Policy and Practice Briefing

Impacts of biofuel crop production in southern Africa: land use change, ecosystem services, poverty alleviation and food security

Key research findings and messages

- Adopting an ecosystem services lens in assessing the local impacts of biofuel crop production offers valuable insights. For example, unravelling the effects of land use change on ecosystem services improves our understanding of the local impacts of biofuel crop production on poverty alleviation and food security. This knowledge can be used to identify best practices and support decision-making and policy design in the production of biofuel crops.
- Biofuel crop production causes changes in land use, and by extension affects the provision of various ecosystem services. Crop type, scale of production and the original land use are key factors in determining whether changes in ecosystem services are negative or positive over a given timeframe. For example, the conversion of agricultural land and partly degraded woodland to large sugarcane plantations in Malawi and Swaziland has had carbon sequestration benefits through carbon stock gains. Similar effects are observed in areas of Malawi where jatropha was promoted as a hedge crop in small family farms. On the contrary, the conversion of savanna woodland for a large jatropha plantation in Mozambique has caused substantial decline in carbon stocks.
- Sugarcane is a mature industrial crop with a long history in southern Africa. Its production can contribute positively to local poverty alleviation and food security. This was observed in both plantation and smallholder settings in Malawi and Swaziland. While the actual effects vary between the various groups involved in sugarcane production, these groups tend to be better off compared to groups not involved in sugarcane production.
- Jatropha is a relatively new and unproven crop in southern Africa and hence its poverty reduction benefits also remain unproven. While workers in jatropha plantations could experience some economic benefits (with positive ripple effects on poverty alleviation and food security), these benefits are somewhat precarious considering the almost total collapse of the jatropha sector in southern Africa. On the other hand, considering the low achieved yields, jatropha cultivation in smallholder settings in Malawi does not seem to offer any significant poverty alleviation and food security benefits to adopting farmers.

Policy context

In recent years, several countries in southern African expanded the production of biofuel crops such as jatropha and sugarcane. Depending on the country, different biofuel crops have been promoted for domestic use in the transport sector or for exports, with the ultimate policy goal usually being to boost energy security nationally and/or support rural development locally.[1,2] At the same time African countries that develop biofuel programmes or support biofuel crop investments must also balance different sustainability goals.[3]

Several African countries started using biofuels in the transport sector in the early 1980s, although Malawi is the only African country to consistently use biofuels (sugarcane ethanol in particular) since that time.[2] The early biofuel efforts in Africa emphasised ethanol from sugarcane, a well-established industrial crop in the region. In the mid to late 2000s, other crops fit for biodiesel production, particularly jatropha, experienced significant expansion. The aim was either to export feedstock to the EU market or substitute domestically for the widely used diesel fuel. Hundreds of thousands of hectares were allocated for jatropha production across the continent,[4] but by the early 2010s most jatropha projects in southern Africa had collapsed.[5]

However, biofuel crop production and use can have multiple impacts that can be negative or positive depending on baseline conditions, crop characteristics, management practices and the local context. Key

Manual sugarcane harvesting at Dwangwa Estate, Malawi
Photo credit: Carla Romeu Dalmau

environmental impacts are related to land use change, biodiversity, greenhouse gas (GHG) emissions and air/ water pollution (among others)[1]. Key socioeconomic impacts are related to poverty, food security, public health and energy security.[1] These impacts are often intertwined and can give rise to multiple complex trade-offs at the local level. Understanding such trade-offs requires the adoption of integrative and system-oriented research approaches.[6,7]

More recently, liquid biofuels for household uses—such as cooking, heating and lighting—have attracted attention as a means of reducing the health and environmental impacts of traditional biomass use.[8] Unsustainable woodfuel harvesting contributes to GHG emissions, particularly in "hotspot" regions such as East Africa.[9] Clean cooking fuels can reduce the serious illnesses and deaths associated with indoor air pollution from traditional biomass, while also supporting achievement of various Sustainable Development Goals (SDGs).[10] Thus, the benefits of using ethanol for household activities could potentially be much greater than in the transport sector.

Research approach

This brief outlines some of the main environmental and socioeconomic impacts of biofuel crop production and use in Malawi, Mozambique and Swaziland. The results are based on a 3-year study conducted in areas of (a) sugarcane production (Dwangwa-Malawi, Tshaneni-Swaziland), (b) jatropha production (Mangochi-Malawi, Buzi-Mozambique), and (c) household ethanol use (Maputo-Mozambique).

We use an ecosystems services framework that links land use change, ecosystem services (i.e. the benefits that humans derive directly and indirectly from ecosystems), human wellbeing and poverty alleviation. Biofuel crop landscapes provide several important ecosystem services such as biofuel feedstock, but can compromise other equally important ecosystem services such as food crops and woodland products.[6, 7, 21] Landscape modification and land use change affects substantially the provision of these ecosystem services to local communities; both by type and magnitude.[7] The resulting trade-offs in ecosystem services provision can vary substantially depending on

