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Research paper

# Multi-dimensional poverty effects around operational biofuel projects in Malawi, Mozambique and Swaziland

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ABSTRACT

There is a long-term concern that the cultivation of biofuel feedstocks could have negative impacts on communities involved in, or adjacent to, such projects. In southern Africa, the acquisition and allocation of large blocks of land for biofuel feedstock production has been especially contentious. The present study investigates the local multi-dimensional poverty effects of growing biofuel crops using the Oxford Poverty & Human Development Initiative's Multidimensional Poverty Index. It investigates different modes of production (large-scale vs. smallholder-based) and different feedstocks (sugarcane vs. jatropha) in four study sites in Malawi, Swaziland and Mozambique. In the sugarcane growing areas, those who participated in its value chain as farmers or workers had lower poverty than those who were not involved. However, for jatropha growing areas, there were no clearly defined differences between the controls and the jatropha farmers in Mangochi, while in Mozambique the plantation workers had slightly lower poverty than the control groups. Although it was not possible to make direct comparisons between all projects, sugarcane areas seem to be better off than non-sugarcane areas. In all projects there was generally high incidence of deprivations in indicators related to living standards, particularly, access to electricity and cooking fuel.



## 1. Introduction

Biofuels production and use has been gaining prominence and significance globally. In Africa, Malawi started producing ethanol from sugarcane molasses in the early 1980s [1], and its biofuel programme has been sustainably integrated into the country's agricultural sector and economy since then [2]. Though various African countries are at different stages of adopting biofuels, the interest in biofuel production and use across the continent has been rising since the mid-2000s [3]. Several countries support biofuel blends of roughly 10% volume fraction in gasoline, including Ethiopia (E10), Kenya (10%), Malawi (varying between 10% and 20%), and Zimbabwe (varying between 5% and 15%) [4,5].

Key reasons that have been cited for this biofuel expansion include energy security, oil price volatility, export potential, poverty reduction, economic development and climate change mitigation [3,4,6,7]. Moreover, biofuels have offered an opportunity to transform Africa's traditional dependence on biomass energy sources to liquid biofuels [8], as well as exploit its under-utilised agricultural land and abundant labour [2,7,9,10].

Jatropha (*Jatropha curcas* L.) and sugarcane (*Saccharum officinarum* L.) are the two most prominent biofuel feedstocks in Sub-

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Saharan Africa (SSA) for biodiesel and ethanol, respectively [4]. Of the two, sugarcane is a well-established crop, and the sugar derived from it has been an important global commodity for hundreds of years. Now, sugarcane is also increasingly being promoted for biofuel. By contrast, jatropha is a recently introduced oil crop whose oil can be directly blended with diesel in small quantities, or be transformed into biodiesel. Since 2000, Jatropha has been widely promoted as a biofuel crop in countries such as Ghana [11], Mozambique [12], Tanzania [13] and Zambia [14] among others. Only recently jatropha has reached harvestable age in some of the areas where it was consciously introduced. Jatropha was strongly promoted as a crop with development potential, both in smallholder and industrial plantation settings [15]. However, only a handful of projects have shown signs of long-term viability in southern Africa [3,16,17].

Biofuel development in the African context eventually became a contentious issue with stakeholders including policymakers, development practitioners and donors having different interests [2,4,7,18]. Concerns have been raised that biofuels might have unintended negative social, economic, and environmental consequences [8,10,19], such as land tenure conflicts, food security decline, and a host of environmental impacts [4,7]. Furthermore, several biofuel projects in African countries have been based on industrial plantations which are likely to lead to inequitable sharing of benefits, increased rural poverty and food insecurity as land is taken away from rural dwellers [1,2,8]. Recently, some studies have attempted to identify the links between the environmental and socioeconomic impacts of biofuels in Africa. Some of these studies have tried to show how biofuel production can be a significant driver of ecosystem change and landscape conversion, and as an extent how it can affect different ecosystem services and constituents of human wellbeing [3,16,20].

Poverty alleviation is a significant dimension related to the human wellbeing aspects of the biofuel debate in Africa, featuring both as a driving force and as an impact of biofuel expansion [4]. In this context, it is necessary to understand the potential for poverty alleviation within biofuel projects in Africa, especially at the local level [2,4,6,21,22]. However, most of the literature about the poverty alleviation effect of biofuels remains theoretical, with little or no empirical data to support the analysis [22]. Quantifying the impact of biofuels on poverty alleviation is important to better understand the impacts of these projects on the local rural communities.

When assessing the poverty outcomes of different interventions, measures can be broadly categorised into unidimensional (which are typically based on financial indicators such as income) and multidimensional (which consider broad access to multiple resources). Recognition for the need to apply multidimensional poverty measures dates back to the 1970s [23,24], and is now receiving renewed attention [25].

There are several advantages related to the use of multidimensional poverty measures. First, a single indicator cannot adequately identify the multiple disadvantages that contribute to poverty whereas a multidimensional approach can include more relevant/comprehensive indicators, such as health, education and living standards [26,27].

Second, a study focusing solely on income poverty can exclude a considerable proportion of people living in multidimensional poverty [28]. Income as a measure of poverty pre-supposes markets for all basic needs, yet such markets do not always exist [29]. In most rural areas of developing countries, and especially in the African context, access to commodity markets can be weak or nonexistent. Most households in such areas produce food for their own consumption (as in our study sites, Section 2.1), which would be neglected in an assessment merely based on income.

Third, poor people themselves view their poverty much more broadly to include various dimensions [30]. As pointed out by Bourguignon and Chakravarty [31], poverty is a multidimensional phenomenon which manifests "*as the failure to reach 'minimally acceptable' levels of different monetary and non-monetary attributes necessary for a subsistence standard of living*". Finally, income tends to neglect the actual command over resources [33], that is to say that to have an income does not imply that the income will be used to access various needs. A person or household can be poor in terms of income but not multidimensionally poor and/or vice versa [27], thus, multidimensional poverty measures need to be applied [32].

The aim of this study is to investigate the local multidimensional poverty effects of growing jatropha and sugarcane as biofuel crops. Considering the strong linkages between changes in ecosystem services and poverty [34–37], the study will also offer insights on whether current multi-dimensional poverty approaches can be used to capture how changes in ecosystem services from biofuel expansion can affect human wellbeing.

Our study adopts the multi-dimensional poverty approach which has been widely applied [23,27,30,32,38,39] as a means of quantifying whether growing biofuel feedstock (a provisioning ecosystem service) has a positive or negative impact on the local population. The study sites are located in Malawi, Mozambique, and Swaziland, and consist of both large-scale commercial plantations and smallholder-based projects where community members are owners of the projects. In addition, it considers a long established feedstock (sugarcane) versus a newly promoted feedstock (jatropha). In this respect the study captures the main biofuel options promoted in southern Africa [4,15].

The paper is structured as follows. Section 2 outlines the study sites and the methodology used to quantify multidimensional poverty. Section 3 outlines the key results, focusing on the comparisons between different groups and the robustness of the results. Finally, Section 4 discusses the main findings in respect to whether biofuels can be successful strategies to alleviate poverty in southern Africa, as well as the limitations and research gaps.

## 2. Methods

### 2.1. Study sites

The projects listed in Table 1, represented both large-scale and smallholder-based models of production.

In Malawi, the sugarcane study site was located at Dwangwa in the Nkhotakota district and the jatropha site in the Mangochi district. Dwangwa is in the Central region of Malawi. The sugarcane production industry is primarily controlled by Illovo Sugar Company, which owns a large irrigated plantation and a mill that processes the cane into sugar. Molasses by-products have been sold to Ethanol Company Limited (EthCo) for ethanol production since 1982 in response to the 1970 energy crisis [40].

At Dwangwa, there are also different community outgrower projects. The small-scale outgrower scheme started in 1996 [41], whereby farmers are integrated in the value chain through outgrower management companies, who, to varying degrees, provide farmers with support for land development, agricultural inputs, extension services, labour at the fields, harvesting and transport services [42]. Some of the outgrowers are under irrigation in large plantation blocks, with each outgrower having an individual field within the plantation. In this case, funding for the project infrastructure was obtained through the Dwangwa Cane Growers Trust (DCGT). In addition, there are also individual farmers growing sugarcane on their private smallholder farms under rainfed conditions. The Trust and associations oversee sales to Illovo.

