. Available on http://www.ine.gov.mz:82/pxweb2005ine/Dialog/Saveshow.asp. Accessed on 20/7/2011.

INE, 2011b. Mozambique statistics [Online]. Available on http//:www.ine.gov.mz. Accessed on 20/7/2011.

Wikipedia 2008. Economy of Mozambique. Available at http://en.wikipedia.org/wiki/Economy_of_Mozambique#Statistics. Accessed on 20/07/2011.

Wikipedia. 2011. Coconut. Last modified 25-12-2011. pp.21

http://en.wikipedia.org/wiki/Coconut

FAO, 2006a. Food and agriculture indicators: Mozambique [Online]. Available on http://FAOSTAT.org. Accessed on 20/7/2011.

FAO, 2006b. Mozambique [Online]. Available on http://www.fao.org/ES/ess/compendium_2006/pdf/MOZ_ESS_E.pdf

Appendix

Appendix 2: RCA Principles and Criteria

1. Establishment of energy crop plantations maintains or increases High Conservation Values
- No conversion of areas with recognized High Conservation Values in or after January 2008. This includes legally protected areas and areas with recognized global importance for biodiversity.
- No conversion of areas with one or more High Conservation Values on or after January 2008 that are not formally recognized as one of the areas referred to in principle 1.a.

2. Establishment of energy crop plantations does not lead to significant reductions in carbon stocks.
- No conversion of areas that had one of the following statuses in January 2008:
    - Continuously forested areas with a canopy cover of more than 30%
    - Peatland
- The carbon payback time for carbon losses resulting from Land Use Change (including above-ground and below-ground carbon stocks), shall not exceed 10 years. To calculate the carbon payback time, the methodology as laid down in the RTFO Technical Guidance shall be used.

3. Establishment of energy crop plantations respects formal and customary land rights
- The formal right to use the land for energy crop cultivation can be demonstrated.
- Both formal and customary land rights (including use rights) must be known. Where potential land conflicts may arise between the energy crop cultivation and formal or customary land rights, viable solutions must have been identified in cooperation with all owners and users of the land.

4. Establishment of energy crop plantations does not cause unwanted displacement effects
- Additional production has been realized without displacing existing (and future) provisioning services of the land. Where existing provisioning services are displaced, alternatives shall be implemented that comply with all criteria for RCAs, for both direct and indirect effects.
- Establishment of energy crop plantations may not lead to the opening of remote areas with High Conservation values through new infrastructure. Remote areas are areas that are currently not or difficult to access due to the absence of infrastructure.

5. Agricultural suitability: the area must be suitable for the target crop, both biophysically as economically

Appendix 2.1: High Conservation Values in the context of RCA in Mozambique

Initially developed by the Forest Steward Council for safeguarding biological or social values of outstanding or critical importance, the HCV has been used in the context of commodity crop planning and management and it is part of the international Sustainable standards (e.g. The Round Table on Sustainable Palm oil (RSPO), The Round Table on Responsible Soy, The Dutch Government Cramer Principles, The UK renewable Transport Fuel Obligation –RTFO, among others). The use of HCV methodology to identify areas of high biodiversity value may also contribute to requirements on environmental sustainability for bio-fuels contained in the draft EU Directive on the promotion of use of energy from renewable resources (Rayden et al., 2009). The HCV methodology has been tested in 2009 in northern Mozambique by GTZ in cooperation with Proforest in the context of agricultural crop expansion.

In this respect, WWF Mozambique is evaluating the application of RCA principles in the context of bio-fuel cultivation in Mozambique. The initiative aimed at field-testing of the RCA principles methodology ensures bio-fuels are produced following sustainability criteria and in particular, to define best practices at both the landscape and the farm level. In this report the identification of HCVs at the country, landscape and site levels overlaps entirely with RCA Principle 1, and partly with Principle 3 and 4. For each principle this overlap is clarified in the analysis.

What are High Conservation Values?
The key to the concept of HCVFs is the **identification and maintenance of High Conservation Values** (HCVs). The FSC's definition of HCVs encompasses exceptional or critical ecological attributes, ecosystem services and social functions1. These are listed below:

- **HCV 1 Areas with Important Levels of Biodiversity**
  - HCV 1.1 Areas that Contain or Provide Biodiversity Support Function to Protection or Conservation Areas
  - HCV 1.2 Critically Endangered Species
  - HCV 1.3 Areas that Contain Habitat for Viable Populations of Endangered, Restricted Range or Protected Species
  - HCV 1.4 Areas that Contain Habitat of Temporary Use by Species or Congregations of Species
- **HCV 2 Natural Landscapes & Dynamics ***
  - HCV 2.1 Large Natural Landscapes with Capacity to Maintain Natural Ecological Processes and Dynamics
  - HCV 2.2 Areas that Contain Two or More Contiguous Ecosystems
  - HCV 2.3 Areas that Contain Representative Populations of Most Naturally Occurring Species
- **HCV 3 Rare or Endangered Ecosystems ***
- **HCV 4 Environmental Services**
  - HCV 4.1 Areas or Ecosystems Important for the Provision of Water and Prevention of Floods for Downstream communities
  - HCV 4.2 Areas Important for the Prevention of Erosion and Sedimentation
  - HCV 4.3 Areas that Function as Natural Barriers to the Spread of Forest or Ground Fire
- **HCV 5 Natural Areas Critical for Meeting the Basic Needs of Local People**
- **HCV 6 Areas Critical for Maintaining the Cultural Identity of Local Communities**

In summary, *a High Conservation Value Forest is the area of forest required to maintain or enhance a High Conservation Value*. A HCVF may be part of a larger forest, for example a riparian zone protecting a stream that is the sole supply of drinking water to a community or a patch of a rare limestone-loving forest within a larger forest area. In other cases, the HCVF may be the whole of a large forest management unit, for example when the forest contains several threatened or endangered species that range throughout the forest. Any forest type – boreal, temperate or tropical, logged or non-logged, natural or plantation can potentially be a HCVF, because HCVF designation relies solely on the presence of High Conservation Values within the forest.

Data collection
Data collection and processing for the RCA assessment was done between April and September 2011, with field activities in June 2011. Participants: Gabriel Albano, Ana Robeiro, Daniel Maula, Rogério Marcos Chiulele, Hans Smit. Documentation available on request

- **Principle 1 and 2:** Data about the biodiversity of Mozambique is collected and the existing pletophora related to flora and fauna is found on reports and/ or "gray" literature as very few of the information has been published. Although still valid as reference, most of the information on flora has been carried out during the colonial period and the existing maps date from the 1960's. During this period the data was collected by naturalists who did not have access to the "new technologies of information" for data collection and processing and the mapping was not very accurate. On the other hand, however, the recent information on flora consists of transcript of the findings from those old periods and deserves a ground checking. The information is presented on maps (is presented in a global scale) making it less appropriate for the study in a specific area.
- The data collection regarding to fauna is less represented. Most of the books publishing on wildlife ecology have been limited to the south of the Zambezi River. The diversity and distribution of wildlife in the northern Mozambique is still to be undertaken and published.

Therefore, most of the existing information on the wildlife ecology in northern Mozambique is derived from extrapolations from known small spots (like the conservation areas) as well as the expert knowledge or judgment from field specialists.