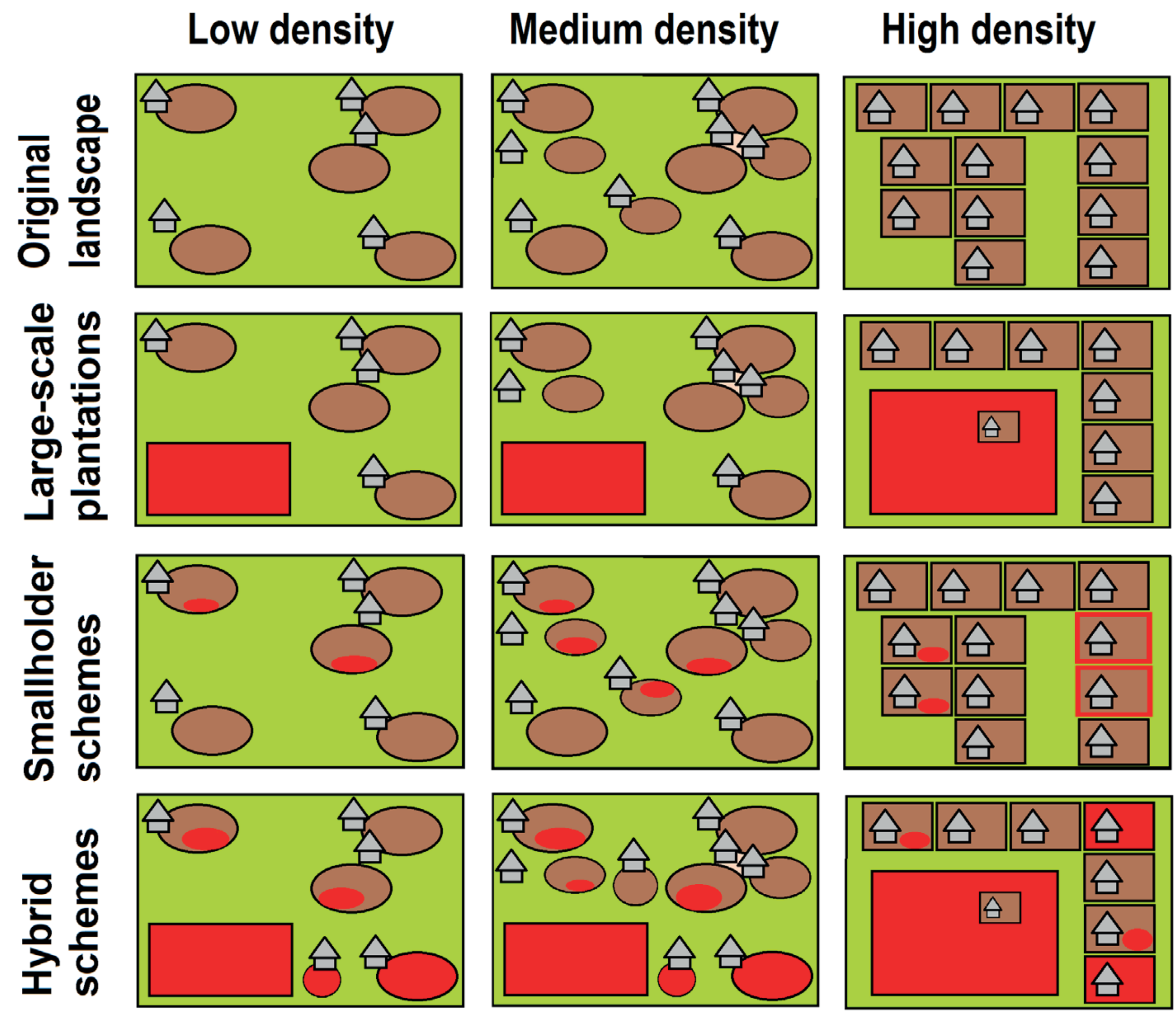

Figure 1: Common biofuel-related landscape modifications.[7]

Note: Green denotes natural ecosystems (e.g. woodland), brown denotes agricultural land, and red denotes biofuel crop production.

the pre-existing land use, crop type, agricultural practices, socioeconomic context and final end-use.[1]

Considering the above, this brief explores how sugarcane and jatropha production in rural areas of southern Africa can affect: (a) land use change; (b) ecosystem services; (c) food security; and (d) multi-dimensional poverty. We complement this analysis with a study that identifies (1) the possible land use impacts of the adoption of ethanol for cooking, and (2) the barriers to ethanol cooking adoption in urban settings.

Study sites

Sugarcane and jatropha are the main biofuel feedstocks in southern Africa. Both can be produced in large plantation and smallholder settings.[1] To represent these key biofuel crops and modes of production we selected four distinct study sites that represent the main feedstock production configurations encountered in southern Africa (Figure 1).[11]

Dwangwa, Malawi (Figure 2a) contains a large sugarcane plantation and a mill established in the 1970s and operated by Illovo Sugar Ltd. Irrigated smallholder sugarcane production started in its current format in the late 1990s under the auspices of Dwangwa Cane Growers Limited (DCGL) and Dwangwa Cane Growers Trust (DCGT). Some farmers have formed associations and grow sugarcane on their individual small family farms under rainfed conditions. Illovo sells the molasses by-products of sugar production to EthCo, a fully owned Malawian company, which then distils it into ethanol. Part of this ethanol is blended with gasoline, which is entirely used within Malawi.

Tshaneni, Swaziland (Figure 2b) contains a large sugarcane plantation operated by the Royal Swazi Sugar Company (RSSC) that has operated since 1958. RSSC also produces ethanol from sugarcane molasses both for domestic and export purposes. In the late 1990s a smallholder community development programme promoted by the Swaziland government (SWADE), developed capacity for irrigated sugarcane production in the late 1990s. Sugarcane

Jatropha scaposa, Mozambique
Photo credit: Ton Rulkens / Flickr

smallholders that were empowered by SWADE have pooled their land and have formed 28 smallholder associations. These associations essentially operate as independent companies that sell sugarcane to the two RSSC mills in Mhulme and Shimunye. All smallholders that have pooled land to form these associations are shareholders and share dividends annually.

Buzi, Mozambique (Figure 2c) is the site of a jatropha plantation (Niqel) that was established in 2006-2007. Niqel planned to eventually develop 10,000 ha of jatropha within savanna woodlands (miombo) but at the time of data collection about 1,700 ha had been planted. Niqel intended to process the seeds into fuel, fertiliser, animal feed and organic pellets.

Table 1: Number of surveyed households.

	Dwangwa, Malawi (sugarcane)	Tshaneni, Swaziland (sugarcane)	Mangochi, Malawi (jatropha)	Buzi, Mozambique (jatropha)	TOTAL
Biofuel crop farmers (irrigated)	101	92	NA	NA	193
Biofuel crop farmers (rainfed)	107	NA	100	NA	207
Workers in large plantations	104	99	NA	96	299
Workers in community plantations	NA	109	NA	NA	109
Not involved, nearby control group	102	97	101	98	398
Not involved, far away control group	99	99	NA	104	302
TOTAL	513	496	201	298	1508

Note: *NA denotes that, due to unique site characteristics, these groups were not present.*

