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Assessing Agricultural Land Use Change in the Midlands Region of KwaZulu-Natal, South Africa: Application of Mixed-Multinomial Logit

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Abstract

On-farm tree cultivation is considered an important strategy to mitigate detrimental environmental impacts of agricultural land-use change (ALUC). In South Africa, however, little is known about farm-level incentives and constraints that govern ALUC decisions among small-scale farmers. To address this knowledge gap, this study employs a mixed multinomial logit (MMNL) model by using a combination of revealed and stated preference data. After correcting for endogeneity, the estimated results show that decisions about ALUC are rationally derived and driven by clear but heterogeneous preferences and trade-offs between crop productivity, food security and labour saving. The results further show that the decision to plant sugarcane is constrained by landholding, whilst farmland afforestation is negatively influenced by household size. Decisions to convert land use are also driven by the behaviour of peer groups and agro-ecological conditions. Based on these findings, important policy implications for sustainable land use are outlined.

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1. Introduction

Environmental management remains a global challenge. Agricultural land use change (ALUC), i.e. the conversion and/or modification of a land cover primarily for agricultural purposes, often entails environmentally unfriendly practices such as clearing natural forestlands and intensifying agricultural production on environmentally sensitive lands (e.g. highly sloped lands, floodplains and wetlands). Such practices constitute one of the major aspects of anthropogenic environmental degradation (Foley et al., 2005). On-farm tree cultivation presents an option to reverse the detrimental environmental impact of ALUC. Tree cultivation provides arrays of private and public benefits, including the restoration of soil fertility in degraded farmlands, *in-situ* conservation of tree species traditionally important for livelihoods (such as food, fuel wood, medicine, construction materials), promotion of entrepreneurship and off-farm opportunities, mitigation of global warming through carbon sequestration, contribution to clean water provision, control of insect pests and diseases, and reduction of air pollution (Leakey, 2010; Stein et al., 2009). Therefore, farmland afforestation is considered a landmark of climate-smart agriculture (FAO, 2013).

The design of appropriate incentive mechanisms to increase on-farm tree cultivation, however, remains a major policy challenge. At farm level, where important ALUC decisions are taken, farmers face a trade-off between land conservation and short-term land productivity (Zelek and Shively 2003). Economists also argue that environmental externalities of tree cultivation increase the gap between the private and social cost of land uses (Alix-Garcia and Wolff, 2014; Sobool, 2004), creating inefficiencies in land allocation. Given that individual farmers are driven by private goals, sub-optimal land allocation to trees could result from under-representation of private goals in the design of sustainable land-use policies. Policy incentives are therefore appropriate to address the market failure in private afforestation.

In South Africa, policies have been designed to integrate environmental planning into the ongoing land reform process. Direct land conservation interventions (e.g. LandCare programme) mainly focus on the rehabilitation of degraded communal lands. Private afforestation is indirectly supported by strategies that seek to extend industrial tree cultivation to small-scale farming areas. Such strategies have taken two major forms, namely the creation of out-grower schemes as a corporate social responsibility of major timber companies (e.g. Sappi Project Grow and Mondi Forestry Partners), and the change in companies' asset structure to comply to the black economic empowerment (BEE) policy (Karumbidza, 2005).

However, research evidence suggests that the policy strategies have scored limited success. Studies detecting ALUC over the last decades show that, although tree cover has considerably increased in commercial farming areas, the expansion of small-scale farming within and on the outside of communal land areas has resulted in the depletion of woody plant cover (Giannecchini et al., 2007; Puttick et al., 2014; Wessels et al., 2011; Wigley et al., 2010). For example, in the KwaZulu-Natal (KZN) province, where the majority of small-scale farming systems are concentrated, Pillay (2010), Wigley et al. (2010) and other studies report that forest cover on small-scale farming areas has generally declined, whilst other agricultural land uses, such as sugarcane, have substantially increased. These trends have accentuated the land degradation process (Giannecchini et al., 2007; Hoffman, 2014; Puttick et al., 2014; Wessels et al., 2011, 2007) and decreased the above- and below-ground CO_2 sink (Republic of South Africa, 2013).

The limited success of policy strategies for farmland afforestation in South Africa can partly be attributed to the limited understanding of individual land-use decision-making processes and their institutional context, as analyses of ALUC in small-scale farming areas remain scanty. Most of the existing studies often use spatially-explicit, non-economic models (Giannecchini et al., 2007; Puttick et al., 2014; Wessels et al., 2011) that overlook individual farmers' attitudes and characteristics that underlie most economic theories of ALUC (Irwin and Geoghegan, 2001). Against this backdrop, this study aims to contribute to the growing literature on ALUC by providing insight into beliefs that underlie farmers' attitudes towards the advantages and disadvantages of specific ALUCs, and their decisions to convert land use to commercial forests and sugarcane plantations in the South African small-scale farm setting.