The jatropha sites in Malawi are situated around the city of

**Table 1**
Key features of the projects.

| Country | Malawi | | | | Mozambique | Swaziland | |
|---|---|---|---|---|---|---|---|
| Project | Dwangwa | | | Mangochi | Buzi | Tshaneni | |
| GPS coordinates | 12° 29′ 55″ S 34⁰ 08′ 38″ E | | | 14° 29′ 20″ S 34° 14′ 51″ E | 19° 44′ 41″ S 33° 57′ 58″ E | 25° 57′ 11″ S 31° 44′ 23″ E | |
| Organisation/arrangement | Illovo | Dwangwa Cane Growers' Trust (DCGT) | associations | BERL | Niqel | RSSC | SWADE |
| Feedstock | Sugar | Sugar | Sugar | Jatropha | Jatropha | Sugar | Sugar |
| Irrigation | Yes | Yes | Yes/No | No | No | Yes | Yes |
| Established | 1977 | Early 1990s | variable | 2008 | 2008 | 1958 (Mhlume) 1979 (Simunye) | 1999 |
| Feedstock production model | Corporate Plantation | Community plot in plantation | Individual smallholdings | Individual smallholdings | Corporate Plantation | Corporate Plantation | Community owned plantation |
| Ownership | Corporate | Individual farmers – linked to trust | Individual farmers | Individual farmers | Corporate | Corporate | Company (owned by farmers) |
| Labour | Paid labour | Farmer, paid labour | Farmer, but paid labour for harvesting | Farmer | Paid labour | Paid labour | Paid labour |
| Financial support (e.g. loans) for the intervention group | n/a | Yes | Yes | No | n/a | n/a | Yes |
| Technical support (e.g. agricultural extension) for the intervention group | n/a | Yes | Yes | Yes | n/a | n/a | Yes |
| Code | IP | CP | IF | IF | IP | IP | CP |

Mangochi in the Southern region of Malawi. In this area, jatropha has been promoted mainly by the Bio Energy Resources Ltd (BERL), which is a Lilongwe-based company that facilitates smallholder-based jatropha projects in several districts of Malawi. BERL purchases the jatropha seeds from thousands of smallholders across Malawi, and extracts and blends the jatropha oil into diesel and kerosene at low volume fractions. The BERL model is based on smallholder farmers growing jatropha as boundary hedges on their smallholder farms [16,43].

In Swaziland, the Royal Swazi Sugar Corporation (RSSC) has a long history of sugar production that started around 1958. Next to RSSC, is a more recent project that was initiated in 1999, it is called the Swaziland Water and Agricultural Development Enterprise (SWADE). The SWADE project uses a unique community development model, where local communities form commercial enterprises to grow and sell sugarcane to RSSC [44]. SWADE creates sugarcane plantations that are managed in the same way as large commercial plantations, but are completely owned by local community members. Individual community members swop their land holdings for shares in a company created by themselves, with all members being equal shareholders. These projects are far larger than smallholder farms, but much smaller than the commercial plantation in the area (RSSC). In addition to providing irrigation infrastructure (which the farmers companies have to pay back over time), potable water is also provided by SWADE to households.

In Mozambique, the study site is located in the Buzi district where the Niqel jatropha plantation is based [16]. This is a conventional large-scale plantation established in a miombo forest area that also contained scattered smallholder farms. The project is in a very poor area where slash-and-burn agriculture still dominates the agricultural practises of the local farms. Paid labour, sourced predominantly from the surrounding communities, work on the Niqel plantation. Surrounding communities are largely involved in subsistence agriculture, but about 9% of the households gain additional paid employment [16]. No jatropha is grown by the smallholder farmers as is the case of jatropha farmers in Mangochi, Malawi.

For a visual representation of each study site and a better understanding of the land use changes that occurred due to each biofuel project, readers are referred to Romeu-Dalmau et al. (this issue) [20].

### 2.2. Data collection and handling

Household data was collected through surveys with different groups involved in the biofuel production value chain as well as matched controls. In our analysis we consider intervention groups (i.e. people involved in the projects such as plantation workers or feedstock smallholder farmers) and control groups (i.e. adjacent community members that are not involved in the project).

The multi-dimensional poverty results are compared at two levels. The first level of comparison is between the different groups in each biofuel project (intervention vs control groups) (Section 2.3). The second level of comparison is between biofuel projects, which entail comparisons between feedstocks and modes of production. Being conscious of the different socioeconomic and environmental conditions between sites, we keep these comparisons to a minimum, and essentially use them to start informed discussions on the poverty alleviation effects of different biofuel options available in southern Africa based on solid empirical findings, that is currently missing from Africa. Although most sugarcane production in the two study areas is currently used for sugar, it is assumed that, from the producer perspective, impacts will be the same regardless of the final use of the feedstock.

Since each project had unique characteristics and setup, the

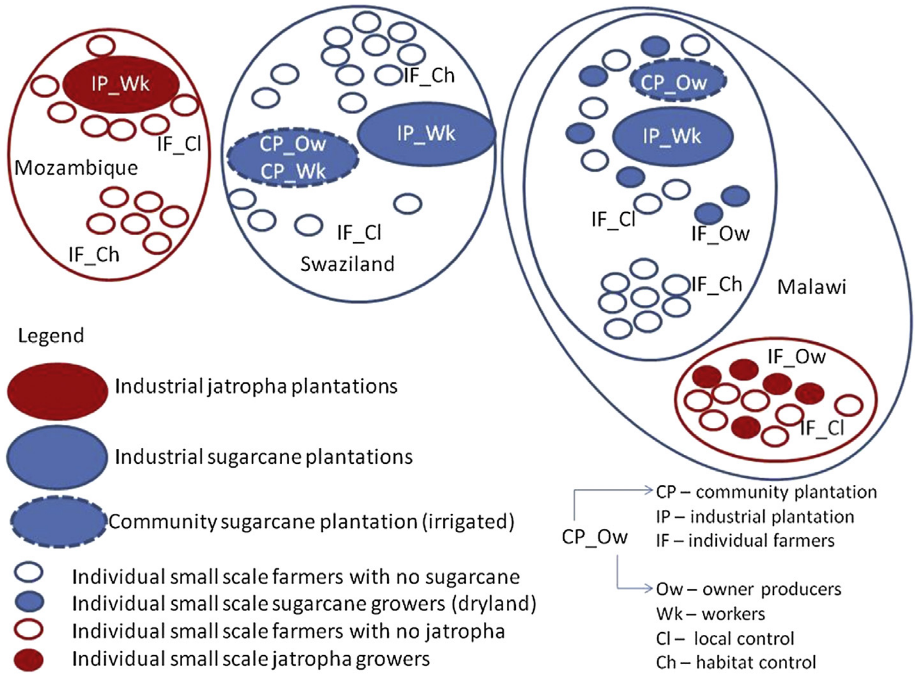


**Fig. 1.** Representation of the various groups in the study.

number and type of intervention and control groups differ slightly, but are clearly described below and summarised in Fig. 1. In areas where large plantations exist (Buzi in Mozambique, Dwangwa in Malawi, Tshaneni in Swaziland), there can be spill over effects on human wellbeing, due to gained access to infrastructure developed by the companies (e.g. roads, schools, and clinics). For this reason, in these areas we selected two types of control groups; the 'local control', which is the population that lives within the area or adjacent to the plantations, and the 'habitat control', which is the population that lives in a distant area, separated from the biofuel project area, but with similar climatic and soil characteristics. In the case of sugarcane areas (Dwangwa in Malawi and Tshaneni in Swaziland), the habitat control areas were those targeted for future expansion. In the case of Mangochi, only one control group was considered as there was no plantation in place.

The period in which the data was collected is as follows: Dwangwa, Malawi (August–September 2014); Mangochi, Malawi (September 2014); Buzi, Mozambique (November–December 2014); and Tshaneni, Swaziland (March–April 2015). A semi-structured questionnaire was distributed to 1544 households, with approximately 100 questionnaires being administered in each study group. Some households with missing data were excluded from the final analysis. The final sample included 1508 households divided almost equally between the different study groups. The breakdown of the sample is shown in Table 2. The respondents were adults who could represent the household and included smallholder farmers and plantation workers. Data handling and analysis was done in Microsoft Access, Microsoft Excel and R, version 3.2.2 [45].