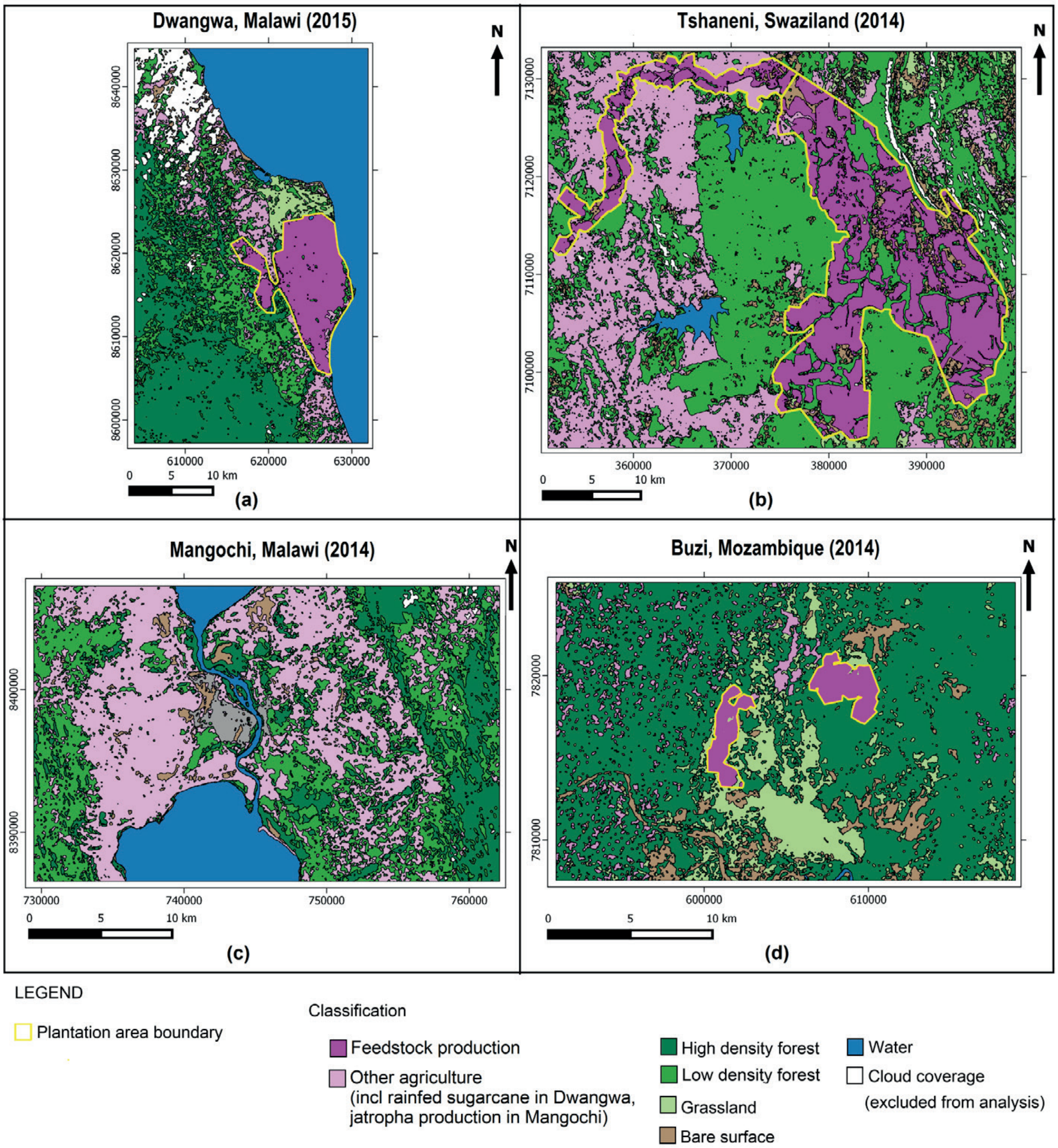

Figure 2: Main land uses in Dwangwa, Malawi (2a), Tshaneni, Swaziland (2b), Mangochi, Malawi (2c), and Buzi, Mozambique (2d).[14]

Mangochi, Malawi (Figure 2d) contains a few hundred jatropha smallholders, most of whom adopted jatropha in 2008 through the extension efforts of a private company, Bio Energy Resources Ltd (BERL). According to the BERL model, farmers would grow jatropha as a hedge or boundary crop on their farms, and then collect and sell the seeds to BERL. In turn, BERL would process the seeds into oil to be blended with conventional transport diesel fuel for use within Malawi.

To understand the effects of landscape conversion on ecosystem services, we undertook land use mapping, ecological surveys and soil analysis. We primarily focused on ecosystem services related to food crops and carbon stocks, and secondarily to woodland products. To understand the effects of engagement in biofuel feedstock value chains on human wellbeing, we conducted household surveys focusing mainly on poverty alleviation and food security. These surveys targeted households involved in feedstock production (as plantation workers or feedstock farmers), and households not involved in feedstock production (control groups).

We also conducted studies in urban areas of Maputo, Mozambique to understand the feasibility of substituting charcoal with ethanol as a cooking fuel. This is because household energy use is significantly greater than the energy use of gasoline-powered vehicles in least developed countries of southern Africa. This means that the extensive promotion and adoption of ethanol for cooking could have substantial impacts in the region.

Charcoal vendor
Photo credit: CIFOR

Charcoal demand has been increasing rapidly in Maputo, raising concerns over its environmental impacts. Maputo is one of the few major cities in Africa that experienced a significant promotion campaign of ethanol stoves and fuel for cooking. Despite some earlier efforts, this promotion was spearheaded by Cleanstar, a company that received large interest from international donors but ended up commercially unviable and collapsed by 2013.[12] We surveyed 341 households in different neighbourhoods of Maputo to understand the factors that influence the adoption and sustained use of ethanol stoves.

Land use change and ecosystem services

Figure 3 illustrates the type and magnitude of land use change in the four study sites. Land use change varied depending on the location, population density and scale of biofuel feedstock production. In both of the sugarcane-growing areas we observed an extensive conversion of agricultural land, low-density forest and high-density forests to sugarcane. In Buzi (Mozambique) the main land use change entailed the conversion of savanna woodland to a jatropha monoculture. In the smallholder jatropha areas (Mangochi, Malawi), we did not observe significant land use change, as jatropha was mainly grown some in hedges around family farms. However, jatropha hedges displaced agricultural land that could have been used to grow other crops or trees. For example, a 500-tree jatropha hedge can reduce the area of an average farm by 7%, which could significantly affect food production considering the small farm sizes in Malawi.[13]

The loss of agricultural land and woodlands indicate the loss of food crops and woodland products.[7] Even though it is difficult to accurately quantify this loss,[13] it could be substantial.[7]

Land use change can also affect carbon sequestration ecosystem services.[7] To assess changes in carbon

Jatropha seeds
Photo credit: Jeff Walker / CIFOR

sequestration services we calculated changes in the carbon stocks of standing biomass, below-ground biomass and soils, before and after landscape conversion. Overall, carbon stock gains are likely for both sugarcane areas, while carbon stock losses are likely for the jatropha plantation in Mozambique (Figure 4). Smallholder jatropha production in hedges is likely to result in carbon stock gains, although the confidence interval is quite wide.