- **Principle 1 HCV 5 & 6 and principle 3:** In addition, field observations and interviews were conducted with local government, agricultural sector and traditional leaders for obtaining information about the crop and for assessing the current land claims to allow for bio-fuel feedstock (energy crop) production as well as land use in general.
- **Principle 4: Displacement effects:** The focus criterion for the site selection was to find 'degraded land', due to the claims related to the potential of *Jatropha* production on 'degraded land', and such lands are considered to have a low risk of 'ILUC'.
- **Principle 5: Agricultural Suitability:** Climatic data were recorded from the National Institute of Meteorology while soil conditions were obtained from maps produced by Ministry of Agriculture. Other relevant information that would help this assessment was recorded on other crops grown in the target region. The desktop research was focused on collecting information about the current situation of *Jatropha* production in the country. This crop was selected due to the estimated potential for Mozambique and focus for bio energy production by the national government.

Appendix 3.1.: National Conservation Values

3.1.1: Regional Conservation Networks

The Zambezian Regional Centre of Endemism (ZRCE) is the most widespread in Southern Africa including parts of Democratic Republic of Congo (DRC), Botswana, Namibia and northern South Africa; large parts of Angola and Tanzânia and whole of Zambia, Malawi and Zimbabwe. In Mozambique, it is the most extensive, occupying more than 50% of the Mozambique surface area. The large part of the ZRCE is occupied by the Great African Plateau and lies more than 900 m above sea level (asl). The higher ground supports Afromontane communities. To the East the ZRCE gradually merges into the coastal plain which belongs however to the Zanzibar –Inhambane Regional Mosaic. There are about 8500 species of which ca 54 % are endemic. Endemic woody genera include Bolusanthus, Cleistochlamys, Colophospermum, Diplorhynchus, Pseudolachnostylis and Viridivia. The Tongoland – Pondoland Regional Mosaic (TPRM) extends from the Limpopo River to the border with South Africa (in Mozambique). The TPRM comprises an estimated 3000 species of which about 40 % are considered endemic to the region. Some species endemic to the region include *Cola natalensis, Cordia caffra, Diospyros inhacaensis, Manilkara concolor, Xylotheca kraussiana, Millettia sutherlandii* among others.

Figure A3.1. The Phytogeography of Africa showing the three phytochoria which occur in Mozambique: the Zambezian Regional Centre of Endemism (ZRCE), the Tongoland- Pondoland Regional Mosaic (TPRM) and the Zanzibar-Inhambene Regional Mosaic (ZIRM) subdivided into Swahilian regional centre of endemism (XIIa) and the Swahilian-Maputaland regional Transition zone (XIIb).

Eighteen Encephalarto species and 12 Aloe species are endemic to the region. The vegetation types include sand forest, dune forest, swamp forest, riverine fringing forest, mosaics of woodland and thickets, grassland and mangroves.

The Zanzibar-Inhambane Regional Mosaic (ZIRM) occupies the coastal belt from Limpopo River (25oS) to the southern Somalia (1oS). The width varies from side to side ranging from 50 to 200 km. Along broad rivers, for example, it penetrates further inland and in northern Mozambique it is very narrow. In general the areas under the ZIRM lie below 200 m. In northern Mozambique, however, there are scattered hills and plateau rising considerably higher (example the Makonde Plateau with ca. 986 m). The ZIRM comprise ca. 3000 species of which hundred are thought to be endemic. Much of the area in northern Mozambique is under cultivation and the native vegetation being replaced by exotic crops such as mango, cashnut and coconut.

Based on a recent review, Clark (2000) subdivide the ZIRM into two parts namely, the Swahilian regional centre of endemism and the Swahilian-Maputaland regional transition zone. The Swahilian regional centre is considered distinctive comprising of "at least several hundreds" of endemic vascular plant species (White 1983, Clark 2000).

3.1.2: Legal requirements

In Mozambique, the biodiversity aspects are dealt with by three main legal instruments: the Environmental law (law 20/97 of 1 October), the Land Law (19/97 of 1 October) and the Forest and wildlife law (10/99 of 7 July). The Environmental Law establishes the norms for the protection of biodiversity in the country. The law establishes the protection and conservation of environmental components as well as the platform for the maintenance and restoration of valued biological ecosystems. The Land law prohibits all forms of land use in the conservation areas except in cases were special authorization is granted for specific activities.

3.1.3: Areas of known high biological value per Province as mapped in figure 3.1.2 (Adapted from MICOA, 2008)

Province	Centre/ sub centre of endemism	The main Habitat/ area of concern	Important biodiversity features	Conservation area	Comments
Niassa Province	Reserva de Niassa	Mecula hill; Galery forest around Lugenda River; Inselbergs; Dambo	Endemic species of lizards, Barlenia sp. (New record for Mozambique)	Reserva Nacional de Niassa	Not well studied
Cabo Delgado	Quirimbas National park	Bilibiza Lake	?	Quirimbas National park	Potential High biodiversity area; Detailed studies needed.
	Coastal Forests of Quiterajo	Plateaux forest Riverine forest	Endemic species (04); Threatened species (04).	Game Farm	Potential High biodiversity area; Detailed studies needed.
	Nhica do Rovuma	Complex natural lake/ Coastal forest system	N/A	None	Potential High biodiversity area; Detailed studies needed.
Nampula	Matibane Coastal forest	Coastal forest	Endemic species Incuria dunensis	Matibane Forest Reserve	Detailed studies needed
Nampula and Zambézia	Great Inselberg Archipelago -	Mount Namuli; Mount Chiperoni; Mount Mabu.	High concentration of plant, butterflies and bird species endemism	No formal protection	Recent studies revealed valuable information. More studies needed.
Zambézia	Coastal forests	Coastal forest in Pebane and Moebase	Known species: Incuria dunensis	No formal protection	More detailed studies needed.
Manica	Chimanimani Massif	Chimanimane afromontane habitats; Vumba hills; Garuso mountains	Above 1000 species recorded; endemic plant genera (1) and species (7). Import bird areas; Endemic animal species	National Reserve	None