The names and codes for all groups in each study site are shown in Table 2. In a nutshell, there are two modes in which community members grow biofuel crops as smallholder farmers, either as a part of a large community plantation (CP_Ow) or as individual farmers (IF_Ow). For workers there are two types of employment, those working on communal plantation "CP_Wk" and those working on industrial plantations "IP_Wk". As explained above,

**Table 2**
Sample breakdown.

| Project and country | Group | Codes | Total households with no missing data |
|---|---|---|---|
| Dwangwa (Malawi), sugarcane | Non-sugarcane individual farmers, outside sugarcane area (habitat control) | IF_Ch | 99 |
| | Non-sugarcane individual farmers, within sugarcane area (local control) | IF_Cl | 102 |
| | Community plantation, irrigated sugarcane (Trust) | CP_Ow | 101 |
| | Individual farmers, rainfed sugarcane | IF_Ow | 107 |
| | Industrial plantation, Sugarcane workers (Illovo) | IP_Wk | 104 |
| Mangochi (Malawi), jatropha | Non-jatropha grower, within jatropha area (local control) | IF_Cl | 101 |
| | Individual farmers growing, jatropha (BERL) | IF_Ow | 100 |
| Tshaneni (Swaziland), sugarcane | Non-sugarcane individual farmers, outside sugarcane area (habitat control) | IF_Ch | 99 |
| | Non-sugarcane individual farmers, within sugarcane area (local control) | IF_Cl | 97 |
| | Community plantation, irrigated farmers (SWADE) | CP_Ow | 92 |
| | Industrial Sugarcane plantation workers (RSSC) | IP_Wk | 99 |
| | Community plantation, irrigated workers (SWADE) | CP_Wk | 109 |
| Buzi (Mozambique), jatropha | Industrial Jatropha plantation workers (Niqel) | IP_Wk | 96 |
| | Individual farmers, outside Niqel area (habitat control) | IF_Ch | 104 |
| | Individual farmers, within Niqel area (local control) | IF_Cl | 98 |
| Total | | | 1508 |

there are two types of controls, the first is the habitat control "IF_Ch" which is outside the biofuel areas (this group is the main basis for comparisons), while the local control "IF_Cl" is a control within the biofuel areas.

### 2.3. Data analysis

In order to quantify multidimensional poverty we adopted the Adjusted Headcount Ratio (Mo), also known as the Multidimensional Poverty Index (MPI). This measure is based on the Alkire and Foster (AF) counting approach [39,46]. This approach identifies the poor by counting the number of people suffering deprivation in various dimensions, as well as the number of dimensions in which they fall below the threshold [47,48]. The MPI measures acute poverty, which is a person's inability to meet minimum internationally comparable standards related to the Millennium Development Goals (MDGs) as well as core functionings [30,32]. This includes 10 indicators across three dimensions: health, education, and standard of living (Table 3).

The MPI has a two-stage identification process commonly referred to as the dual cut-off. The first cut-off determines whether an individual or household is deprived in a specific indicator dimension (the deprivation cut-off), while the second cut-off determines the number of indicator dimensions for a person to be considered poor (the poverty cut-off) [23,38,46,49]. Key to this approach is the censoring of data, as it ignores deprivations of those not fulfilling the dual cut-off conditions [23,30,50]. The dual cut-off identification strategy has desirable attributes of being 'poverty focused' and 'deprivation focused' [49].

The Adjusted Headcount Ratio (Mo) is the product of two partial indices "H" and "A" (Eq (1)) [30,51,52].

$$Mo = H \times A \tag{1}$$

"H" is the incidence of poverty (multidimensional headcount ratio) representing the percentage of the population that is poor (Eq (2)). "A" is the intensity of poverty which represents the average deprivation score across the poor (Eq (3)). For a detailed specification of the Mo, refer to [49]. In brief, some of the important components and formulas are defined below (Eqs (2)–(4)).

$$\mathrm{H} = \mathrm{q}/\mathrm{n} \tag{2}$$

Where q represents the number of people identified as poor based on the dual cut-off criteria, n is the total number of people in the sample (i.e. the population).

$$\mathrm{A} = \sum_{i=1}^{n} \frac{c_i(k)}{q} \tag{3}$$

Where $c_i(k)$ is the censored deprivation score, which $(k)$ represents the share of possible deprivations experienced by a poor person $i$.

Considering Eqs (1)–(3), the Adjusted Headcount Ratio (Mo) can be expressed as:

$$M_o = \sum_{i=1}^{n} \frac{c_i(k)}{q} = H\ x\ A = \ \frac{q}{n}\ x\ \frac{1}{q}\sum_{i-1}^{q} c_i(k) = \ \frac{1}{n}\sum_{i-1}^{n} c_i(k) \tag{4}$$

The dimensions, indicators, weights, and cut-offs used in this study (Table 3) were drawn mainly from the MPI work of the Oxford Poverty & Human Development Initiative (OPHI) [27,32]. The three dimensions studied (health, education, and living standards) were given equal weighting, i.e. 33.33% each. This weighting is justifiable as the three dimensions were assumed to have roughly the same intrinsic value [30,32,53]. We then adopted the poverty cut-off of 33.33%, i.e. a person was identified as multidimensionally poor if he or she had a deprivation score higher than or equal to 1/3. This cut-off has been widely used in the application of the MPI, for example [30], and [32].

It is important to highlight that this study used a slightly different measure of nutrition (within health dimension) than the one used by OPHI [54]. Usually, the nutrition indicator assesses undernourishment based on the weight-for-age indicator for children and the Body Mass Index (BMI) for adults [32]. However, due to data limitations (i.e. we could not weigh all the members of the household), the present study uses the Food Consumption Score (FCS), a standardised metric developed by the Food and Nutrition Technical Assistance (FANTA) projects [55,56] as a measure of dietary diversity and a proxy of food security. Households that failed to reach the acceptable FCS were considered deprived for the nutrition indicator. The general acceptable FCS is > 35, though this can vary depending on the context and dietary patterns of the population in question [57]. In our study we used the same nutrition cut-off for the three countries as all study sites were located in rural areas where maize subsistence agriculture was the dominant livelihood activity. As a result local diets were generally similar and overwhelmingly dominated by maize.

### 2.4. Hypothesis testing and statistical inference

It is important to assess whether the differences in poverty levels between groups are significant. In this context, standard errors are important for the construction of confidence intervals and

**Table 3**
Dimensions, indicators, weights, and cut-offs for the MPI.

| Dimension | Indicator | Cut-off for deprivation | Weight |
|---|---|---|---|
| Education | Years of schooling | No household member has completed 5 years of schooling | 1/6 |
| | Child school attendance | If any school-age child is not attending school in years 1–8 | 1/6 |
| Health | Nutrition | Below the acceptable Food Consumption Score (FCS) i.e. an FCS of 35 or below | 1/6 |
| | Child mortality | A child has died in the family in the last 5 years | 1/6 |
| Living standards | Improved drinking water | The household does not have access to improved drinking water (according to MDG guidelines), or safe drinking water is more than a 30 min walk from home (roundtrip) | 1/18 |
| | Improved sanitation | The household's sanitation facility is not improved (according to MDG guidelines), or is improved but shared with other households | 1/18 |
| | Clean cooking fuel | The household cooks with dung, charcoal or wood | 1/18 |
| | Electricity | The household has no electricity. | 1/18 |
| | Flooring material | The flooring material is made of dirt, sand or dung. | 1/18 |
| | Asset ownership | The household does not own more than one radio, TV, telephone, bike, motorbike or refrigerator, and does not own a car, truck or tractor | 1/18 |

Source: adapted from Refs. [32,45].

hypothesis testing [30,53]. Standard errors can be estimated through the analytical approach and the resampling approach.

For the present study, the bootstrap resampling method was adopted with a total of 100 bootstrap samples per group drawn. The bootstrap method is an important tool for statistical inference for inequality and poverty measures [30,58,59]. The standard error estimated from the standard deviation of the sampling distribution of the bootstrap samples is used to get the statistic of interest in each sample [60,61]. Two entities will have unambiguously different MPIs if the confidence intervals of their MPIs do not overlap [32]. The lower the standard errors the better they provide reliable point estimates [32,62].

### 2.5. Robustness tests and regression analysis

To avoid misleading conclusions [63], it is key to conduct robustness analyses on poverty measures, to assess how robust is the measured multidimensional poverty to changes in indicators, cut-offs, and weights [30,32,64]. Such analyses provide better insights about poverty [65], and help to build consensus or to clarify points of disagreement [62]. In the present study, robustness was tested by conducting restricted dominance analysis on a limited range of cut-offs for the different parameters, i.e. weights, indicator deprivation cut-offs, and poverty cut-offs. We then plotted the levels of the MPIs as these parameters varied. In addition, the robustness was also assessed using the Spearman rank correlation coefficient ($R\rho$) method of comparing the original rankings of the MPIs of groups, to their alternative rankings obtained as parameters were varied. For more information on robustness analysis see Refs. [23,30,32,38,53,66,67].