Carbon gains in smallholder jatropha settings materialise because jatropha trees largely replace perennial crops such as maize, which have a low standing biomass.[14] Carbon stock gains are likely in sugarcane areas due to the higher above ground biomass of the densely-planted sugarcane crops, when compared with the low standing biomass of the already partly-degraded surrounding landscape (largely due to fuelwood extraction).[14] The substantial carbon stock loss at the jatropha plantation in Buzi, Mozambique can be attributed to the loss of high-density savanna woodlands (Figure 3). While, the carbon stocks of the jatropha plantation at full maturity are not known, they will depend partly on agricultural management practices. However, given the low wood density and relatively small size of jatropha trees compared with indigenous forest trees, the overall carbon stocks of the above and below-ground biomass stocks of the jatropha plantation are likely to remain substantially lower than those of the converted savanna woodland.[14]

Food security

Quantifying the food security outcomes of biofuel crop production is complicated. There are several mechanisms simultaneously at play that can affect food

Sugarcane harvesting, Malawi
Photo credit: Josh / flickr

security, especially in areas dominated by subsistence agriculture.[7,15,16] For example, local food production can decrease due to the conversion of cropland to biofuel crop plantations, or the diversion of land in small farms from food crops to feedstock. Furthermore, plantation workers and biofuel feedstock smallholders invest their labour (and agricultural inputs in the case of smallholders) for feedstock production activities instead of cultivating food crops. On the other hand, the introduction of industrial crops in areas of subsistence farming can create income opportunities through paid employment in plantations and new markets for biofuel feedstock.[17] This extra income can be used to purchase food or invest in more productive food crop and agricultural systems.[18]

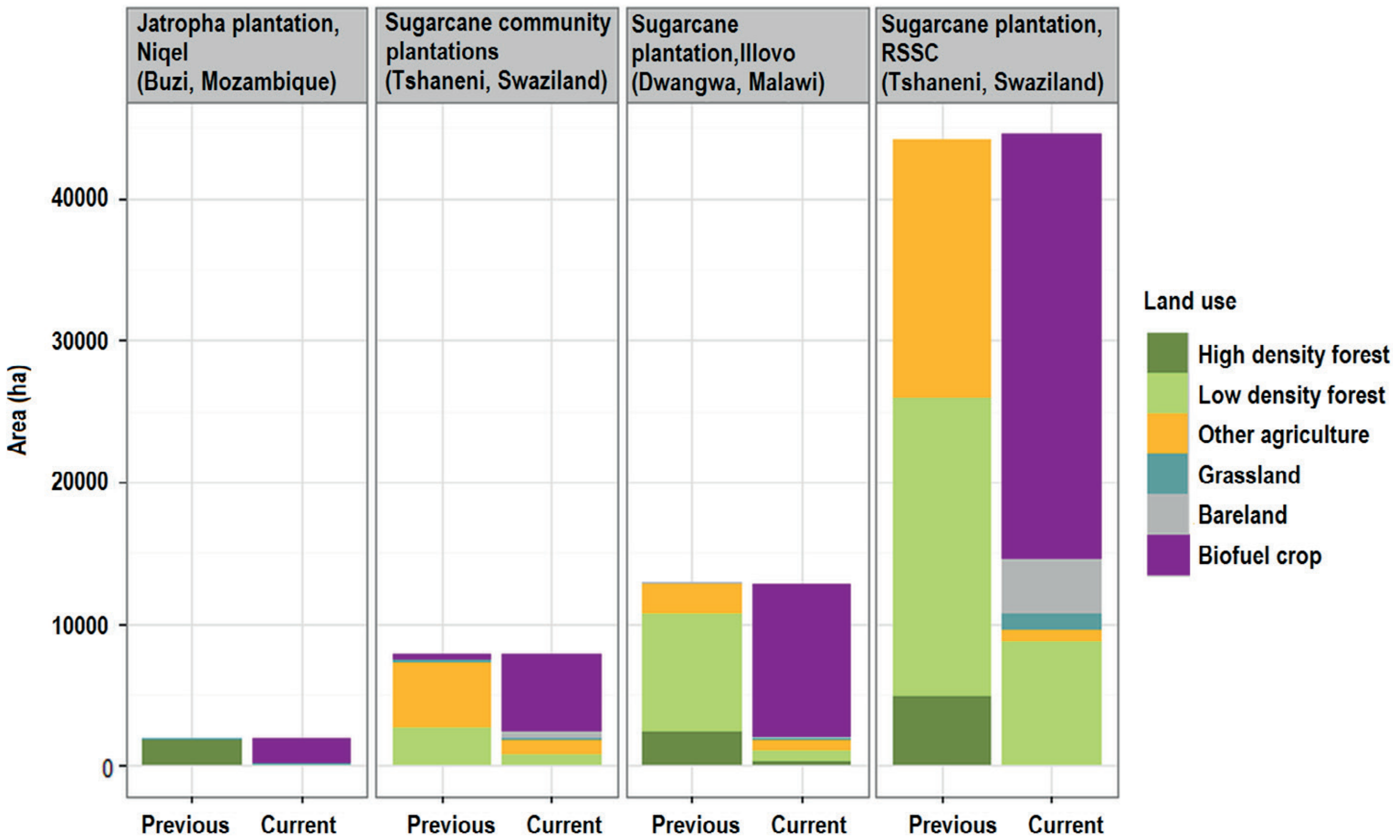

Figure 3: Land use change across study sites.[14]

