Chapter 21
Potential Impacts of Biofuel Development on Biodiversity in Chobe District, Botswana

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Abstract There is a need to use cleared idle agricultural land for biofuel production in order to avoid adverse impacts on food security and biodiversity. This chapter examines the potential impacts of biofuel development on biodiversity in Chobe District, Botswana, using literature review and stakeholder interviews. The stakeholders interviewed confirmed that there are significant areas of idle agricultural land available in the district, but most of it is not cleared. Therefore, the production of biofuels in Chobe District may on the one hand negatively affect biodiversity through the clearing of new land, but on the other hand it may not adversely affect food security since idle agricultural land will be used. The use of marginal land for biofuel production may also harm biodiversity (plant and animal species). This chapter shows that the use of jatropha and sweet sorghum for biofuel production is likely to have a lower impact on biodiversity compared to corn. In conclusion, research on biology, chemistry as well as agronomic aspects of energy crops should be undertaken prior to large-scale biofuel development in Botswana.

Keywords Biofuels • Biodiversity • Land use change • Climate change • Botswana

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21.1 Introduction

Biofuels are produced from biomass for a wide range of applications such as cooking, heating, cooling, and transport. Biofuels can be solid (e.g. fuel-wood), liquid (e.g. bioethanol, biodiesel) or gaseous (e.g. biogas) (FAO 2008). However, the term biofuel nowadays mainly refers to liquid biofuels such as bioethanol and biodiesel (UNEP 2008) and this chapter has adopted this definition. The major driving forces behind biofuel development are concerns about increasing energy prices, depletion of fossil energy sources, concerns about the environment and rural development (Dufey 2006; Goldemberg 2009). With respect to the environment the major issues of concern revolve around the following themes: greenhouse gas emissions, land-use change, water quality and quantity, air quality and biodiversity loss, the subject of this chapter (Dufey 2006).

The relationship between biodiversity and biofuel development in Botswana is still not clearly understood. Biodiversity is defined as the number, variety and variability of species of plants, animals, and micro-organisms as well as their ecosystems and ecological processes (Wallace 2007; Pearce et al. 1991, 1993). Biodiversity is essential for maintaining ecosystems which are important for the provision of ecosystem services essential for the well-being and survival of humans. The Millennium Ecosystem Assessment (MEA 2003) defines ecosystem services as “the benefits which people obtain from ecosystems”. Ecosystem services are categorized by the MEA as follows: (1) provisioning services such as food, medicines and water, (2) regulating services such as water quality regulation and flood control, (3) cultural services such as recreation and tourism and aesthetic values and (4) supporting services such as soil formation and photosynthesis (Wallace 2007).

Not all the economic benefits associated with biodiversity conservation are known. Each species is unique and not necessarily substitutable, and it is not known which species will become resources in the future (Bishop 1978). There is currently an uncertainty about future losses in biodiversity and their irreversibility. Although biofuel development is associated with a number of benefits, it can also have negative impacts, particularly if not guided by appropriate practices and policies. It can, for instance, lead to loss in biodiversity, increase in greenhouse gas emissions, food insecurity and aggravation of poverty (UNEP 2008).

Compared to other countries in southern Africa, Botswana has high faunal and low floral biodiversity. The number of species in Botswana is estimated to be as follows: 150 mammals, 570 birds, 131 insects, 82 fish, and 2,150–3,000 plant species (MEWT 2007). Most of these species are concentrated in conservation areas of Chobe National Park, Moremi Game Reserve in the Okavango Delta, and Makgadikgadi Pans (MEWT 2007). In these areas, like in other parts of southern Africa, high rainfall is associated with high species diversity (O’Brien 1993). According to Sekhwela (2000), there is an increasing number of species with increasing rainfall. A feasibility study undertaken in 2007 on behalf of the Ministry of Minerals, Energy and Water Resources suggested that there is a potential for the production and use of liquid biofuels for transport in Botswana, with high potential for bioethanol in the northern part of the country and biodiesel in the Central District (EECG 2007).