It is vital to do regression analysis to have in-depth understanding of how various factors influence poverty at the household level [68]. Regression is an important technique for summarizing data, testing hypotheses and determining the influence of independent variables on a dependent variable [64]. A logit regression model was used in this study to assess the potential determinants of multidimensional poverty at the household level, as this regression model is widely used in poverty analysis [64,69]. For model specification see Alkire et al. [68]. The output of a logit is directly interpretable, providing the relative chance of being multidimensionally poor [68].

The dependent variable was binary, i.e. whether the household was identified as multi-dimensionally poor or not, taking values 1 and 0 respectively. To counter the challenge of endogeneity in the model [68], demographic and socioeconomic characteristics that had not been used in the construction of the MPI were used as predictor variables. The predictor variables were:

- Household involved in sugarcane farming (1 = farming, 0 = non-farming)
- Household involved in jatropha farming (1 = farming, 0 = non-farming)
- Household member working at a biofuel plantation (1 = working, 0 = non-working)
- Number of years involved in biofuels
- Household located within biofuel area (1 = within, 0 = outside)
- Age of household head
- Cattle ownership (number of cattle owned by the household)
- Area of land (hectares)
- Household size (number of household members)

As recommended by Peng et al. [70], a number of statistical tests are applied to evaluate the model and the individual predictors. These include the:

- Wald test
- Hosmer-Lemeshow

Both the Wald and the Hosmer-Lemeshow (H-L) tests were done in R, version 3.2.2 [45], using the “aod” package [71] and the “ResourceSelection” package [72] respectively.

## 3. Results

### 3.1. Deprivation against individual MPI indicators

Table 4 shows the fraction (%) deprivations in various indicators, the lower the fraction the less deprived the households (in a particular group) are in that indicator. It can be clearly seen that most of the indicators that show high deprivation in all study sites belong to the living standards dimension (Table 4).

Overall, there is over 70% deprivation on electricity and clean cooking fuel in all groups studied. The workers of the industrial sugarcane plantation (IP_Wk) in Swaziland were an exception, as only 3% and 57% were deprived in clean cooking fuel and electricity, respectively. Indicators with the least deprivation (less than 23%) for all groups across all projects were those related to nutrition and child mortality. Another indicator with low deprivation scores across all study sites (with the exception of groups in Buzi, Mozambique), is child school attendance.

In Dwangwa (Malawi), the general pattern of deprivation in indicators is more or less the same for non-growers of sugarcane in

**Table 4**
Incidence of deprivation against each of the MPI indicators, expressed as a fraction (%) of the total population in each group.

| Project | Group | Years of schooling | Child school attendance | Nutrition | Child mortality | Improved drinking water | Improved sanitation | Clean cooking fuel | Electricity | Flooring material | Assets |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dwangwa (Malawi), sugarcane | IF_Ch | 36% | 4% | 19% | 2% | 18% | 78% | 98% | 98% | 69% | 19% |
| | IF_Cl | 30% | 13% | 18% | 4% | 19% | 85% | 98% | 98% | 73% | 23% |
| | CP_Ow | 9% | 13% | 1% | 5% | 33% | 67% | 100% | 99% | 34% | 1% |
| | IF_Ow | 17% | 16% | 6% | 3% | 18% | 67% | 92% | 89% | 40% | 9% |
| | IP_Wk | 17% | 7% | 6% | 5% | 4% | 66% | 97% | 94% | 0% | 2% |
| Mangochi (Malawi), jatropha | IF_Cl | 53% | 8% | 7% | 12% | 31% | 95% | 99% | 100% | 93% | 32% |
| | IF_Ow | 57% | 2% | 12% | 11% | 26% | 86% | 100% | 100% | 87% | 28% |
| Tshaneni (Swaziland), sugarcane | IF_Ch | 32% | 11% | 13% | 13% | 34% | 59% | 100% | 96% | 14% | 20% |
| | IF_Cl | 23% | 3% | 18% | 6% | 31% | 32% | 99% | 78% | 17% | 6% |
| | CP_Ow | 15% | 2% | 7% | 4% | 2% | 15% | 99% | 71% | 6% | 3% |
| | IP_Wk | 4% | 15% | 2% | 4% | 0% | 5% | 3% | 57% | 0% | 1% |
| | CP_Wk | 19% | 10% | 2% | 4% | 5% | 6% | 97% | 88% | 2% | 4% |
| Buzi (Mozambique), jatropha | IP_Wk | 34% | 47% | 5% | 23% | 83% | 81% | 100% | 100% | 88% | 6% |
| | IF_Ch | 52% | 45% | 4% | 12% | 80% | 98% | 100% | 100% | 95% | 13% |
| | IF_Cl | 59% | 37% | 18% | 17% | 90% | 91% | 99% | 100% | 90% | 29% |

the local control (IF_Cl) and non-growers of sugarcane in the habitat control (IF_Ch) (Table 4). All groups involved in sugarcane growing (i.e. intervention groups), either owner producers or workers, had relatively low deprivation in all indicators, and in almost all cases the deprivation was less than those not involved in sugarcane growing (both the local control (IF_Cl) and the habitat control (IF_Ch)).

In Tshaneni (Swaziland), industrial plantation workers (IP_Wk) were generally the least deprived group in most indicators. Communal plantation workers (CP_Wk) and communal plantation owners (CP_Ow) also had low deprivations in many indicators. Both the local control (IF_Cl) and the habitat control (IF_Ch) had relatively higher deprivations in many indicators, though the habitat control (IF_Ch) seems to have greater deprivation in all the indicators when compared to the local control (IF_Cl).

In Mangochi (Malawi), the pattern of deprivation was more or less the same for the local control (IF_Cl) and the jatropha farmers (IF_Ow), though the jatropha farmers seemed to be slightly less deprived than the local control.

In Buzi (Mozambique), there were no clear differences on deprivation between the three groups. The households of the habitat control (IF_Ch) were slightly more deprived than the households in the other two groups (local control (IF_Cl) and the jatropha plantation workers (IP_Wk)) on the sanitation and floor indicators, while the local control was slightly more deprived than other groups in the water and education indicators.

If we focus on the differences on deprivation between the regions that grow sugarcane and the regions that grow jatropha, both jatropha areas (Buzi and Mangochi) exhibit greater levels of deprivation in MPI indicators compared to sugarcane areas (Dwangwa and Tshaneni), regardless of which groups (control or intervention) are considered. There are also clear project site differences, with Tshaneni (Swaziland) being the least deprived in most indicators and Buzi (Mozambique) being the most deprived in most indicators.

### 3.2. The MPI and its components

As outlined, the objective of the paper was to assess the multidimensional poverty effects around biofuel projects by comparing biofuel intervention groups and control groups (Section 1). Table 5 includes the MPI (Mo) values as well as standard errors and 99%

**Table 5**
The MPI and its components.

| Project/feedstock | Group | Mo | Standard error | 99% confidence interval | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| Dwangwa (Malawi), sugarcane | IF_Ch | 0.194 | 0.00276 | 0.180 | 0.208 |
| | IF_Cl | 0.223 | 0.00256 | 0.210 | 0.236 |
| | IF_Ow | 0.132 | 0.00229 | 0.120 | 0.144 |
| | CP_Ow | 0.091 | 0.00196 | 0.081 | 0.101 |
| | IP_Wk | 0.084 | 0.00173 | 0.075 | 0.093 |
| Tshaneni (Swaziland), sugarcane | IF_Ch | 0.192 | 0.00251 | 0.179 | 0.205 |
| | IF_Cl | 0.118 | 0.00202 | 0.108 | 0.128 |
| | CP_Ow | 0.034 | 0.00119 | 0.028 | 0.040 |
| | CP_Wk | 0.029 | 0.00089 | 0.024 | 0.034 |
| | IP_Wk | 0.003 | 0.00028 | 0.002 | 0.004 |
| Mangochi (Malawi), jatropha | IF_Cl | 0.301 | 0.00236 | 0.289 | 0.313 |
| | IF_Ow | 0.301 | 0.00229 | 0.289 | 0.313 |
| Buzi (Mozambique), jatropha | IF_Ch | 0.403 | 0.00222 | 0.392 | 0.414 |
| | IF_Cl | 0.436 | 0.00315 | 0.420 | 0.452 |
| | IP_Wk | 0.382 | 0.00243 | 0.370 | 0.394 |