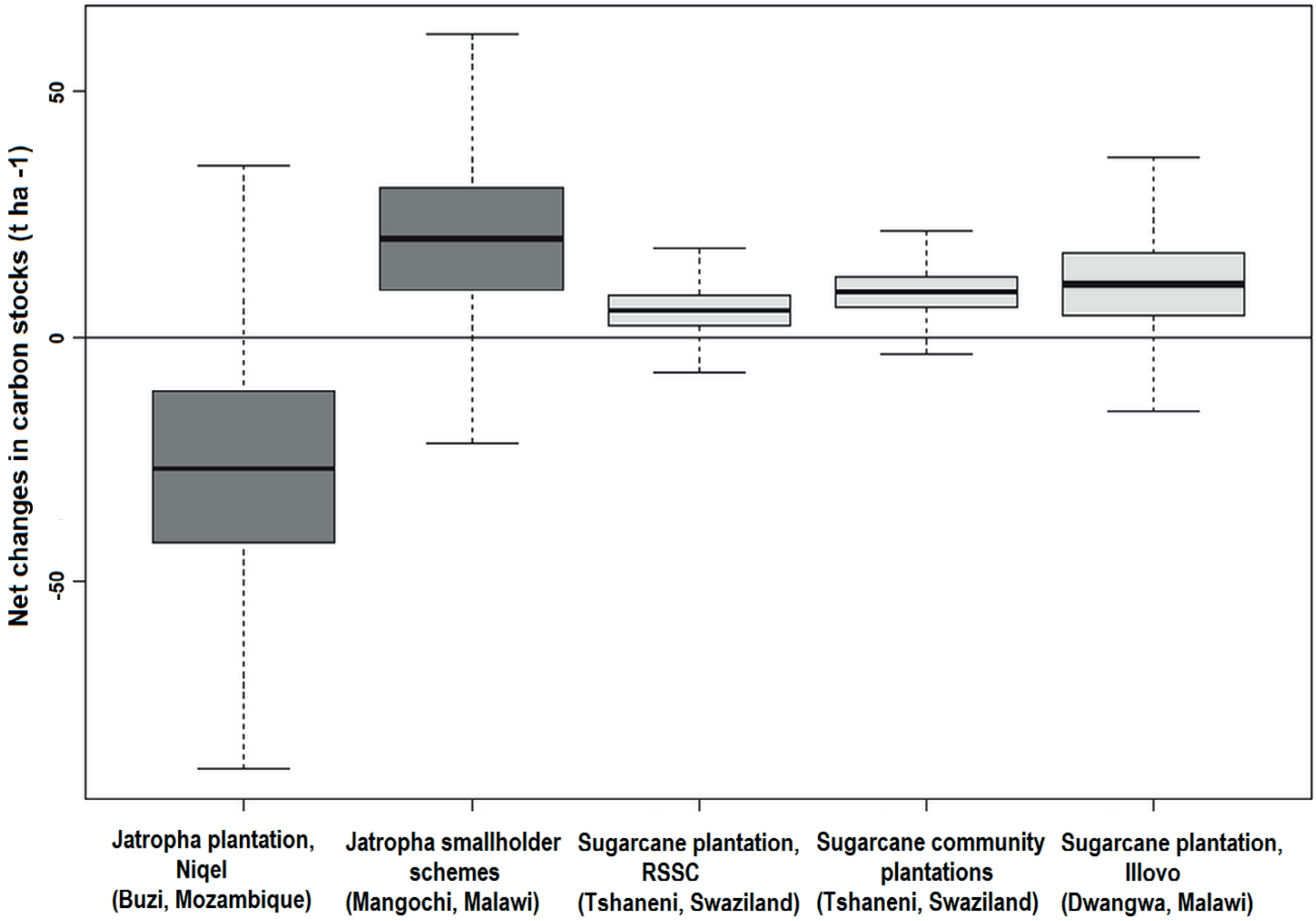

Figure 4: Net changes in carbon stocks across study sites over a 20-year period.[14]

To avoid the complications posed by the interaction of the different mechanisms discussed above, we used two standardised measures of observed food security, the Food Consumption Score (FCS) and the Household Food Insecurity Access Scale (HFIAS).[19] The FCS is a measure of diet diversity in the 7 days prior to the household survey with higher scores generally indicating higher food security. The HFIAS captures perceptions of hunger in the 4 weeks prior to the household survey, with lower scores indicating households with better food security. Figures 5-6 outline the FCS and HFIAS levels of the study groups.

Those involved in sugarcane production, whether as plantation workers or smallholder producers, exhibited better food security levels than control groups both for the FCS and HFIAS, and in most cases statistically significant. The only exceptions were HFIAS levels for Illovo plantation workers in Dwangwa-Malawi, and sugarcane smallholders in Tshaneni-Swaziland. It is not clear why this happens but focus group discussions

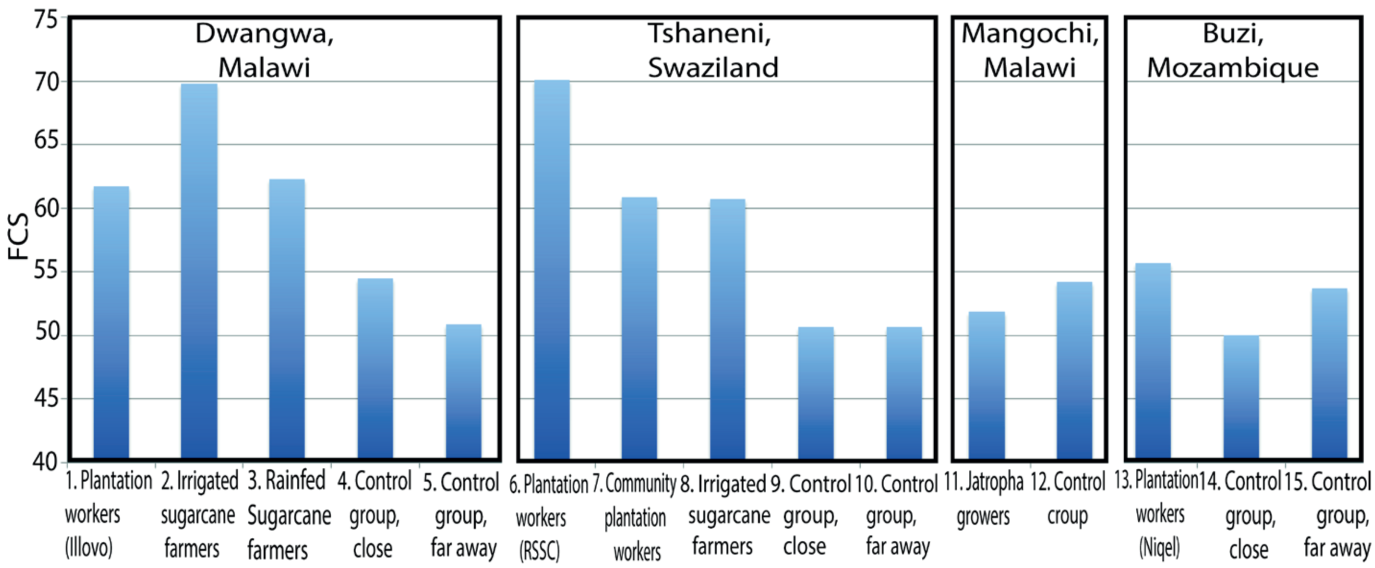

Figure 5: Food Consumption Score (FCS) across study groups and sites.