This chapter presents a critical analysis of the potential impacts of the production of biofuels on biodiversity in Chobe District in Botswana. The specific objectives of the study are: (1) examine, through a state of the art literature review, how biofuel crops recommended for Botswana are likely to contribute to sustainable production and use of biofuels, (2) assess the potential impacts of using pristine land for biofuel production on biodiversity using existing literature, and (3) assess the perceptions of relevant stakeholders on the potential impacts of biofuel development on biodiversity.

21.2 Drivers of Loss in Biodiversity

Biofuel development may affect biodiversity in a negative or positive way, though most of the impacts are likely to be negative. According to Sala et al. (2009) and Omann et al. (2009), the major drivers of loss in biodiversity include habitat loss, increase in invasive species, pollution and climate change. Habitat loss, which is a major threat to biodiversity in Botswana (MEWT 2007), can be caused by direct and indirect impacts of biofuel production. Direct impacts occur when there is conversion of land from forest or grassland, whereas indirect impacts occur when conversion of agricultural land induces conversion of natural vegetation to agricultural production elsewhere (Smeets 2008). According to Fargione et al. (2008), the conversion of natural habitats such as "rainforests, peatlands, savannas, or grasslands" for biofuel production creates the so-called "biofuel carbon debt". This carbon debt is caused by CO_2 emissions which can be many times larger than the greenhouse gas (GHG) savings resulting from the substitution of fossil fuels by biofuels. It would thereby take decades to repay this debt from the benefits of carbon obtained from biofuel production. Furthermore, it is estimated that 10% substitution of petrol and diesel by biofuels will require 38% and 43% of the current cropland in Europe and USA, respectively (UNEP 2008).

If forests or grasslands are replaced by a single crop with low genetic diversity, the adverse impacts of habitat loss are even higher because monocultures are vulnerable to attacks by pests and diseases than diverse habitat patchworks (Royal Society 2008). The increase in pests and diseases is likely to lead to an increase in the use of pesticides/herbicides. In Botswana, the use of pesticides and herbicides has been found to affect non-target species and contribute to further loss in biodiversity (Arup Atkins 1990). The invasiveness of biofuel crops depends on the environment and type of the biofuel feedstock (Groom et al. 2008). According to the Royal Society (2008), some of the characteristics that make crops suitable for biofuel production (e.g. fast growth and high yields) also make them potential candidates for invasiveness. In addition, species which are not invasive in their native environment may become invasive in other environments.

Finally, climate change is one of the key drivers of loss in biodiversity, particularly in dry-land countries such as Botswana, where the global long-term predictions suggest that the climate is likely to become drier and hotter (MEWT 2007). According to Ravindranath et al. (2010) and FAO (2008), greenhouse gas emission savings of first generation biofuels are estimated to range from 20% to 60%. However, most of these studies exclude the impact of biofuels on land use change, which may be a major contributor to CO_2 emissions from biofuels (Ravindranath et al. 2010). Therefore, climate change and biodiversity are closely linked and policies for reducing climate change are also policies for conservation of biodiversity (UNEP 2008).

21.3 Principles for Sustainable Biodiversity

In recent years, there have been a number of initiatives worldwide concerned with the development of the sustainable production of biofuels. The Roundtable on Sustainable Biofuels (RSB) brings together different types of stakeholders concerned with the sustainability of biofuels (RSB 2009). The RSB has developed 12 principles for the production and use of biofuels. Biodiversity conservation, which is covered by Principle 7, states that “biofuel operations shall avoid negative impacts on biodiversity, ecosystems and other conservation values”. The Principle states that in order to achieve this objective there is need to ensure that biofuel production takes place in areas with minimum risk to biodiversity loss. The RSB further states that production of biofuels should only take place in areas of high risk if strict observation of conservation values is ensured.