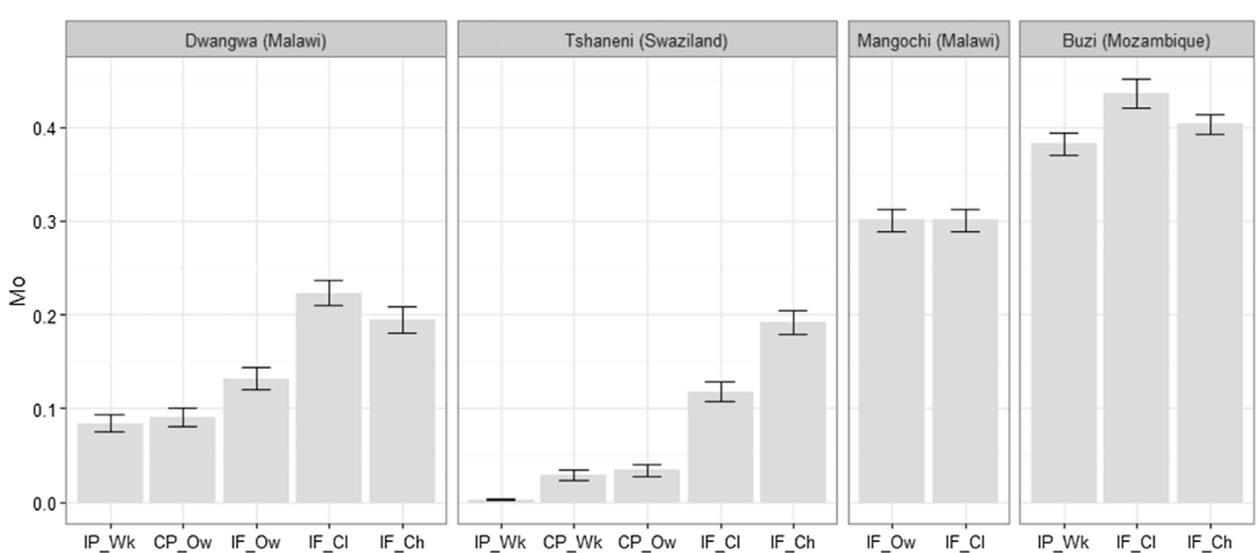


**Fig. 2.** MPIs and the 99% confidence intervals (the upper and lower bounds) for the various groups.

confidence intervals for each study group, in each study site. To clearly show the MPI levels and the 99% confidence intervals, Fig. 2 was plotted. As pointed out (Section 2.4), for the MPIs of any two groups to be significantly different, the confidence intervals of their MPIs should not overlap.

For Dwangwa (Malawi), the lowest MPI was consistently found for groups involved in the sugarcane value chains. Industrial sugarcane plantation workers (IP_Wk i.e. Illovo workers) had the lowest MPI of 0.084, followed by communal sugarcane plantation owners (CP_Ow) with an MPI of 0.091, then individual dryland sugarcane farmers (IF_Ow) with an MPI of 0.132. While the industrial sugarcane plantation workers (IP_Wk) had a lower MPI than communal sugarcane plantation owners (CP_Ow), the confidence intervals show that the difference is not significant. However, the MPIs of both industrial sugarcane plantation workers (IP_Wk) and communal sugarcane plantation owners (CP_Ow) were significantly lower than that of non-sugarcane farmer control groups (IF_Cl and IF_Ch). The non-sugarcane farmers in the local control (IF_Cl) had an MPI of 0.223, which was significantly higher than that of non-sugarcane farmers in the habitat control, who had an MPI of 0.194.

The Tshaneni study site in Swaziland exhibited almost similar patterns. Industrial sugarcane plantation workers (IP_Wk i.e. RSSC workers) had an MPI of 0.003, which was significantly lower than any other group in the study site. Community plantation workers (CP_Wk i.e. SWADE workers) had an MPI of 0.029, which was lower than that of community plantation owners (CP_Ow i.e. SWADE farmers) who had an MPI of 0.034, however, the difference was not significant. In terms of control groups, the local control (IF_Cl) had an MPI of 0.118, which was significantly lower than that of the habitat control which was 0.192. In conclusion, all the sugarcane intervention groups (workers and farmers) had significantly lower MPIs than the control groups.

In Buzi (Mozambique), the industrial jatropha plantation workers had lower a MPI of 0.382, which was lower than the MPI of smallholder farmers in the local control (IF_Cl) which is 0.436, and that for the smallholder farmers in the habitat control (IF_Ch) which is 0.403. The MPI for local habitat is higher than for control habitat.

On the contrary, there were no significant differences between the MPI levels of jatropha growers and non-growers at Mangochi (Malawi). The MPI score was exactly the same for the local control and the households growing jatropha (0.301).

If sugarcane areas are compared to jatropha areas, any group in a jatropha area had significantly higher MPIs than any group in the sugarcane areas. Households involved in any intervention group (farmers or workers) generally had lower MPIs than both the local and the habitat control within that study site (except for Mangochi, as stated above). When control groups are compared, there are contrasting results. While in Dwangwa (Malawi) and in Buzi (Mozambique) habitat controls have lower MPIs than local controls, the contrary is true for the study site in Swaziland.

### 3.3. Robustness tests

As outlined in section 2.5, a robustness analysis was done to test whether the ordering of the MPIs of different groups significantly changed or remained constant when changing different parameters. In this paper, while the overall ordering was assessed for all groups, the main focus of the robustness tests was to assess the robustness of the ordering of the habitat control against that of other groups i.e. whether the habitat control was dominated by other groups or vice versa. The robustness of the MPI results was tested by varying weights, indicator deprivation cut-offs, and the poverty cut-off.

In terms of weights, in this study we used equal weights across the three dimensions (health, education, and standard of living), i.e. 33.33% each (Section 2.3). The original specification of equal weights across the three dimensions was varied across three alternative weighting structures based on [32,53]. The three alternative weighting scenarios used are presented in Table 6. With very few exceptions, the ordering of groups was robust to changes in weights (Fig. 3).

The asset indicator deprivation cut-off varied from either one, three or five assets from the list “radio, TV, telephone, bike, motorbike or refrigerator but excluding a car or truck or tractor”. The ordering of the groups was also generally robust to the variation of the asset indicator cut-off (Fig. 4)

In terms of the nutrition indicator, two food consumption score (FCS) deprivation cut-offs were used in the present study (>35

**Table 6**
Weighting variation.

| Weighting type | Dimension | | |
|---|---|---|---|
| | Education | Health | Living standards |
| Original weighting 1 | 33.33% | 33.33% | 33.33% |
| Alternative weighting 2 | 50% | 25% | 25% |
| Alternative weighting 3 | 25% | 50% | 25% |
| Alternative weighting 4 | 25% | 25% | 50% |