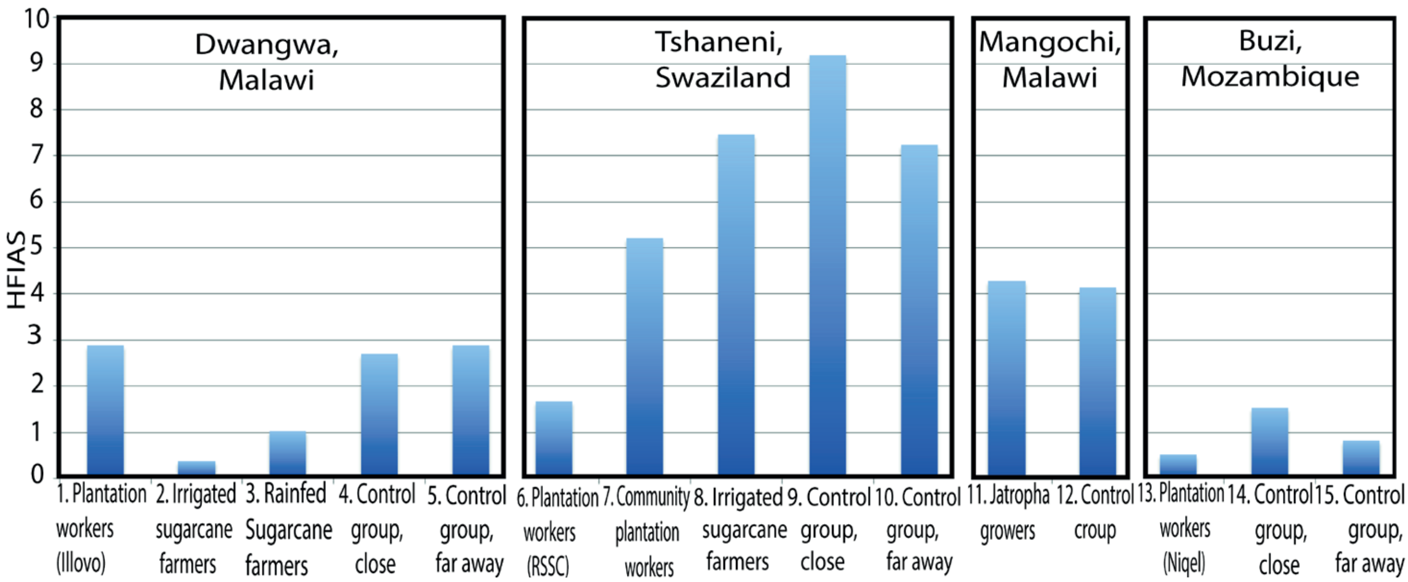

Figure 6: Household Food Insecurity Access Scale (HFIAS) across study groups and sites.

and expert interviews suggest that workers at the Illovo plantation may be concerned that their income is not enough to meet their food needs, as their salary often runs out by the end of the month. For Swaziland it is possible that the study was conducted several months before households received their income from selling sugarcane, which was also a period of high food insecurity during the onset of the 2015-2016 drought.

Results from the jatropha sites are somewhat different. Smallholder jatropha growers in Malawi (Mangochi) did not exhibit statistically significant differences in food security levels, when compared to non-growers (both for FCS and HFIAS). Workers in the jatropha plantation in Mozambique (Buzi) had better (and statistically significant) food security levels for FCS and HFIAS compared to the two control groups.

Multidimensional poverty

To capture the poverty alleviation effects of biofuel crop production we used the multi-dimensional poverty index (MPI) pioneered by the Oxford Poverty and Human Development Initiative (OPHI, 2015). The MPI is a composite measure of 10 indicators divided across three main categories: (a) education, (b) health, and (c) living standards.

Households involved as plantation workers or sugarcane growers, had lower poverty levels than control groups in Dwangwa, Tshaneni and Buzi (Figure 7). However, poverty levels were the same for smallholder jatropha farmers and non-jatropha farmers in Mangochi. This suggests that the poverty alleviation outcomes of involvement in feedstock crop production can vary between different crops and modes of engagement.

In order to better understand and compare how different aspects of human wellbeing are (or are not) affected by involvement in biofuel crop production, it is important to consider the deprivation across individual poverty indicators. Table 2 summarises deprivation levels across study sites and groups for each of the individual indicators of the MPI.

In Dwangwa (Malawi) control groups fared worse for flooring material, years of schooling and improved

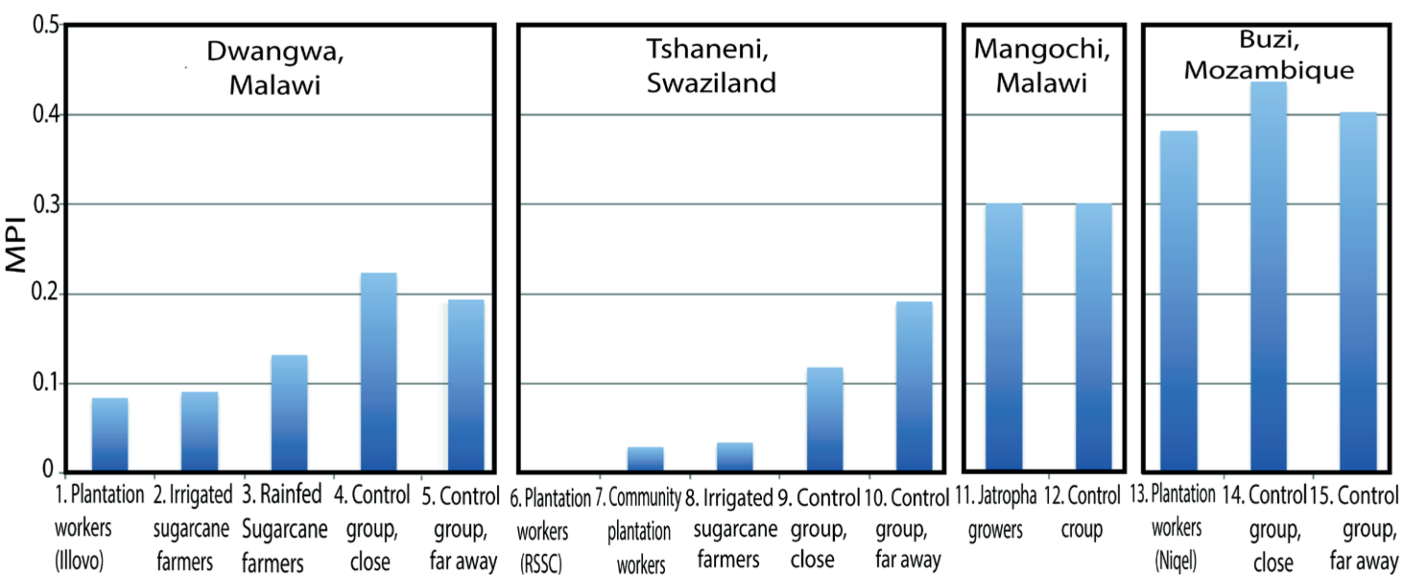

Figure 7: Multidimensional poverty across study groups and sites.[17]

Table 2: Deprivation for individual MPI indicators across study groups and sites (Mudombi et al., 2016).