Further principles for production and use of biofuels have been developed by the Competence Platform on Energy Crop and Agro-forestry Systems (COMPETE) project. With regards to biodiversity, COMPETE recommends that good practices which do not harm biodiversity and the ecosystem should be adopted in the production and use of biofuels (Janssen et al. 2009). Apart from the general principles on production and use of biofuels, other scholars have developed principles specific to the impacts of biofuels on biodiversity. For instance, Groom et al. (2007, p. 608) have developed 12 principles for the promotion of “sustainably grown, biodiversity friendly biofuels”. Some of the important issues raised by these principles include: (1) minimal use of land and agricultural inputs (fertilizer, pesticides and water), (2) promotion of restoration of degraded or marginal areas, (3) avoided use of invasive species, and (4) adoption of conservation tillage or other conservation oriented methods.

21.4 Research Methods

21.4.1 Study Area

According to the 2001 Census Report (CSO 2002), Chobe District has a land area of 22,052 km^2, and a human population of 18,258. The district is situated in northern Botswana and shares the border with Namibia in the north-west, Zambia in the

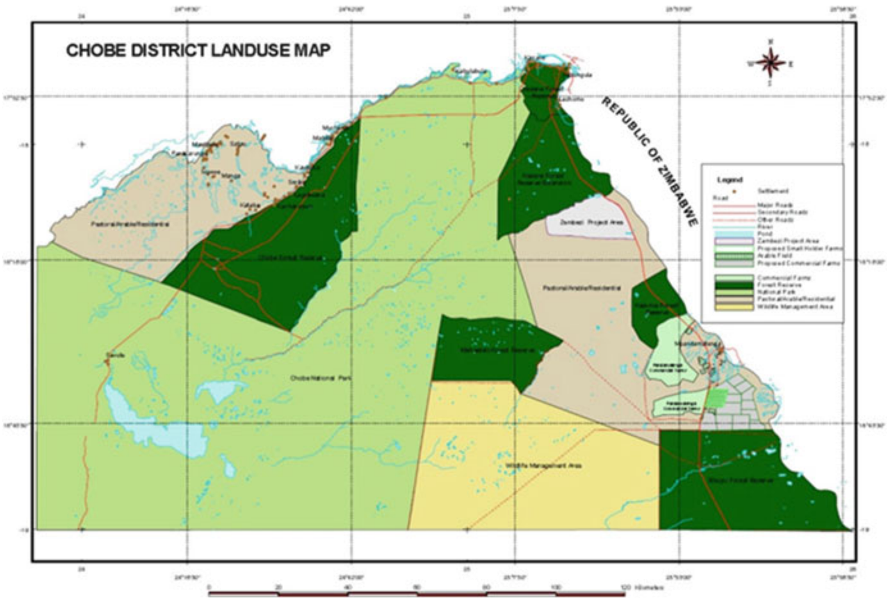

Fig. 21.1 Map of Chobe district, Botswana (Source: Ministry of Agriculture 2010)

north, and Zimbabwe in the east (Fig. 21.1). Chobe District has a low population density of one person per km^2, compared to the national average of three persons per km^2. The district has two land tenure categories, namely state land and tribal land. State land accounts for 69% of the district, mainly in the form of the protected areas of Chobe National Park and forest reserves which, as noted above, are areas of relatively high species diversity. Chobe National Park, covering an area of 10,566 km^2 (50% of the land in Chobe District) is the second largest park in Botswana with a very high diversity of wildlife, including a high number of elephants. There are six forest reserves in Chobe District covering an area of 4,096 km^2 or 19% of the land mass in the district, namely Kasane, Kasane Extension, Chobe, Kazuma, Maikaelelo and Sibuyu forest reserves (Kgathi and Sekhwela 2003). Tribal land accounts for 31% of the land area in Chobe District. Part of this land is designated as wildlife management areas (WMAs), which cover 10.7% of the land in the district. Eight villages of Pandamatenga, Lesoma, Kazungula, Mabele/Muchenje, Kavimba, Satau, and Parakarungu are settled on tribal land. About 80% of the district is therefore gazetted as conservation areas with free roaming wildlife. Thus, there is a shortage of land for livestock, crop production and other livelihood activities. Biomass is a major source of household energy in the district as 94% of households use fuelwood as their principal source of energy.