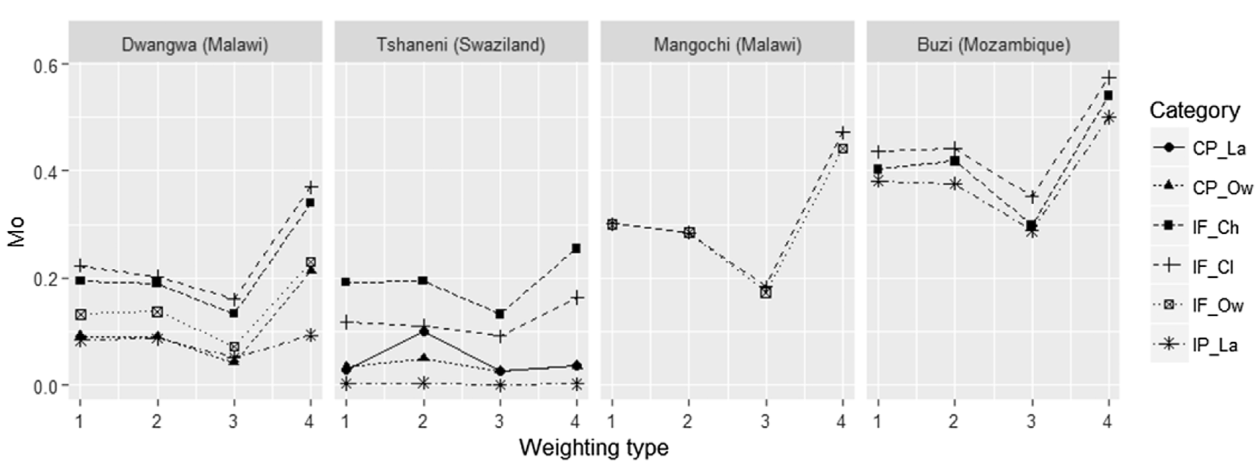


**Fig. 3.** Robustness to weights variation.

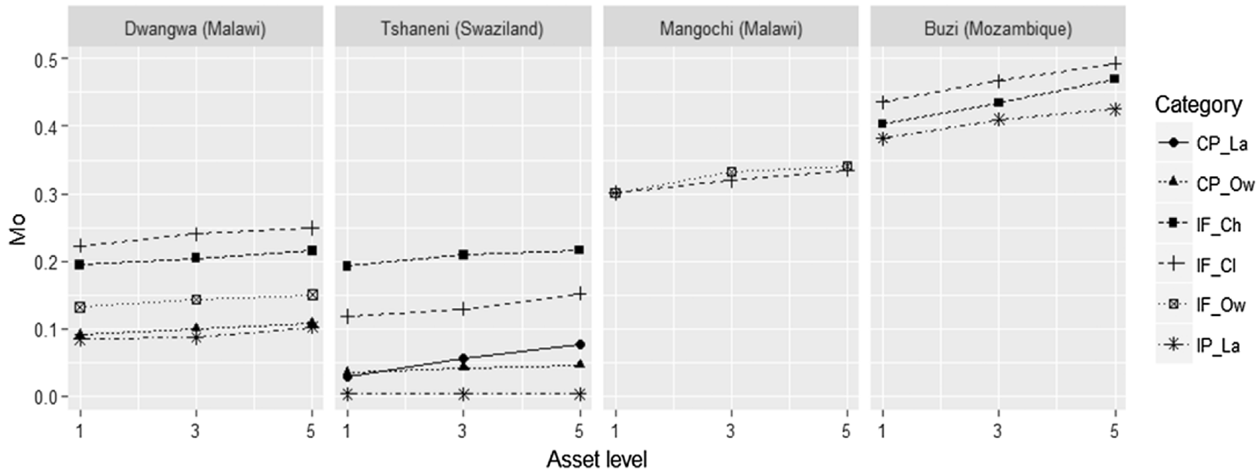


**Fig. 4.** Robustness to asset indicator deprivation cut-off variation.

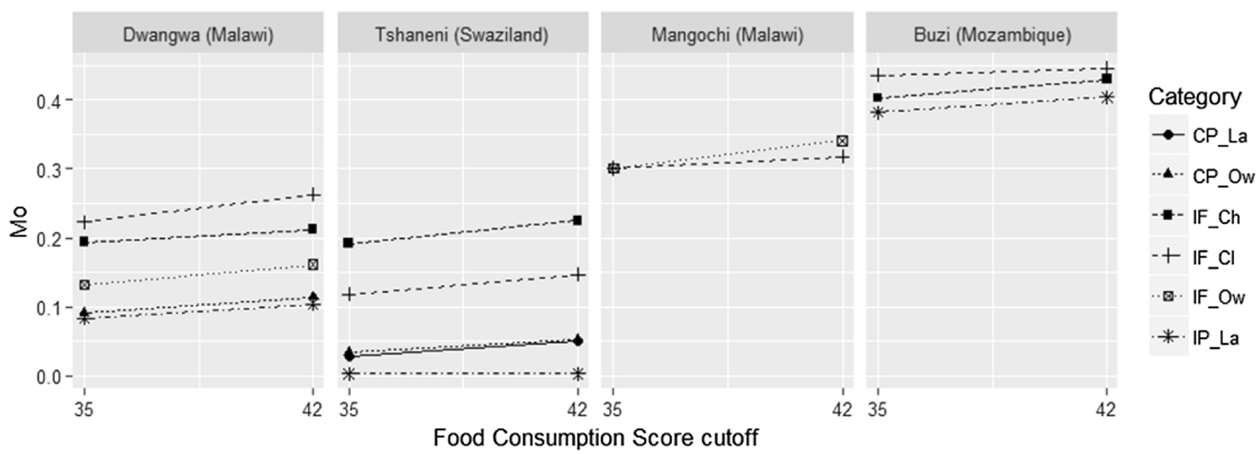


**Fig. 5.** Robustness to the nutrition indicator deprivation cut-off variation.

and > 42) (Section 2.3). It is noteworthy to point out that the general acceptable FCS is (>35), however, for populations that have high frequency of consumption of sugar and oil the cut-off can be (>42) [57]. The robustness test for this indicator suggests that the ranking of the various groups across all projects was generally robust to changes in the nutrition indicator (Fig. 5).

For robustness to the poverty cut-off, the original poverty cut-off of 33.33% and the alternative cut-offs were: 10%, 20%, and 40%. The ordering of groups was generally robust to the changes in the poverty cut-off, though some groups were more sensitive than others at certain cut-offs (Fig. 6).

### 3.4. Regression analysis results

Table 7 includes the results of the regression conducted to assess the potential determinants of multidimensional poverty at the household level. As highlighted in section 2.5, a number of statistical tests were applied to evaluate the model and the individual predictors. The Wald test had a chi-square value of 84.4, with seven degrees of freedom and a p-value < 0.001. This p-value shows that the independent variables included in the model were significant predictors of the dependent variable [73]. The Hosmer-Lemeshow (H-L) test of goodness of fit had a chi-square value of 12.49, with eight degrees of freedom and a p-value of 0.130. This p-value indicates no evidence of poor fit, suggesting that the model fitted to the data reasonably well [73].

The results show that six of the nine predictors had significant relationships with the dependent variable. Four predictors namely "sugarcane farming", "household having a member working at a biofuel plantation", "number of years involved in biofuels", and "cattle ownership" had very high significant negative relationships with the likelihood of being multidimensionally poor. On the other hand, "jatropha farming" and "household size" had significant positive relationships with the likelihood of being multidimensionally poor. "Being located within a biofuel area", "age of the household head" and "area of land" were not significantly related to being multidimensionally poor. The odds of being multidimensionally poor for sugarcane farmers was 0.336 times that of non-sugarcane farmers, while the odds of being multidimensionally poor for jatropha farmers was 2.221 times that of non-jatropha farmers. The odds of being multidimensionally poor for households with a member working for a biofuel plantation was 0.445 times that of households with no member working for a biofuel plantation. The odds of being multidimensionally poor decreased with cattle ownership while it increased with an increase in household size.

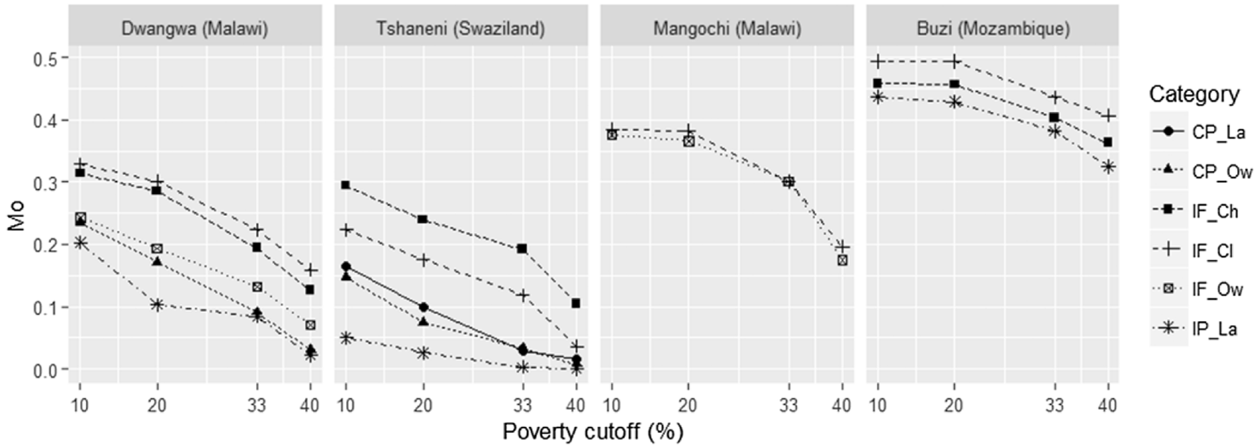


**Fig. 6.** Robustness to the poverty cut-off variation.

## 4. Discussion

### *4.1. Poverty alleviation potential of biofuels in southern Africa*

When comparing intervention groups with control groups, in three out of the four study sites (Buzi, Dwangwa, Tshaneni), groups involved in biofuel value chains had consistently lower MPIs than control groups. This applied to both plantation workers and feedstock farmers.