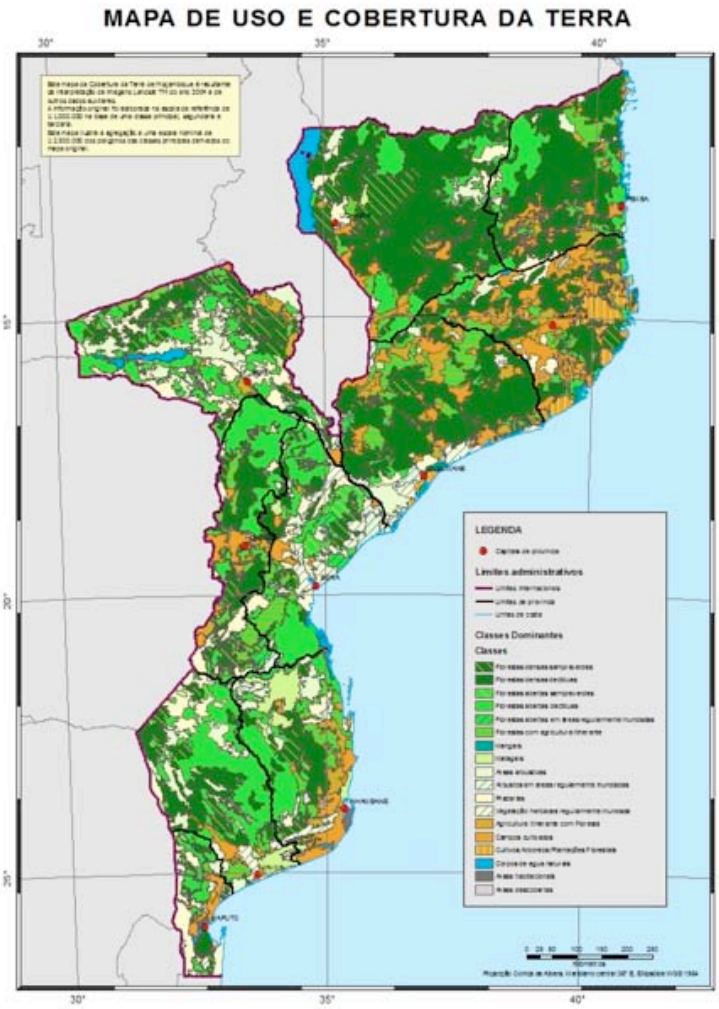
Sofala	Gorongosa Marromeu Complex	Gorongosa Mountain; Tropical Forest on the Cheringoma Plateau; Grassland on wetland plain along the Zambezi delta	Diversity of habitats/ecosystems; Endemic animal and Plant species.	Partly under Gorongoza National Park; Partly under the Marromeu Ramsar wetlands;	The Zambeze portion of the Wetland not conserved.
Gaza and Inhambane	Halophytic vegetation	Along the Changane River	Unique vegetation type in the country	No conserved status	Detailed studies needed
Maputo	Maputaland Centre of Endemism	Sand forest; Wooded Grassland; Bobole forest.	Endemic vegetation types; More than 2500 species recorded; At least 03 genera and more than 230 species endemic	Licuati Forest Reserve; Bobole Forest reserve; Maputo Special reserve.	Enforcement of conservation status needed.

3.1.4: Species in Red Lists

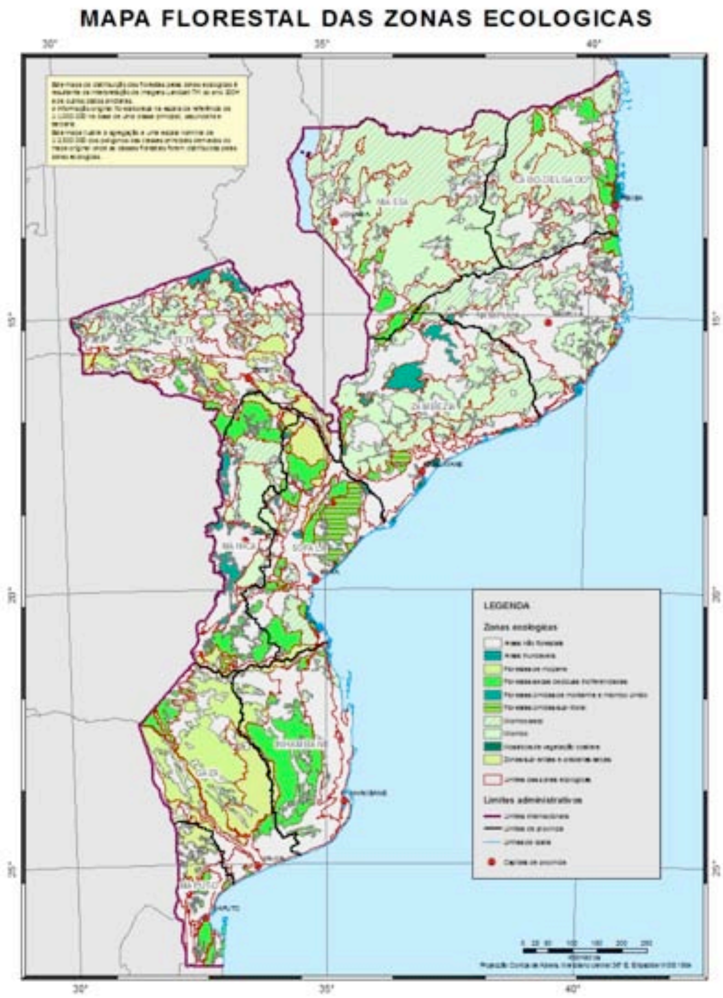
- **Plants:** In Mozambique, 300 plant species are listed in the Red Data List (Bandeira e Izidine, 1995) of which one is known to be extinct, six are critically threatened and six are threatened and the rest are in the categories of vulnerable, low risk, or with insufficient data. 50% of the species listed under the Red Data List are endemic and 22% are confirmed nearly endemic.
- **Animals:** According to MICOA (2008), there are 4,271 terrestrial animal recorded species of which 72% comprise of insects.
- **Mammals:** Three sub species of terrestrial mammals are considered endemic to the northern Mozambique, namely: *Equus burchelli* subs. *boehmi* (zebra), *Connochaetes taurinus johnstonii* (blue Niassa wildbeast) and *Aepycerus melampus* subs. *johnstonii* (johnstonii impala). There are at least three extinct or threatened to extinction (*Cerato thorium simum*, *Damaliscus lunatus*, *Tragelaphus spekei*) and five Threatened species (*Diceros bicornis*, *Giraffa camelopardalis*, *Hippotragus equinum*, *Redunca fulvorufula* and *Acinomyx jutabus*). Other endangered and vulnerable mammals known from Mozambique include African Wild dog (*Lycaon pictus*), African elephant (*Loxodonta africana*), Common hippopotamus (*Hippopotamus amphibius*), and lion (*Panthera leo*) (www.iucnredlist.org).
- **Birds:** Seven hundred thirty five species of bird species have been identified for Mozambique (MICOA, 2006). According to this author, the majority of these bird species is migratory and can also be found in neighboring countries. Bird species areas include the Marromeu Complex (Bento & Beifuss, 2003), Inhaca Island (Kalk, 1995; de Boer & Bento, 1999) and Banhine National Park. Most of the endemic bird species are associated to the mountainous habitats, specially the insenlbergs including Chiperone, Namuli, Mecula hills, Gorongosa and Chimanimani massif complexes. About 20 species of birds are known to be of interest for conservation.
- **Herptofauna - Reptiles and amphibians:** Data about herptofauna is not complete. About 167 species of reptiles have been identified recently. The endemic species were identified in Chimanimani (*Platysaurus ocoellatus* – the flat rock lizard), along the coastal forests in Zambezia Province (*Dromophis* sp. and *Lygodactylus* sp.) and a new species of lizard (*Cordylus maculae*) was recently identified from the Mecula hills. The Red Data List (www.iucnredlist.org) identifies 9 species of reptiles of conservation concern for Mozambique.

  The herpetofauna diversity area is the Zambeze delta with more than 200 species of reptiles and 90 amphibians identified (Timberlake, 2000) and probably the Maputaland Regional Centre of endemism. Of the 129 species of known finbos from Southern Africa, 16,28% (21) are found on Maputaland Regional Center of endemism. Three species are terrestrial and the rest depend on water.