21.4.2 Research Methods

Data for this study were obtained through primary sources and a comprehensive review of secondary sources, both published and unpublished literature (grey literature, unpublished reports and planning documents). These included feasibility studies, environmental impact assessment studies and development plans. Published literature was mainly in the form of recent academic journal articles.

Qualitative data was collected through field observation and semi structured interviews were conducted with key stakeholders from relevant departments in Kasane and Gaborone (in March/April 2010 respectively). These included departments of Agricultural Research, Crop Production, Energy Affairs, Environmental Affairs, Forestry and Range Resources, Plant Resources, Ministry of Wildlife and Tourism, Physical Planning, Office of Research and Development (University of Botswana), commercial farmers and subsistence farmers. A total of 16 respondents (12 men and 4 women) completed a self-administered questionnaire that consisted of both closed and open ended questions. Respondents were asked to comment on the suitability of a number of biofuel crops for biofuel production in Botswana's Chobe District and potential impacts on biodiversity for production on agricultural land, marginal land, and forest reserve land.

21.5 Results

21.5.1 Biofuel Crops

The type of feedstock used for the production of biofuels is a major factor which determines the extent to which biofuels impact on sustainability, including biodiversity (Groom et al. 2008). The feasibility study for the production and use of biofuels in Botswana recommended sugarcane and sweet sorghum as suitable biofuel crops for production in Chobe district, whereas jatropha was recommended for growing in other parts of the country. These crops were selected because of their low costs of production and their suitability to the environmental conditions (EECG 2007). The production costs for sweet sorghum were estimated to range from Botswana Pula (BWP) 50/ton (8 US$) for small-scale production to BWP 60/ton (10 US$) for mechanized production. Those for jatropha were estimated to be BWP 610/ton/ha for plantations producing seed for 20 years and BWP 540 for those producing seeds for a longer period of 40 years (EECG 2007). The competitive advantage for these crops has also been analyzed. For instance, it was estimated that the price of jatropha based biodiesel in Botswana would be competitive with diesel at crude oil prices of 70 US$ per barrel (BWP 434). On the other hand, ethanol produced from sweet sorghum and sugarcane was found to be competitive with petrol at crude oil prices of 50 US$ (BWP 310) and 70 US$ (BWP 434) per barrel, respectively