In both sugarcane study sites - Dwangwa (Malawi) and Tshaneni (Swaziland), control groups tended to be significantly poorer than intervention groups. In Dwangwa, where sugarcane was grown under both irrigated and dryland conditions, irrigated smallholders had lower poverty levels than dryland farmers. In both sugarcane projects (Dwangwa and Tshaneni) access to irrigation was possible because land was pooled to form large production entities. However it was facilitation by the Trusts (Dwangwa) and SWADE (Tshaneni), as well as the respective national governments, which made it possible to access the loan capital to develop the irrigation schemes and develop technical skills for sugarcane production. Farmers belonging to these entities had lower poverty, including some communal plantation owners in Tshaneni, who are yet to receive the actual sugarcane dividends as they are still repaying their loans. This may indicate that there are additional benefits of belonging to these schemes, which are in excess of the cash returns from crop sales.

In Buzi, jatropha plantation workers had lower poverty than farmers in the control groups, but the poverty differential was not as high as in the sugarcane areas. The farmers within the local control had marginally higher poverty than farmers in the habitat control, which would seem to indicate that there was no measurable benefit accruing to farmers for being close to the plantation (e.g. access to roads built by the jatropha company). Similarly, there was little evidence that these farmers were being disadvantaged. In Mangochi, there were no differences in poverty levels between jatropha farmers and the control group.

When the projects are compared, it can be seen that, in general, the sugarcane study sites had relatively lower MPIs (lower poverty) than the jatropha sites across all study groups. Jatropha project sites experienced greater deprivation in most indicators than sugarcane project areas. Perhaps this is because sugarcane is a well-established crop that has a long cultivation history in both sugarcane study sites. This means that the benefits accumulated as a result of sugarcane farming fall not only within the intervention groups but also to the control groups due to spillover effects. By contrast, it could be argued that jatropha is a new crop, for instance, the farms in Mangochi are only in their first or second year of harvesting. As a result, farmers have so far received very little income from jatropha sales, so impacts on poverty reduction could have hardly happened.

This is also evident from the average years of involvement in jatropha and sugarcane value chains:

- In Mangochi (Malawi), individual jatropha farmers (7.4 years)
- In Buzi (Mozambique), industrial plantation workers (6.1 years)
- In Dwangwa (Malawi), industrial plantation workers (18.2 years), communal plantation workers (18.9 years), individual rainfed sugarcane farmers (7.2 years)

**Table 7**
Regression analysis results.

| | Estimate | Odds ratio | Marginal effects | Std. Error | z value | Pr(>\|z\|) | Significance level |
|---|---|---|---|---|---|---|---|
| (Intercept) | −0.349 | 0.705 | | 0.256 | −1.363 | 0.173 | |
| Sugarcane farming (1 = farming, 0 = non-farming) | −1.092 | 0.336 | −0.232 | 0.221 | −4.937 | 0.000 | **** |
| Jatropha farming (1 = farming, 0 = non-farming) | 0.798 | 2.221 | 0.197 | 0.253 | 3.155 | 0.002 | *** |
| Member working at a biofuel plantation (1 = working, 0 = non-working) | −0.810 | 0.445 | −0.183 | 0.199 | −4.071 | 0.000 | **** |
| Number of years involved in biofuels | −0.040 | 0.961 | −0.010 | 0.011 | −3.576 | 0.000 | **** |
| Located within biofuel area (1 = within, 0 = outside) | 0.212 | 1.236 | 0.050 | 0.152 | 1.397 | 0.162 | |
| Age of household head | 0.004 | 1.004 | 0.001 | 0.004 | 0.839 | 0.402 | |
| Cattle ownership (number of cattle owned) | −0.072 | 0.931 | −0.017 | 0.016 | −4.373 | 0.000 | **** |
| Area of land (hectares) | 0.014 | 1.014 | 0.003 | 0.010 | 1.363 | 0.173 | |
| Household size | 0.044 | 1.045 | 0.011 | 0.022 | 2.026 | 0.043 | ** |

Significance levels: '****' 0.001, '***' 0.01, '**' 0.05, '*' 0.1.

- In Tshaneni (Swaziland), communal plantation workers (7.9 years), industrial plantation workers (15 years), and communal plantation farm owners (14.6 years).

It is noteworthy to state that the relatively higher poverty observed in jatropha areas does not imply that jatropha growing results in poverty, but rather that jatropha has been promoted in places of existing extreme poverty. The Mangochi (Malawi) results suggest that to date jatropha has had no impact (either positive or negative) on poverty levels, but in Buzi (Mozambique), workers have benefited from the jatropha project whilst the surrounding community showed no signs of benefit in terms of the MPI scores.

By contrast, the intervention groups in sugarcane areas had substantively lower poverty than both their control areas and the intervention and control groups in the jatropha areas. Though causation is hard to prove, it seems a reasonable assumption that sugarcane growing has reduced the poverty levels for those involved in the sugarcane value chain. Though it is tempting to suggest that those not engaged in the sugarcane value chain have been disadvantaged by sugarcane growing in the area, an alternative interpretation might be that it is the poorer farmers with less land and other resources that were unable to enter the sugar value chain in the first place.

Multidimensional poverty was found to be relatively lower amongst biofuel plantation workers when compared to all other groups. The regression analysis (Section 3.4) showed that having a household member working for a biofuel plantation reduced significantly the odds of being multidimensionally poor. Many rural areas in SSA have very limited job opportunities, such that even low-paying jobs (like the ones offered in the studied biofuel projects) are in demand [11]. Therefore, feedstock production, especially at plantations can be an important source of employment and better livelihoods in rural areas around such feedstock plantations.

While it is difficult to establish a strong causality between involvement in biofuel value chains (e.g. working or farming) and poverty alleviation, the variable “number of years involved in biofuels” (Table 5) suggests that being involved in biofuels for longer periods reduced the odds of being multidimensionally poor. This might be due to the fact that accumulated income over time was invested within the household to improve different aspects related to multi-dimensional poverty such as assets and education. In this respect involvement in biofuel chains can indeed have a poverty alleviation effect for those involved in them, but the actual effects might take time to materialise.

Another variable that was found to have a significant negative relationship with the likelihood of being multidimensionally poor is cattle ownership (Section 3.4). That implies that the more livestock a household has, the less poor it is. Though livestock ownership in general, and cattle ownership in particular, are not considered in the calculation of the MPI, it is important to bear in mind that these are important household assets (and indicators of wealth) especially in rural areas of southern Africa. Living standard indicators (such as access to assets) are means rather than ends [32], thus, in rural areas, livestock ownership is an important means to accessing various ends. Livestock is an asset which can be sold in order to send children to school, to meet household nutritional requirements amongst other needs. Considering that cattle ownership can be seen as an alternative measure of wealth in the study areas, this attests to an extent, the validity of our results.

This study found that household size had a positive relationship with the likelihood of being multidimensionally poor. This supports the findings of Levine et al. [23] in a study done in Uganda. They found that household size had a large bearing on multidimensional poverty. However, they argued that while larger households are likely to be poorer, household size also plays a role due to the design of the multidimensional poverty measure. There are shared negative effects and shared positive effects when a household is taken as unit of analysis while not considering intra-household disparities [23,30].

In terms of the methodology, the MPI results were generally robust to various parameter changes (Section 3.3). The general robustness of the MPIs of different groups is supported by the Spearman's rank correlation analysis. In summary (see appendix), the Spearman's rank correlation coefficients of MPIs based on different weights specification exceed 0.96 (Table A1); for poverty cut-offs they exceed 0.98 (Table A2); for asset indicator deprivation cut-offs they exceed 0.99 (Table A3); and for nutrition indicator deprivation cut-offs it exceeds 0.99 (Table A4).