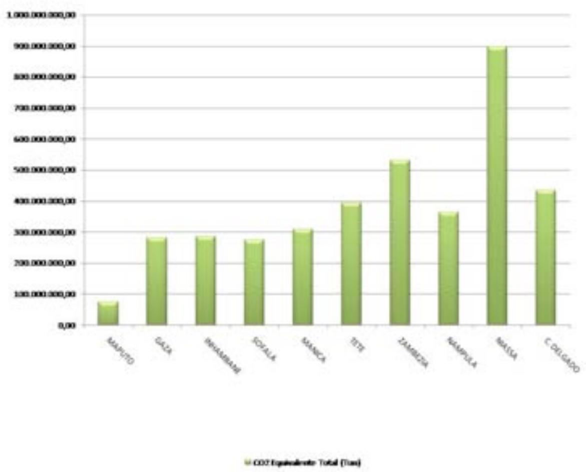
3.1.5: Vegetation types Mozambique (based on Marzoli *et* al. 2007)



3.1.6: Areas important for biodiversity



Appendix 3.2: Chart of the stocks of CO2 equivalent per province



Appendix 3.4.: Classification land use systems

3.4.1: Classification cultivation and farming systems

Man can obtain food from nature, for instance collecting fruits, nuts, honey, mushrooms, or hunting wild animals and birds. Globally, and/or regionally, nature does not provide enough food, and man started some millennia ago to domesticate animals and to cultivate land. In other words man developed different land use systems to obtain food in a controlled way. For instance: guiding large herds from one area of green natural grazing land to another area; establishing pastures for grazing; crop and tree cultivation.

Cultivation and farming systems can be classified according to a number of particular features:

- *Classification according to the implements used for cultivation*: hoe-farming or spade-farming; farming with plows and animal traction; and farming with plows and tractors.
- *Classification according to the degree of commercialization*: subsistence farming, if virtually not any crop and animal products are sold; partly commercialized farming, less than 50% of the value of the produce is sold; and commercialized farming, more than 50% of the value of the produce is sold.
- *Classification according to the intensity of (land use) rotation.* Land use rotation has to be distinguished from crop rotation. Namely land use rotation, or long term rotation, describes the changes in use of the same land, alternatively for cropping, or fallow, or ley, or etc.. Whereas crop rotation describes the short-term sequence of different arable crops on one field, and the rotation of these crops between the fields of one farm.

3.4.2: Classification of land use systems based on fraction of land cultivated (FLC)

Based on FLC the following classification of land use systems can be made (Ruthenberg, 1980.p.14-18):

- Shifting cultivation systems FLC < 33%;
- Fallow systems FLC 33% - 66%;
- Intensive subsistence agriculture FLC > 66%;
- Continuous cropping FLC = 100%.
- Multiple cropping when "FLC" > 100%. Namely when on 50% of the land 2 crops a year are grown, and on the other 50% of the land 1 crop a year, "FLC" = 150%. And in case 3 crops a year are grown on all land "FLC" = 300%.

Classification of farming systems in tropical Africa and their sustainability, adapted from Okigbo (Okigbo, 1990 .p.333,336).

- Highly Sustainable (HS); Sustainable (S); Not Sustainable (NS); Sometimes Sustainable (SS); Sustainable under specified circumstances (SU).
- Risk of soil degradation due to erosion (E), due to nutrient mining (N).

Traditional and transitional systems.

- 1a. Shifting cultivation, phase 1. Shifting cultivation. FLC < 10% HS.
- 1b. Shifting cultivation, phase 1. Nomadic herding. FLC < 10% SS / E.
- 2. Shifting cultivation, phase 2. Bush fallowing or land rotation. FLC 10%-20% NS / N,E.
- 3. Shifting cultivation, phase 3. Rudimentary sedentary agriculture. FLC 25%-50% NS / N,E.
- 4a. Shifting cultivation, phase 4. Compound or homestead farming and intensive subsistence agriculture. LFC > 50% S / E.
- 4b. Shifting cultivation, phase 4. Intensive subsistence agriculture. LFC > 50% SU / N,E.
- 5a. Terrace farming. SU / N.
- 5b. Floodland agriculture. HS.
- 6. Mediterranean agriculture (traditional). SU / N,E.

Modern farming systems and their local adaptations.
1: Mixed farming. S / N,E.
2: Livestock ranching. SU / E,N.
3: Intensive livestock production (poultry, pigs, dairying). SU.
4a: Small-scale irrigated farms (lowland rice, vegetables, and arables). S / N.
4b: Small scale fish farming. HS
5: Large-scale farms and plantations.
a) large-scale food and arable crop farms based on natural rainfall. NS / E,N.
b) irrigation schemes involving crop production. SU / N.
c) large-scale tree crop plantations. S / E.
6: Specialized horticulture.
a) market gardening. HS.
b) truck gardening and fruit plantations. SU / E.
c) commercial fruit and vegetable production for processing. SS / E,N.

Classification according to the type of natural vegetation at the end of the fallow period.
- Forest fallow: woody vegetation with trunks and a closed canopy in which the trees are ecologically dominant.
- Bush or thicket fallow: dense wood vegetation without trunks.
- Savanna fallow: mixture of fire resistant trees, shrubs, and grass, in which the grasses are ecologically dominant.
- Grass fallow: grasses and some herbs without woody vegetation.

Classification focusing on diverse other features.
- Ley system. Describes situations in which the fallow is grazed. Plants establish spontaneous on land that has carried crops for some years, grass and shrubs can form the major components and serve as rough pasture. In other situations specific grasses and shrubs can be planted on purpose for grazing. In both cases the ley sward can be grazed for several years before being cultivated again for cropping.
- Field systems. Fields are clearly separated from each other. Some field are practically permanently cropped. Others fields are treated as permanent grassland, whether it is rough or well cared for.
- Perennial crop systems. Within this category can be perennial crops like sisal, bush-crops like tea and coffee, and tree crops like oil-palm and rubber.

Appendix 3.5: Biophysical suitability Mozambique *Jatropha*

3.5.1: *Jatropha* production in Mozambique, name of institution, province and size of operation (Source: CEPAGRI, 2011)

Name of the project/ Company	Province	Area (ha)
Luis Mondlane	Cabo-Delgado	10 000
Sub-total		10 000
Energem, Lda	Gaza	1 000
Energem, Lda	Gaza	999
Nyelete Mondlane	Gaza	1 000
Sub-total		2 999
Ana de Fátima Domingos C	Inhambane	100
Daniel Job Lázaro Chango	Inhambane	100
Guilherme Francisco Nhanala Junior	Inhambane	100
Inveragro/ESV Bio-Africa/Sab Mozambique	Inhambane	6 334
Jorge Lázaro Piores Chongo	Inhambane	100
José António Cumbane	Inhambane	100
Leonardo Guilhermae Nhanala	Inhambane	100
Lúcia da Natividade Guilherme Nhanala	Inhambane	100
Marilia Zita Jafete Namburete	Inhambane	100
Omar Cassamo	Inhambane	2 905
Socidade *Jatropha* enterprises, Lda	Inhambane	1 000
Sociedade Chamc Agri Lda	Inhambane	950
Sociedade Chamc Investiments Lda	Inhambane	496