Site	Group	Years of schooling	Child school attendance	Nutrition	Child mortality	Drinking water	Improved sanitation	Clean cooking fuel	Electricity	Flooring material
Dwanga (Malawi), sugarcane	Plantation workers (Illovo)	17%	7%	6%	5%	4%	66%	97%	94%	0%
	Irrigated sugarcane farmers	9%	13%	1%	5%	33%	67%	100%	99%	34%
	Rainfed sugarcane farmers	17%	16%	6%	3%	18%	67%	92%	89%	40%
	Control group, close	30%	13%	18%	4%	19%	85%	98%	98%	73%
	Control group, far away	36%	4%	19%	2%	18%	78%	98%	98%	69%
Tshaneni (Swaziland), sugarcane	Plantation workers (RSSC)	4%	15%	2%	4%	0%	5%	3%	57%	0%
	Community plantation workers	19%	10%	2%	4%	5%	6%	97%	88%	2%
	Irrigated sugarcane farmers	15%	2%	7%	4%	2%	15%	99%	71%	6%
	Control group, close	23%	3%	18%	6%	31%	32%	99%	78%	17%
	Control group, far away	32%	11%	13%	13%	34%	59%	100%	96%	14%
Mangochi (Malawi), jatropha	Jatropha growers	57%	2%	12%	11%	26%	86%	100%	100%	87%
	Control group	53%	8%	7%	12%	31%	95%	99%	100%	93%
Buzi (Mozambique), jatropha	Plantation workers (Niqel)	34%	47%	5%	23%	83%	81%	100%	100%	88%
	Control group, close	59%	37%	18%	17%	90%	91%	99%	100%	90%
	Control group, far away	52%	45%	4%	12%	80%	98%	100%	100%	95%

sanitation. Differences for indicators related to electricity access, clean cooking fuels, nutrition and child mortality were small between groups. Jatropha smallholders and control groups in Mangochi (Malawi) have little-to-no difference across all indicators, with both groups experiencing rather high deprivation for indicators related to schooling, access to electricity, clean cooking fuels, and improved sanitation. Groups in Tshaneni (Swaziland) have low levels of deprivation for most indicators, with control groups being worse off in nearly all indicator categories. Nevertheless, all groups in Tshaneni have high levels of deprivation for access to electricity and clean cooking fuel. All groups in Buzi (Mozambique) face high levels of deprivation for flooring material, electricity access, clean cooking fuel and improved sanitation. Jatropha workers have lower levels of deprivation for schooling and access to improved sanitation, compared with the two control groups.

Essentially all groups across all sites are deprived in terms of access to electricity and clean cooking fuels, which is somewhat ironic for areas that host energy-related projects. Second, although all study sites (except Buzi, Mozambique) have reasonable access to clean drinking water, only in Swaziland is access nearly universal among groups involved in biofuel crop production. This is largely because one of the major aims of the sugarcane smallholder programme promoted by SWADE was to enhance clean water provision in the wider project area. Third, control groups tend to be more deprived for indicators related to physical infrastructure such as flooring material and improved sanitation. Expert interviews and focus group discussions suggest that groups involved in biofuel crop production (especially plantation workers) have likely benefitted from the infrastructure developed by the different companies.

Figure 7 and Table 2 highlight that the overall levels of poverty are somewhat different across the four study sites. All groups in the jatropha areas of Buzi and Mangochi, as well as the faraway control groups in sugarcane areas register much higher levels of multi-dimensional poverty compared to groups involved in sugarcane production in Dwangwa and Tshaneni. Although the data provide no proof on causation, there is a strong correlation between involvement in sugarcane production and lower poverty.

Adoption and sustained use of ethanol stoves in urban areas

In order to further appreciate the overall impact of biofuel expansion in southern Africa, it is important to also explore the factors that govern its uptake and sustained use. As discussed, the transport sector has traditionally been the main target of biofuel interventions in southern Africa.[1] Liquid biofuels have not been widely promoted for household activities such as cooking. In fact, solid biomass fuels such as fuelwood and charcoal dominate by far the market for cooking fuel in Africa. However, as the overall energy demand of the household sector dwarfs that of the transport sector, the extensive promotion and sustained use of biofuels for cooking could have substantial impacts on ecosystem services.

Figure 8 outlines the land requirement of different household cooking options in Mozambique, taking into account the fuel requirements of different stoves and the prevailing woody biomass productivity and use in the region. We then conduct a comparison of five representative stove types across two land use scenarios; (a) severe biomass overharvesting leading to semi-permanent deforestation, (b) sustainable biomass harvesting. The results suggest that in most cases biomass stoves require much larger areas to provide the necessary fuel compared with ethanol stoves (Figure 8).

Woodlands in Mozambique provide substantial ecosystem services related to carbon sequestration (see above) and woodland products.[20] It is safe to assume that the extensive promotion, uptake and sustained use of ethanol stoves that use domestically produced ethanol fuel could help maintain important ecosystem services in the country.

However, costs were the greatest concern about stove adoption, sustained use and quiting in Maputo.[12] Ethanol stoves were primarily used for quick cooking tasks such as boiling water for tea, rather than cooking the main meals such as maize and beans. For such tasks charcoal stoves were preferred. Furthermore, households that adopted ethanol stoves tended to have the lowest levels of multi-dimensional poverty, followed by those that adopted ethanol and then quit, and finally those that never adopted.[12]

This suggest that the economic status of households can affect profoundly stove adoption and use decisions. Indeed, ethanol in Maputo is much more expensive when compared to other cooking fuels, and especially charcoal, in terms of price per unit energy.[12] Depending on the purchased quantity ethanol was much more expensive (12.05-16.43 USD/MJ) than charcoal (4.28-8.28 USD/MJ), LPG (5.23 USD/MJ), kerosene (5.80 USD/MJ) and electricity (1.49-5.17 USD/MJ). Expert interviews suggest that one of the reasons behind the high ethanol price has been the reluctance of the Mozambican government to reduce the high value added tax on ethanol.