### 4.2. Limitations and research gaps

A key issue that this study could not discern is whether households which were found to be better off, were better off because of their involvement in the biofuel projects, or because they were already privileged before. For example, in the case of sugarcane smallholders in the SWADE project in Tshaneni (Swaziland), it is those in the community who had agricultural land close to the Komati river (and thus could be irrigated more easily), that were included in the project. In many instances only one household in a homestead may have had the ownership of the land, and typically this would be the most senior household.

Furthermore, it is noteworthy to point out some of shortcomings of the MPI, particularly in relation to this study. There is an unfortunate bias in the criteria used in the MPI calculation. For instance, as it relates to the present study, sugarcane plantation workers were mostly living in houses provided by the company with better access to some amenities, such as access to improved water, flooring, and sanitation, which lowers to an extent the MPI (i.e. less poverty). But, since these plantation workers do not own those houses, the moment that they are longer employed, they are likely to be deprived in those indicator categories, especially if they have no proper livelihood alternatives. So a worker who is not multidimensionally poor today according to the MPI, if fired from work, might be multidimensionally poor tomorrow. As a result, while plantation workers generally appeared to have a lower level of poverty than farmers, over extended periods those farmers might be better off than the workers as the farmers have significant control and command over the resources and facilities they accessed.

Though this study did not find a significant relationship between land ownership and the likelihood of being multidimensionally poor (Section 3.4), land access and ownership is a highly topical issue in Africa, especially when it comes to biofuels. It is important to point out that land ownership might not relate to poverty reduction per se, but it is the actual access and utilisation of that land that will likely contribute to poverty reduction. Our study design was more aligned towards households with land, since the level of analysis for all groups other than plantation workers, were households involved in farming. The design therefore did not capture potential land displacement which has been a contentious issue at Dwangwa (Malawi) [74]. In Mangochi (Malawi), smallholders grow jatropha on their own land so land ownership is not a big issue. The BERL model used in Mangochi recommended farmers to grow jatropha on farm boundaries, which may help ensure land tenure. The Niqel (Buzi, Mozambique) project did displace some farmers, but these were able to establish farms (partly with the help of Niqel) on newly allocated land, as land is not a scare resource in this particular location [16]. However, at the community level, land has been lost to the jatropha project, with no indication of community-wide poverty reduction other than benefits to the plantation workers.

In Tshaneni (Swaziland), the community plantation owners (i.e. SWADE farmers) retained their land, and have been able to move from very low subsistence agriculture to high value sugarcane production. In addition, due to irrigation being available, farmers can now grow small plots of vegetables under irrigated conditions. However, there are some challenges relating changes in land availability as a result of the implementation of the SWADE project. For instance, a 2008 FAO study [44] highlighted that in some parts of the community, households were resettled and clustered in one area or were not resettled (they remained where they were before) but were made to cede their land for the sugarcane plantation. Each family was left with a very small portion of land available both as living space and for farming other crops besides sugar cane.

When it comes to the indicators used in the MPI, the FCS has a short assessment period (7 days) and as a result can be very sensitive to the timing of the survey (e.g. period after receiving wages/agricultural income, lean period of the year). Fieldwork in each site was conducted for small periods (1–1.5 months) during which control and intervention groups were measured simultaneously. As a result we expect that such effects have not affected significantly the first level of comparison (within biofuel projects). However they may have an effect on the second level of comparison (between biofuel projects). This uncertainty should be considered when using the MPI results for cross-project comparisons.

While we identified on several occasions that groups involved in biofuel value chains (i.e. intervention groups) tend to have much lower multidimensional poverty scores, it has not been possible to establish concrete causation whether involvement in biofuel chains was the main driver of this poverty differential. Another gap is to identify whether the poverty levels of control groups have been influenced by the development of the biofuel projects, particularly in areas of large land transformation.

In other words, we cannot concretely clarify whether the involvement in biofuel chains can lead to less poverty for those involved (lower MPI levels of involved households) or more poverty to those not involved (higher MPI scores of control groups) due to loss of access to resources such as communal land.

Even though our study alludes to the potentially positive poverty alleviation effect that involvement in biofuel projects has for local communities (especially those involved over longer periods), these remain important gaps in the biofuel literature particularly in southern Africa, where biofuels have been adopted as a means of rural development and poverty alleviation [4].

As to the suitability of the MPI to assess local poverty impacts from biofuel expansion, it was found that the method could discern differences between the study groups at the level of individual projects, and could provide a standardised metric against which to compare projects in different countries. As the tool in effect measures the long-term impact of accumulated assets, it would appear to be better suited to the long-established sugarcane projects rather than the recently established jatropha projects. Therefore, the MPI may be a less appropriate tool for comparisons between the two feedstocks, rather than between the same feedstock in different countries or between different groups. However, having said that, some of the relatively newly established sugarcane associations linked to SWADE in Tshaneni (Swaziland), which were of approximately similar age to the jatropha projects, showed a huge difference in poverty levels.

One benefit of the methodology is that it has been used globally and as such values obtained from project data can be compared to both national and international norms. However, the criteria selected against which to assess poverty may be locally inappropriate, or biased by specific circumstances particular to one group. For instance, workers living in housing provided by the company, have low MPI values due to the disproportionately positive impact on indicators such as sanitation, drinking water and housing, but the MPI misses out on aspects that may be more important such as ownership of houses and land or aspects of family cohesion.

Finally, the specific indicators used for the construction of the MPI cannot link well MPI patterns to changes in ecosystem services due to land conversion for biofuel production. In particular, the lack of indicators related to land (and the specific ecosystem services it provides) makes it difficult for the current version of the MPI to be used as a metric to assess the human wellbeing outcomes of changes in ecosystem services from biofuel expansion. As a result unless specific modifications are made in the selection of indicators, the MPI can be at best a complementary measure to other tools/methods for ecosystem services studies in biofuel contexts.

## 5. Conclusion

The present study investigated the local poverty effects of growing biofuel crops. It adopted a multi-dimensional poverty approach for different modes of production (large-scale vs smallholder-based) and different feedstocks (sugarcane vs jatropha).

Results suggest that in the sugarcane-growing areas, i.e. Dwangwa (Malawi) and Tshaneni (Swaziland), those who participated in sugarcane activities such as plantation workers and sugarcane farmers had consistently lower poverty than those who were not involved (control groups).

On the other hand, in jatropha-growing areas results were mixed. While there were no clearly defined differences between control groups and jatropha farmers in Mangochi (Malawi), the plantation workers in Buzi (Mozambique) had slightly lower poverty than their respective control groups. This may in part be a consequence of the jatropha projects being new and not having had time to impact on poverty. However the low jatropha yields, particularly for the Mangochi project in Malawi, suggest that a decrease in poverty is highly unlikely unless yields improve substantively in the future.

It is important to highlight that the criteria selected against which to assess poverty may be locally inappropriate, biased by specific circumstances particular to a certain group and not reflect changes in ecosystem services due to land conversion for biofuel production. For example, living in housing provided by biofuel companies affected disproportionately many of the indicators such as improved sanitation, water, and flooring, but misses out on aspects that may be more important such as ownership of the houses/land or aspects of family cohesion. As a result, studies using the MPI should critically interpret their findings based on the local context else they run the risk of providing flawed conclusions about the poverty alleviation potential of different development interventions.

## Acknowledgements

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## Appendices

**Table A1**
Spearman's Rank correlation different specifications of MPI (weights variation).

| | MPI original weighting 1 | MPI alternative weighting 2 | MPI alternative weighting 3 |
|---|---|---|---|
| MPI Alternative weighting 2 | 0.976 | | |
| MPI Alternative weighting 3 | 0.993 | 0.972 | |
| MPI Alternative weighting 4 | 0.990 | 0.961 | 0.976 |

**Table A2**
Spearman's Rank correlation different specifications of MPI (poverty cut-off variation).

| Poverty cut-offs | MPI at 33% | MPI at 10% | MPI at 20% |
|---|---|---|---|
| MPI at 10% | 0.987 | | |
| MPI at 20% | 0.993 | 0.997 | |
| MPI at 40% | 0.993 | 0.988 | 0.991 |

**Table A3**
Spearman's Rank correlation different specifications of MPI (asset indicator deprivation cut-off variation).

| | MPI asset level 1 | MPI asset level 2 |
|---|---|---|
| MPI Asset level 2 | 0.993 | |
| MPI Asset level 3 | 0.990 | 0.997 |

**Table A4**
Spearman's Rank correlation different specifications of MPI (nutrition indicator deprivation cut-off variation).

| | MPI at FCS (>35) |
|---|---|
| MPI at FCS (>42) | 0.996 |

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