Sociedade Chamc Investiments Lda	Inhambane	1 000
Sub-total		13 485
Biodiesel de Manica	Manica	8 000
Quinta das Laranjeiras	Manica	5 000
Sun Bio-fuels	Manica	5 000
SUN BIO-FUELS	Manica	3 700
Sub-total		21 700
Bio-energia Mozambique	Maputo	6 950
Deulco Envest	Maputo	1 220
Moçambique - Inhlavuka	Maputo	4 143
Sub-total		12 313
Antonio Anibal de Riela	Nampula	1 000
Aviam	Nampula	15 550
Fautino Omar Atumane	Nampula	1 000
Ischaca Abdul Ali Baraca	Nampula	1 000
Olivia Theima Moises	Nampula	1 000
Sabino Omar Assane	Nampula	1 000
Verus Moç Lda, BioEnergy Project, Monapo	Nampula	10 000
Sub-total		30 550
Associacao de Transformaçao Rural	Sofala	5 000
Balvano, SDVZ	Sofala	9 800
Elion Africa	Sofala	1 000
Enerterra	Sofala	18 508
Projecto NIQEL	Sofala	10 000
SUN BIO-FUELS	Sofala	5 000
ZAMCORP-Indico Cluster AJ1	Sofala	20 400
Sub-total		69 708
Total		160 755

3.5.2: Suitability for *Jatropha*) for each province (source: Zonemento Agrario, 2011 scenario 1).

Suitability *Jatropha* Mozambique			
Province	Moderate	Marginal	Not suitable
C.Del	944.400,0	366.000,0	114.800,0
Nias	564.400,0	547.600,0	81.200,0
Namp	1.138.000,0	216.000,0	86.400,0
Zamb	1.554.000,0	1.141.200,0	232.400,0
Tet	860.400,0	1.352.800,0	756.000,0
Man	378.800,0	695.600,0	359.600,0
Sof	367.200,0	885.200,0	285.200,0
Inh	754.000,0	495.200,0	1.830.400,0
Gaz	26.400,0	451.600,0	1.491.200,0
Map	3.200,0	100.800,0	834.800,0
Total	6.590.800,0	6.252.000,0	6.072.000,0

3.5.4: Biophysical suitability requirements *Jatropha*

Altitude and climate (Brittaine and Lutaladio, 2010; Eijck van, 2010)

- *Jatropha* seems to be well adapted to altitudes from sea level to 1.300 à 1.500 m a.s.l.
- *Jatropha* is intolerant to frost, it is well adapted to temperatures between 20 – 28 ^{o}C
- *Jatropha* can survive under very dry conditions in regions with a precipitation of 250 – 300 mm/yr; for flowering and seed set it needs 600 mm/yr; for optimum production 1.000 – 1.500 mm/yr. In areas with more than 2.000 à 2.500 mm/yr it will be subject to attack by fungi, and very likely its root development will be hampered by too wet surface soil.

Soils and soil fertility

- *Jatropha* grows well on aerated sands and loams of more than 45 cm deep.
- *Jatropha* is intolerant of waterlogged conditions.
- *Jatropha* grows well in soils with pH 5,5 – 8,5, the optimum pH range is 6 – 8. (The pH range coincides with pH-values prevalent in regions with a precipitation of 800 – 1.200 mm/yr.)
- *Jatropha* can invade very poor (not wet) soils where few other species will establish or persist. However on such poor soils, the production of *Jatropha* will be poor too. *Jatropha* needs soils with at least low-medium to preferably medium (or better) soil fertility to give a reasonable production.

Soil fertilization, legumes and mycorrhiza

There is no unequivocal information on the advantages of fertilizing *Jatropha*. Another approach to the question, to fertilize or not, is: "at least soil replenishment with plant nutrients carried off with crop products and with crop residues not left in the field". Along this line Table 1 has been developed.

	Seed yield kg dm/ha/yr		
	500	1000	1500
Removed* N kg/ha/yr	15	30	45
Fertilization** N kg/ha/yr	30	60	90
Removed* P kg/ha/yr	2	4	6
Fertilization** P kg/ha/yr	20 (46 P_2O_5)	41 (94 P_2O_5)	61 (140 kg P_2O_5)
Removed* K kg/ha/yr	15	30	45
Fertilization** K kg/ha/yr	38 (46 K_2O)	75 (90 K_2O)	113 (136 K_2O)

Table 3.5.2.1.:Soil nutrient removal by *Jatropha* production and fertilizer requirement to maintain production (adapted from Jongschaap et al., 2007. Cited in Eijck van, et al. 2010.p.30)

* Nutrients removed by fruits, + 25% of pruned material from stems and branches.
** Fertilization equals nutrients needed for tree growth and seed production, considering that not all nutrients applied to the soil will be taken up by the trees (leaching, chemical fixation by soil compounds, incorporation in soil organic matter).

The fertilizer requirements cited in Table 1 are very high. And too high for P, it will not or hardly leach from the soil, and in the *Jatropha* soils generally with pH >6 no fixation of P by aluminum will occur. Thus P will accumulate from fertilization in excess of 10 kg P/ha/yr, which cabn be considered as unnecessary. With respect to K in tropical climates with a precipitation of less than 1.000 mm/yr little or no K will leach from the soil.

With respect to N-fertilization losses of 50% are normal, even so the recommended rates seem high. Planting of N-fixing leguminous food, feed or cover crops can result in carry-over of N to the *Jatropha*. With respect to liberating and providing P from the soil, as such, inoculating the *Jatropha* at seeding and/or the soil with mycorrhiza can be beneficial (Brittaine and Lutaladio, 2010. p.35).

Pests and diseases (Brittaine and Lutaladio, 2010. p. 37; Öhman, 2011. p.65).

It is popularly reported that pests and diseases do not pose a significant threat to *Jatropha*, due to the insecticidal and toxic characteristics of all parts of the plant. Observations on free standing older trees would appear to confirm this, but occasional incidence of pests and diseases is reported under plantation monoculture, and may be of economic significance. Global inventories sum up to a total of potential attacks by 10 different pests (beetles, bugs, terminates, etc.) and 8 different diseases (root rot, rust, mildew, etc.).

Appendix 4.0: Background Zambezia province

Location: Zambezia Province is located in the central region between parallels 14 and 59 'and 18 ° 54' 40 "south latitude and between the meridians 35 ° 17 '53" and 39 ° longitude. With around 400 km of coastline, bathed by the Indian Ocean to the east, making out with the provinces of Nampula and Niassa in the north west with the Republic of Malawi and the Tete Province and south by the Province of Sofala. It has an area of 105,008 km2 of which 103,127 km2 land area of 1,881 km2 and consist of inland waters. Zambezia Province has a forest area of 8,536,750 ha of forests, 105,500 ha of mangroves and 1,093,750. There savanna, totaling 9,355,500 (*Source provincial Government Zambezia*)

Administration: The province is administratively divided into 16 districts, three cities, being the Qulimane (which is the capital, with the status of district) and two D-level, 45 administrative posts and 189 Villages. Highlights three regions: North, Abrage districts Gile, High Molocué, Gurué, lie, Namarroi, Lugela and Pebane, and South districts formed hair Namacurra and Nicoadala, Quelimane, Mopeia, and Chinde Inhassunge

Climate: The province is under the influence of equatorial pressionário Valley and the Mozambique Channel that affect the thermal values, which increases average temperatures, the warm current that gives the channel temperature and humidity on the coast, thus providing abundant rainfall. In the intertropical convergence zone, dragging down the trade winds, loaded with moisture, the subtropical anticyclones in the southern hemisphere, from the zones of high pressure associated with the mass of hot air. The interior is under the influence of altiude, giving moderate temperatures. All these factors condition that the Province has three types of climates: humid tropical, coastal, tropical dry, inside and altitude tropical highlands of the interior. The relative humidity in the rainy season varies from 75-80% in the dry tropical climate 90-100% in the humid tropical.