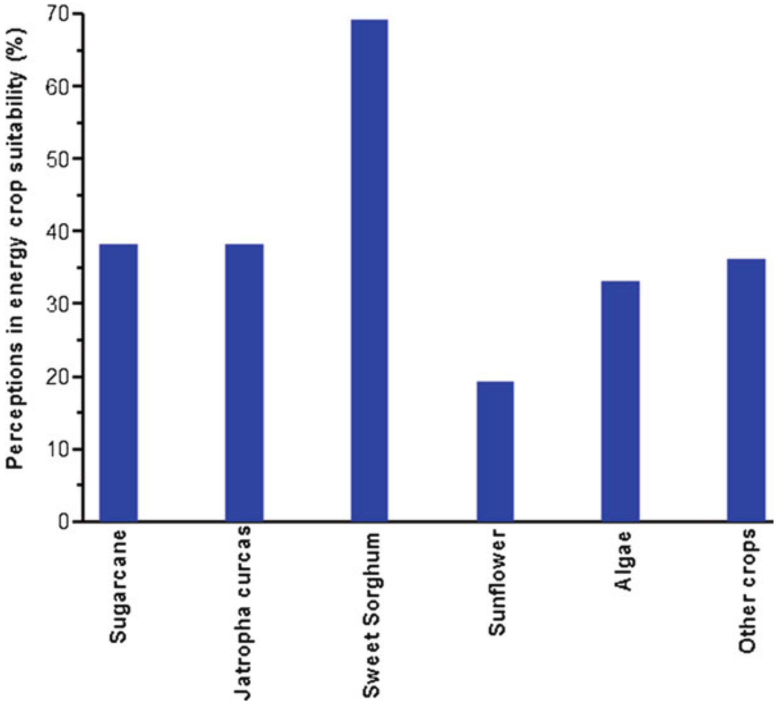

Fig. 21.2 Stakeholder perceptions on suitability of biofuel feedstocks in Botswana

(EECG 2007). This feasibility study included economic assessments only and did not address social and environmental costs (EECG 2007).

21.5.1.1 Perceptions About the Suitability of Feedstocks

The survey showed that sweet sorghum is considered the most suitable crop for biofuel production in the district by 69% of the stakeholders as it is already grown at subsistence level (Fig. 21.2). The stakeholders were aware that efficient first generation conversion technologies are available for producing bioethanol from sweet sorghum. Most of the stakeholders expressed reservations about the suitability of growing jatropha in the district and only 38% of them thought it should be encouraged. Most of them expressed the view that decisions on the selection of biofuel crops should be research-led rather than policy-led. Regarding sugarcane, the general concern is its high water needs, making it unsuitable for semi-arid conditions of Botswana. Few stakeholders are against growing of biofuel crops in the district, arguing that the district is already experiencing shortage of land, as 80% of the land is occupied by protected areas and forest reserves. In their view, Chobe District has a comparative advantage for tourism rather than biofuel development and the production of the latter would have an adverse effect on tourism. They suggested that it was better to produce biofuels in other districts. These views were mainly expressed by stakeholders from government departments and institutions dealing with issues on environment and natural resources.

21.5.1.2 Characteristics of the Recommended Biofuel Feedstocks

Literature sources suggest that sweet sorghum as biofuel crop may overcome the problem of food-fuel conflict as the crop produces fuel and animal feed from stalks and food from grains (FBAE 2009). The same area of land can therefore be used for the production of food, fuel, and feed. This saves agricultural land and avoids negative impacts on biodiversity associated with land conversion. Jatropha is described as a drought resistant crop which can be grown on marginal lands unsuitable for most other crops (UEMOA 2009). However, there is need to determine the extent to which the crop is drought resistant as evidence from Namibia seems to suggest that the crop does not perform well in arid conditions (Namibia Press Agency 2010). In general, yields tend to be lower on marginal lands, ranging from as low as 2–3 ton of dry seeds per ha on marginal or degraded areas to 5 ton of dry seeds per ha on good soils (Ndong et al. 2009). The fuel yields per ha of jatropha are amongst the lowest, whereas those of sweet sorghum are reasonably good compared to corn (Table 21.1). The low yields are compensated by the fact that jatropha can be integrated with food crop production as practised in Mali (see Chap. 22). The production of biofuels from jatropha is not land intensive compared to other energy crops as the same area of land may be used to produce fuel, household energy and even soap (Kumar and Sharma 2008). The foregoing suggests that biofuels produced from jatropha and sweet sorghum are likely to have low ecological footprints (in terms of the amount of land needed for biofuel production) associated with low impacts on biodiversity.

Table 21.1 also shows that production of these energy crops requires low amounts of water, fertilizer and pesticide compared to the production of corn. Low use of these inputs suggests that biodiversity may not be much affected. Table 21.1 also presents GHG emission savings ranging from 20% to 72% for jatropha biodiesel in West Africa and Thailand, based on life cycle assessments (FAO 2008). GHG emission savings of biofuels from jatropha thus seem higher than those of other first generation biofuels, probably due to low requirements on input and tillage (Francis et al. 2005). Finally, even larger GHG emission savings are expected for next generation biofuels as indicated in Table 21.1.