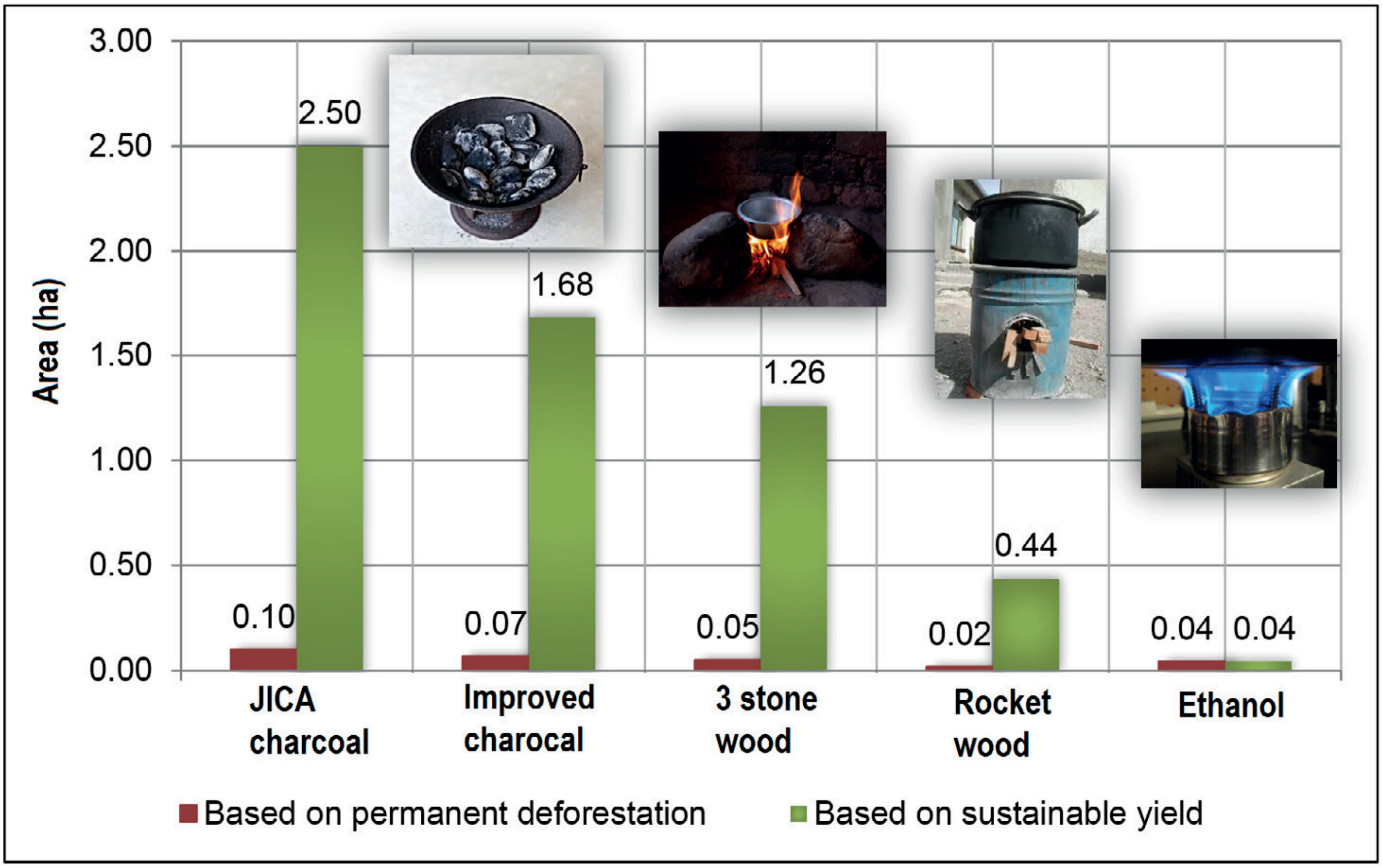

Figure 8: Land requirement in Mozambique for meeting the annual household fuel requirements for different stove types.

Dirt road through sugarcane, Southern Africa
Photo credit: Getty Images

Conclusions and policy implications

- Landscape conversion for sugarcane production incurs various trade-offs. It can lead to the loss of ecosystem services derived from forest and agricultural land, such as food crops and woodland products. However, its high productivity can offer substantial carbon sequestration benefits in the form of increased carbon stocks. Such carbon stock gains indicate possibly high GHG emission reductions from ethanol fuels. However further analysis across the entire value chain would be needed to ascertain the magnitude of these benefits. Still it would be valuable for policy-makers in the region to consider the promotion of sugarcane ethanol use as an option to support their National Determined Contributions (NDCs) under the Paris climate agreement.
- The poverty alleviation and food security outcomes of involvement in sugarcane production vary, but appear to be largely positive, both for plantation workers and smallholders. Policy-makers should consider such socioeconomic benefits together with broader ecosystem services trade-offs when deciding, establishing or further promoting sugarcane or ethanol support schemes.
- Jatropha production seems unlikely to successfully enhance poverty alleviation or food security in the near term. While some benefits are observed for plantation workers, these are precarious given the widespread collapse of the sector in southern Africa. The low yields achieved in smallholder settings also raise doubts about the overall benefit to jatropha growers. At the same time the ecological benefits and costs of jatropha can depend strongly on the characteristics of the original land use. Policy support for jatropha should be given only if preceded or accompanied by dedicated longer-term efforts to improve yields, reduce production costs, and create enabling market conditions.
- The mode of smallholder involvement in biofuel feedstock production ranged considerably, both across and (in some cases) within projects. In Dwangwa and Mangochi smallholders simply re-allotted portions of their family farms to sugarcane and jatropha respectively. In Tshaneni (and to a lesser extend in Dwangwa) irrigated sugarcane smallholders became owners/partners in community plantations that operate as private enterprises. When aiming to promote biofuel crop production as a pro-poor rural development strategy, it is important to identify innovative models that can increase feedstock production (and the income farmers receive) without disadvantaging them
- Practically every study group faced deprivation with respect to access to electricity and clean cooking fuels. Greater emphasis should be placed on promoting local energy co-benefits from biofuel projects established in rural areas of Africa. Improved access to modern energy options could further boost the local poverty alleviation effects of biofuel crop production.
- Promoting ethanol use to urban households could bring substantial environmental benefits, especially if it replaces unsustainably harvested charcoal. However high costs have been the predominant factor in discouraging the adoption and sustained use of ethanol cookstoves in Maputo city. Policies that reduce the high upfront cost of ethanol stoves and the high costs of purchasing fuel could provide a strong incentive for the adoption and sustained use of ethanol stoves in urban areas of southern Africa.
- Highly complex trade-offs occur when promoting biofuel interventions in sub-Saharan Africa. Policy-makers and other stakeholders should weigh the short- and long-term benefits and costs of these energy options, including their positive and negative impacts on ecosystems, and human wellbeing in urban and rural settings. Such trade-offs should be evaluated before determining whether particular biofuel feedstocks and modes of production and use, warrant policy support.

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Credit

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Beetle crawling on the buds of a jatropha bush, Mangochi, Malawi
Photo credit: Carla Romeu Dalmau

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espa ecosystem services for poverty alleviation

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