Population and ethnic diversity: Zambezia Province, with an estimated population of 3,890,453 inhabitants, about 20% of the total population of the country, is one of the most populated provinces. Zambezia has the highest levels of fertility (crude birth rate of 50.8 per 1000), mortality (17 per 1000) and natural growth (6.68% per annum). The principal economic activity that absorbs most of the economically active population is agriculture, mainly subsistence, employing about 82% of the workforce. The system of farming population largely characterized by plantation companies that do not require skilled labor is one of the causes that can be used to explain the low levels of schooling, vocational training and participation of women in employment (Source Government Zambezia).

The ethnic and linguistic diversity (Cultural Mosaic) of the population makes in Zambezia Province with unique characteristics compared to other country's in fact the existence of five ethnic groups, including Chuabo, Makua-Lomu, manhaua, Marengo and senas is unique in the country. In the province there are the following language groups: Mainde and Pondzo in Chinde, Senas in Mopeia and Morrumbala, Nhyanjas and merengue in Milange, Chuabo in Quelimane, Inhassunge, Nicoadala, Namacurra and Mocuba; Macua.Lomué in Gurué, Pebane, lie, Gile, Built-In Molocué and Moroccan í, Manhaua in Lugela and Nharinga in Maganja da Costa. In addition to the predominantly African beliefs in Zambezia the following religions: Christian, Protenstantes, Moculumanas and Hindu.

Appendix 4.1

4.1.1: Plant species that are a priority for conservation in Zambezia Province (www. iucnredlist.org)

Scientific name	Family	IUCN status	Note
Blephsris dunensis Vollesen	Acanthaceae	VU B1B2cD2	endemic
Celosia pandurata Baker	Amaranthaceae	VU D2	endemic
Impatiens psycantha Launert	Balsaminaceae	VU D2	endemic
Impatiens psychadelphiodes Launert	Balsaminaceae	VU D2	endemic
Rhodognaphalon mossambicense Sprague	Bombacaceae	VU D2	endemic
Combretum caudatisepalum Exell & Garcia	Combretaceae	VU D2	endemic
Combretum stocksii Sprague	Combretaceae	VU D2	endemic
Cassula morrumbalensis R. Fern.	Crassulaceae	VU B1B2cD2	endemic
Dichapetalum zambesianum Torre	Dichapetaceae	VU D2	endemic
Homalium mossambicensis Paiva	Flacourtiaceae	VU B1B2cD2	endemic
Icuria dunensis Wieringa	Fabaceae	EN A2c	endemic
Hugonia elliptica N. Robson	Linaceae	VU D2	endemic
Ammania elate R. Fern.	Lythraceae	VU D2	endemic
Digitaria appropinquata Goetgh	Poaceae	VU D2	endemic
Adenia zambesiensis R. & A. Fern.	Passifloraceae	VU D2	endemic
Digitaria megasthenes Goetgh	Poaceae	VU D2	endemic
Oldenlandia verrucitesta Verdc.	Rubiaceae	VU D2	endemic
Cola mossambicensis Wild	Sterculiaceae	VU A1a	near-endemic
Bombeya lastii K.Schum.	Sterculiaceae	VU B1B2cD2	endemic
Tricliceras auriculatum (A. & R.Fern.) R.Fern	Turneraceae	VU D2	endemic
Vahlia capensis (L.F.) Thunb.subsp.macrontha Bridson	Vahliaceae	VU D2	endemic
Cissus bathyrhakodes Werderm.	Vitaceae	VU D2	

4.1.2: Species of Mammals with conservation priority in Zambezia Province (www. iucnredlist.org)

Species	Common name	IUCN status
Lycaon pictus	African wild dog	Endangered
Diceros bicornis	Buffalo	Critically endangered
Hippopotamus amphibious	Hippo	Vulnerable
Panthera leo	Lion	Vulnerable

4.1.3: HCV 1.2: data input

For the identification of the critically endangered species that occur near or in the study area a landscape analysis was made in order to verify if the distribution of the endangered species, and their habitats in the study area or its surroundings. The information used was the following:

- IUCN Red data List (www.iucnredlist.org). This list presents the species identified as endangered according to international consensus.
- CITES Appendix (www.cites.org). CITES is the international agreement between governments on species that need protection from extinction. CITES is a mechanism by which it is ensured that the trade of wild animals and plants does not threaten survival of the species.
- Distribution of large mammals (e.g. Rhino, Elephants, lions, leopard and buffalos).

4.1.4: Analysis HCV 1.3

The assessment of HCV 1.3 aims to identify habitats that could sustain viable populations of protected, endangered, or restricted range of species in or near the study area. The species under consideration include those species that are categorized as:

- Endangered or vulnerable species based on IUCN Red data List
- Data from CITES Appendix 1 and 2;

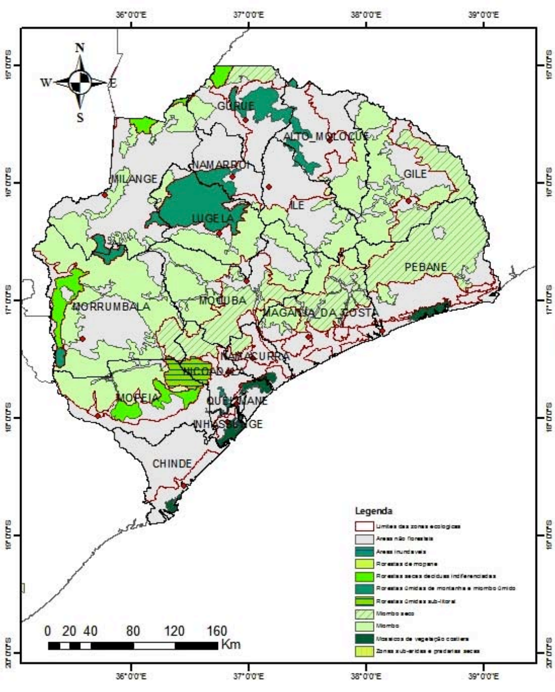
- Endemic species lists (important bird Area (IBA))