21.5.2 Use of Agricultural Land

Biofuel development is considered biodiversity friendly if it does not replace cropland needed for food production. Most stakeholders emphasized the need to avoid

Table 21.1 Comparison of efficiencies and input requirement for energy crops

Biofuel	Crops	Greenhouse gas savings (%)	Energy conversion efficiency	Fuel yield (l/ha)	Water use	Fertilizer use	Pesticides use
First generation ethanol	Sugarcane	87–97[a]	8–10.2[a]	5,000[b]	High	High	Medium
First generation ethanol	Corn	9.6–13.8[a]	1.1–1.3[a]	2,370[b]	High	High	High
First generation ethanol	Sweet sorghum	53	–	3,000[b]	Low	Medium	Medium
Biodiesel	Jatropha	20[b]–72[c]	4.72–6.03[d]	1,250[b]	Low	Low	Low
Next generation biodiesel	Microalgae	320[a]	–	49,700–108,800[a]	Medium	Low	Low

[a]Groom et al. (2008)
[b]Ravindranath et al. (2010)
[c]Ndong (2009)
[d]Prueksakorn and Gweewala (2008)

the trade-off between land for biofuel and food production. It is generally known that poverty is one of the main causes of biodiversity loss as it results in "forced over-use" of natural resources (MEWT 2007). More than 60% of the stakeholders said there is no idle, un-cleared agricultural land in Chobe District and that new land would have to be cleared for biofuel production. The impacts on biodiversity will depend on the type of land use which existed before the introduction of biofuel plantations. If natural habitats are replaced by monocultures, the impacts on biodiversity may be negative. The substitution of land already in use for food production would however have a negative impact on food production. This may have a negative impact on food security in Botswana, a country already with a high dependency on imports of cereals. According to Arup Atkins (1990), the conversion of natural habitats to arable agriculture in the Pandamatenga area in Chobe District was found to have adverse impacts on biodiversity, particularly with respect to certain antelope species. This suggests that further change of land use for biofuel development will negatively impact on the biodiversity of different land systems.

21.5.3 Use of Marginal Land

According to the Gallager Review, marginal land and idle land should be used for the production of feedstocks for biofuels (RFA 2008). Out of a total of 682,000 ha of arable land in eastern Botswana in 2009, 200,000 ha (29%) is marginal land (Fig. 21.2). 63% of the stakeholders said there is marginal land in Chobe District which is not used for agricultural production and could therefore be available for biofuel production. This marginal land refers to 5,000 ha of land in Pandamatenga considered not suitable for arable agriculture by the Ministry of Agriculture (Modise 2009). The soil in this area is mainly vertisolic clay not suitable for agriculture as it is not well drained and easily 'waterlogged'. However, the area is well endowed with 22 woody plant species, 15 grass species and 24 broadleaved/forbes species. It is not known whether these species are specific to this rather unusual habitat as a comprehensive plant survey has not been done in Chobe District. The area was found to be exclusive habitat of some rare antelopes (Arup Atkins 1990), such as Oribi (*Ourebia ourebi*), Reedbuck (*Redunca arundinum*), Roan (*Hippotragus equines*), Sable (*Hippotragus niger*), and Tsesebe (*Damaliscus lunatus*). These species were found to occur predominantly on these habitat types only found in the northern and southern plains in Pandamatenga area of Chobe District (Arup Atkins 1990).

Although energy crops such as jatropha are reported to perform well on marginal land, yields tend to be lower on such land. Jatropha yields on marginal land may be reduced by 10–20% compared to those in high rainfall areas (FAO 2008). In some cases, the development of biofuels on marginal lands, such as those of Pandamatenga, may negatively impact on biodiversity in the form of animal species, vegetation, and soil biota. In other cases, however, the growing of biofuel crops on marginal lands may have a positive impact on biodiversity since it may lead to the restoration of lands.