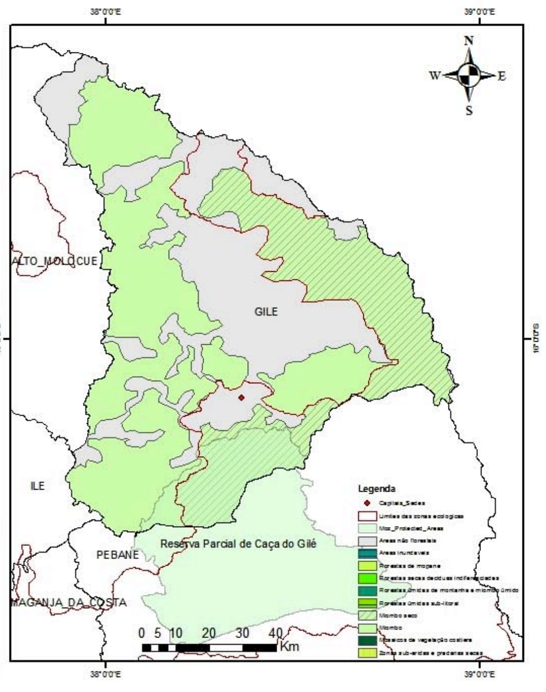
Data Input

- Forest cover map (Ministry of Forestry, 2005
- IBA and EBA; (WWW.africanbirdclub.org), 09.08.2011.
- Distribution of large mammals

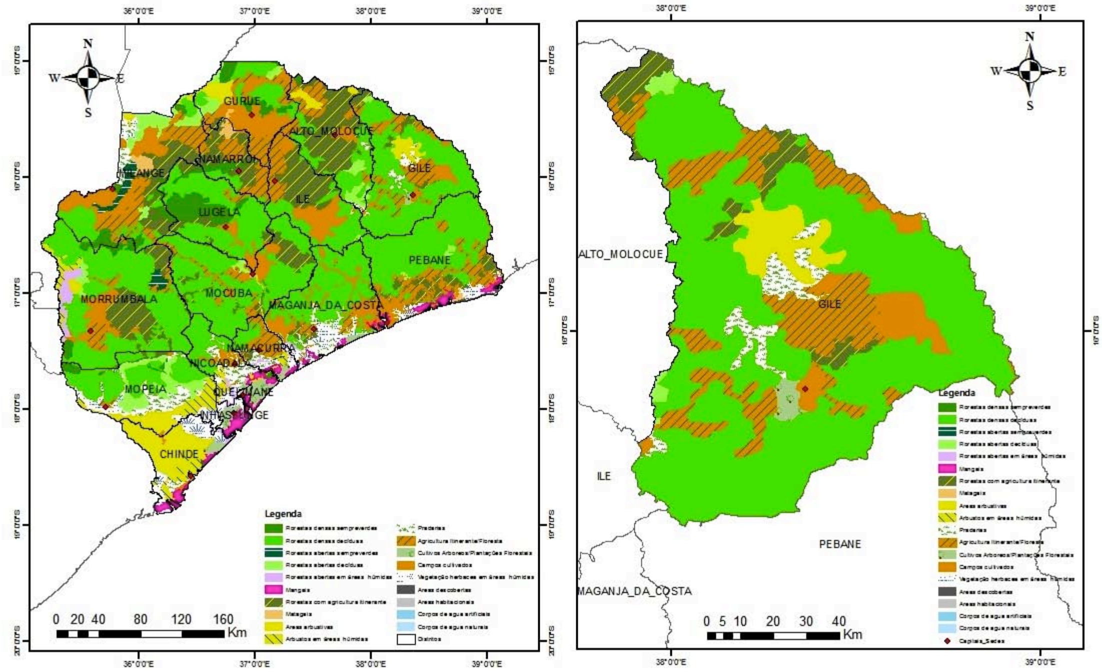
The inselbergs (e.g. Chiperone, Namuli, Mabu) have been reported to contain extensive areas of montane forest and grasslands rich in biodiversity. The area is known to be the habitat for important bird species such as the Namuli Apalis and Dapple-throat (described as vulnerable on the IUCN Red Data List) and the latter being endemic (Timberlake, 2009). In addition, these vegetation types support viable populations of the Cholo Alethe (endangered and endemic to Southern Malawi and Adjacent areas in northern Mozambique). Due to habitat pressure on the Malawian side most of the populations of this species are restricted to the Mozambican side. The presence of the Namuli apalis- *Apalis lynesi*, the Dapple-throat – *Arcanator orostruthus* and Cholo Alethe- *Alethe choloensis* has been a valid argument for considering the Namuli mountains an Important Bird Area -IBA (www.africanbirdclub.org, 2011; Timberlake, 2009).

The Moebase forest is part of the coastal forest of eastern Africa, known to be rich in endemic species. A new species for science (*Icuria dunensis*) was recently described (Weringa, 1999) in this forest patch. The patch is thought to be one of the remnants of a forest which was once continuous throughout the eastern side of Afrika.

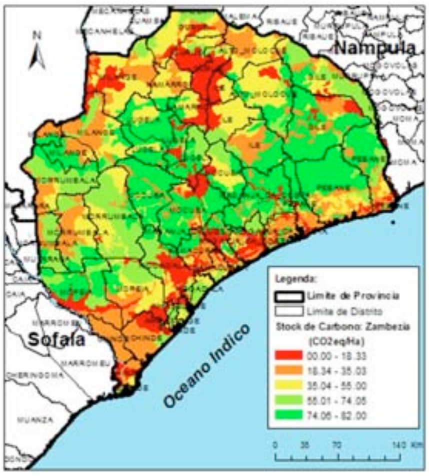


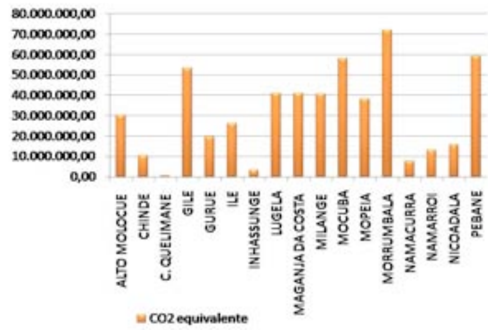


4.1.5: HCV 2.1: Large natural landscapes in Zambezia



Appendix 4.2: Distribution of Carbon stocks in Zambezia





Appendix 4.4.1: Quantification shifting cultivation in Zambezia based on FLC

The following calculations support the information on this shifting cultivation cycle only partly. Assuming that the land is cropped during 2 years, then calculations indicate that it is fallowed during 5,7 years. Namely FLC = [Crop years : (Fallow years + Crop Years) = [2 : (F + 2)] = 0,26; then F = 5,7 years. Assuming that the land is cropped during 4 years, then the calculations indicate that it is fallowed during 11,4 years. Namely FLC = [Crop years : (Fallow years + Crop Years) = [4 : (F + 4)] = 0,26; then F = 11,4 years.]]
Based on the average FLC = 26 % the smallholder agriculture in Zambezia can be classified according to Ruthenberg as: (FLC <33%). The farms on which a shorter fallow period is practiced fall in the category of "fallow system agriculture" (FLC 33% - 66%). According to Okigbo the agricultural system can be classified as "shifting cultivation phase 3, rudimentary sedentary agriculture" (FLC 25% - 50%).