This suggests that the impact of biofuel development on marginal lands is context specific. In the context of marginal lands as defined in Chobe District (i.e. not suitable for arable agriculture), the development of biofuels may not necessarily lead to positive impacts on biodiversity. This suggests that there is need for internationally agreed definitions of the concepts of idle and marginal land as suggested by the Gallagher Review (RFA 2008).

21.5.4 Conversion of Forest Reserves

There is a global concern that biofuel production is one of the major factors that will contribute to loss of natural habitats in many parts of the world in the future. Most stakeholders (75%) were concerned that the production of biofuels could encroach on natural habitats of forest reserves which currently account for 19% of the land area in Chobe District. In their view, the replacement of pristine areas such as forest reserves by monoculture plantations could result in negative environmental impacts which could adversely affect biodiversity. They were also aware that the replacement of natural habitats with biofuel crops could also result in more carbon dioxide emissions into the atmosphere as carbon sequestration rates of natural habitats tend to be higher than those of biofuel crops. All stakeholders held the view that biofuel development will need to be controlled to avoid encroachment into conservation areas.

The forest surveys of 1992 found that the forest reserves hold a number of woody and herbaceous plant species that support and provide habitat to diverse fauna species (Norwegian Forestry Society 1992). The list of woody plant species recorded over forest reserves was over 90, whilst there were only seven shrub species and over 24 grass species, which increased when floodplain areas were included. Arup Atkins (1990) noted that a large number of wildlife species depend on the various vegetation and species types for their existence and hence such links are likely to be affected by any loss of habitat through land clearing. Therefore, the use of forest reserves for biofuel production will not only lead to loss of floral species, but also wildlife and soil biota species that are currently not well studied and documented in the forest areas of the Chobe District.

21.6 Conclusion

The use of recommended biofuel crops (jatropha and sweet sorghum) for biofuel production is likely to have a lower impact on biodiversity compared to corn. The results are based on analysis of factors likely to affect the ecological footprint including inputs (land, water, fertilizers, etc.), energy conversion efficiency and emission of greenhouse gases.

A number of studies have revealed that there is large potential for growing jatropha in semi-arid regions of Africa and Botswana in particular even though it is native to the coastal areas of South America and Mexico (Francis et al. 2005). However, Kumar and Sharma (2008) highlight the need for further information on biology, chemistry, and agronomic aspects before implementing industrial applications.

The study also suggests the need to use cleared idle agricultural land for biofuel production in order to avoid adverse impacts on food security and biodiversity. The stakeholders interviewed in this study considered that there was plenty of idle agricultural land in the district, but most of it was not cleared. This suggests that the production of biofuels in Chobe District may negatively affect biodiversity since it will result in the clearing of new land, but it may not adversely affect food security since idle agricultural land will be used.

Though marginal land exists in the agricultural area of Pandamatenga, its use is likely to adversely affect biodiversity since the area is richly endowed with plant and animal species. Furthermore, biofuel production on marginal lands will lead to low yields and low economic returns. The stakeholders also emphasised the need to avoid the replacement of pristine areas such as forest reserves by monoculture plantations as this will have a negative impact on biodiversity and climate change.

In conclusion, measures should be taken to ensure that the production of biofuels in Botswana is sustainable in social, economic and environmental terms. The failure to do so may result in adverse consequences on biodiversity. To achieve sustainability of biofuel development, it is necessary to develop criteria for their production and use in Botswana including criteria addressing biodiversity conservation. Other criteria should address greenhouse gas emissions, energy balances, other environmental aspects, as well as wider socio-economic and political issues. Whilst the production of first generation biofuels is generally encouraged in Botswana, slow and careful development is recommended. Furthermore, research on second generation biofuels produced from ligno-cellulosic biomass should be increased as they are likely to be more compatible with biodiversity conservation and sustainable development.

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