Appendix 4.5: Estimated crop roduction potential Mozambique

4.5.1: Global and local yield data of crops considered for bio-energy in Mozambique

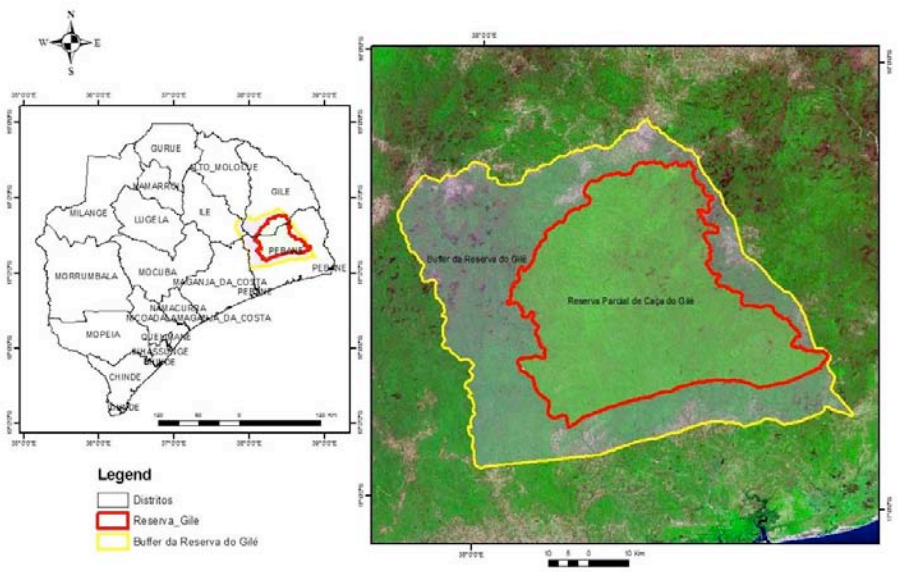
Crop; product; growth period, or harvest interval	Mitchell, 2011. Global.	Vries de, et. al., 2011. Mozambique; 1.400 mm. Crop-model calculations	Euroconsult, 1989 Global. Extensive/ Intensive	FAO, 2008; FAO, 2009. Mozambique	Other literature sources. Mozambique *
	ton fresh crop product/ha/yr				
sugarcane; stalks; 1 year	66	76 (plant nutrients optimal)	30 // 60	14 (1990-2008); 40 (1970-1989)	65 (2008-2010) (USDA, 2011); **<u>14-30</u>** (Köster, 2011)
sweet sorghum; stalks; 4-6 months	27	46 (plant nutrients optimal)	n.d.	n.d.	30-46 stalks, plus 2-4 grain (ICRISAT, >2007), different varieties; **<u>8-10</u>** (Köster, 2011)
cassava; 1 year; roots	12 Nigeria; 18 Thailand	29 (plant nutrients optimal); 10 (soil P-deficient); 19 (soil medium fertility)	7-10 // 25	5	**<u>5-10</u>** (Köster, 2011)
cocos palm; continuous; copra	5 (nut or copra?)	n.d.	0,5-1 // 2,5	n.d.	**<u>0,6-0,7</u>** (Bourdeix, et al., >2000).
Jatropha	5	n.d.	n.d.	n.d.	**<u>0,8-2</u>** (Köster, 2011)

* in bold and underlined, default range for smallholders in Zambezia, Mozambique
Halas the above reflections on fertilizer use are way beyond the actual situation of smallholders in Africa. With respect to smallholders in Mozambique is remarked: "the majority is impoverished and largely isolated from the benefits of policy, good advice and improved technologies"; a mere 4% of them used fertilizers in 2007 (Coughlin, 2011. p.321, 345).

Appendix 5.0.1: List of data to be obtained through field activities in phase III

Principle	Further analysis	What (Data)	How (Activity)	Expertise
P1: HCV 1.1	No	-	-	-
P1: HCV 1.2	Yes	Presence red list species	Interview local community	Ecology
P1: HCV 1.3	Yes	Current forest cover	Vegetation cover ass.	Ecology
P1: HCV 1.4	Yes	Temporal presence migratory species	Interview local expert	Ecology
P1: HCV 2.1	Yes	Current forest cover	Vegetation cover ass.	Ecology
P1: HCV 2.2	Yes	Current forest cover	Vegetation cover ass.	Ecology
P1: HCV 2.3	Yes	Current forest cover	Vegetation cover ass.	Ecology
P1: HCV 3	Yes	Current forest cover	Vegetation cover ass.	Ecology
P1: HCV 4.1	Yes	Water extraction areas	Interview local community	Sociology
P1: HCV 4.2	No	-	-	-
P1: HCV 4.3	Yes	Land management practices	Interview local community	Sociology
P1: HCV 5	Yes	Food, water, medicine source	Interview local community	Sociology
P1: HCV 6	Yes	Precence cultural values MU's	Interview representative sample of community	Sociology
P2: Carbon	Yes	Aboveground biomass	Vegetation assessment + dbh measurement	Ecology
P3: L.R.	Yes	Distribution land rights	Interview village heads	Sociology
P4: Displ.	Yes	Current land use local communities	Interview local community	Agronomy/Sociology
P5: Agr. Suit.	Yes	Economic feasibility development	Interview agronomist *Jatropha* comp.	Agronomy

Appendix 5.1.1 Gile Reserve with the buffer zone (area of vigilance) on the northern border of the Reserve.



Appendix 5.2:

5.2.1: Methodology used for carbon stock measurements

The above ground biomass was estimated following the Hairiah *et al*. (s/d) Field Manual. To assess the above ground biomass stock on trees rectangular plots (5 X 40 m) were used on different land cover/use types and quadrate (0.5 X 0.5 m) plots for the understory vegetation. Both plots were placed on a casual basis on the selected vegetation type. The girth of each tree was measured at 1.3 m using a measuring tape and the scientific name identified using field guides (Palgrave, 1995; van Wyk and van Wyk, 2008) and/or expert knowledge. A local parataxonomist helped with the local names. The understory vegetation present in the quadrate was removed for drying and weighing at the Marine Biology Research Station (MBRS) lab in Inhaca.

Brown (2002) developed generalized allometric equations relationships stratified by land cover/use types appropriate for tropical regions. The allometric equations based on the diameter at breast height (dbh) of the trees explain more than 95% of the variations in above ground carbon stocks of tropical forest environments. The standard allometric equation for dry (<1500 mm) tropical forests suggested by Brown *et al*. (1989) was used to derive the above ground biomass of the trees. The carbon fraction was determined by using the established default 50% of biomass (IPCC, 2006).

Appendix 5.4.1: Distribution population per village for Mamala (in green communities in research area), Zambezia Province, District Gilé (Source: Government of the City of Mamala (May 2011))

Name of Community	Inhabitants
Inlepa	2.088
Naholoca	1.226
Pacane	2.614
Mareca	4.624
Macolo	1.427
Murihiua	2.955
Cualulo	694
Maneia	900
Namipissa	1.005
Ilute	4.153
Namicopo	2.545
Namarrepo	1.005
Muriosse	3.000
Macussa	315
Total	**28.551**

Appendix 5.4.2: Distribution population per village for Moiane, Zambezia Province, District Gilé (Source: Government of the City of Mamala (May 2011))

Name of Community	Inhabitants
Nampela	2.486
Retua	3.417
Muilua	753
Nahipa	800
Nhanhiua	473
Ingela	650
Maua	545
Cachamia	430
Nauro	330
Nivale	607
Tamiha	545
Mucura	250
Cocholiua	559
Muhano	952
Napote	694
TOTAL	**13.491**