To this end, the study applies the mixed multinomial logit (MMNL) estimation technique (McFadden and Train, 2000). This technique is increasingly receiving attention among ALUC scholars (Brey, Riera and Mogas et al., 2007; Dde Valck et al., 2014; Goibov et al., 2012). This paper adopts a method that uses a combination of revealed preference (RP) and stated preference (SP) data, unlike previous studies that mainly use discrete choice experiments (DCE) of the SP technique (Cameron, 1992). Research shows that joint revealed-stated preference analyses produce more robust estimates and better identification of attributes, and reduces the potential endogeneity and other biases in welfare measurement, such as informational and hypothetical biases (Whitehead et al., 2008).

The remainder of this article is subdivided into six sections. Section 2 provides a brief review of the empirical literature on ALUC. Section 3 elicits the conceptual framework, while section 4 presents the empirical strategy used. Section 5 describes the study area and data used in the MMNL model. Section 6 reports the estimation results and discusses the major findings. Section 7 presents some concluding remarks.

2. Literature review

A rich empirical literature on land-use conversion from agriculture to forestry use was drawn from well-established theories to show how farm-level factors influence ALUC decisions. A review by Edwards-Jones (2006) argues that, at micro-level, utility maximisation prevails over profit maximisation behaviour. It defines four categories of determinants for the demand of ALUC: (i) characteristics of the new land use to be adopted; (ii) farmer and household characteristics; (iii) farm structure; and (iv) the wider social milieu.

Regarding the characteristics of land use, behavioural studies draw from Lancaster's (1966) characteristic-based demand theory and the assumption that land use is differentiated by its multi-functionality (Pérez-Soba et al., 2008) to show how farmers subjectively value alternative land uses. In many cases, behavioural studies are based on the land-use functions (LUFs) framework, which integrates the perceived changes in a large set of indicators into LUFs and is balanced around the three dimensions of sustainability, namely economic, societal and ecological sustainability (Pérez-Soba et al., 2008). Evidence from various parts of the world suggests that farmers prioritise economic functions, such as income generation and cost saving (Irshad et al., 2011; Martínez-García et al., 2013), whilst required financial investment and the difficulty of management are important disincentives (Martínez-García et al., 2013; Zubair and Garforth, 2006). Social functions of land use, such as food security, health and work provision are also found among the priority functions (Purushothaman et al., 2013). In addition, farmers highly value the provision of ecosystem services, such as biomass production, prevention of soil erosion, improvement of water quality and biodiversity conservation (Irshad et al., 2011; Poppenborg and Koellner, 2013; Zubair and Garforth, 2006).

Actual land-use conversion decisions, however, are controlled by sets of farm-level factors, gender being among the key determinants of ALUC. Research shows that the gender effect in land-use decision-making is mediated by differences in values, attitudes towards risk, entitlements and learning processes (Villamor et al. 2014). Women in developing countries are more risk averse, and tend to control food crop production. They are mainly driven by household food security but are constrained by a lack of land-tenure rights and insufficient time to participate in training and experimentation required for market-orientated agriculture (Villamor et al., 2014). Age is another factor of ALUC. The effect of age on ALUC is mediated by attitudes towards investment and risk. High dependency makes early investment problematic, disposing younger farmers to high discount rates and risk aversion, thereby increasing their preference for short-rotation cultivation (Perz et al., 2006; Walker et al., 2002).

Regarding household characteristics, economists argue that the effect of household size on ALUC is defined by market conditions. When households are not well integrated into the market economy, the Chayanovian model posits that households tend to intensify (or deforest) as they increase in size, due to increased labour availability and heightened demand for household consumption (Angelsen, 1999; Klemick, 2011; Perz et al., 2006). When the market exclusion assumption is relaxed, empirical studies show that market access factors associated with skills, wealth, and risk aversion dictate land-use change through flexibility of input substitution (Parks, 1995; Walker et al., 2002). The off-farm income generated by participation in labour markets relaxes household liquidity constraints and increases their flexibility of input substitution (e.g. using hired labour) (Parks, 1995; Walker et al., 2002). The effect of liquidity constraint on ALUC, however, is not unambiguous (Kaimowitz and Angelsen, 1998). In some cases (Klemick, 2011), a liquidity constraint has discouraged intensification, whilst in others (Uchida et al., 2009) it has accentuated reliance/pressure on farmland resources.

With regard to farm characteristics, studies show that the effect of farm size is mediated by the levels of technological risk and fixed costs associated with each alternative land use (Just and Zilberman, 1983; Schatzki, 2003). With increasing (decreasing) relative risk aversion, the share of land devoted to modern technology would be decreasing (increasing) in size if modern technology was more risky and/or required high fixed cost outlays (Just and Zilberman, 1983). Farm location also influences ALUC through land rents. The von Thünen model suggests that only high-value crops (such as sugarcane) can be cultivated near roads and cities, given that land value increases with proximity and ease of access to physical markets (due to decreasing cost of production or transport) (Erenstein et al., 2006; Walker, 2014). Access to technology also governs ALUC. Empirical studies (Kajisa and Payongayong, 2013) have vindicated the Boserupian model that explains the process from extensification towards intensification, based on the prevailing material conditions (i.e. access to technology).

Spatial characteristics also influence ALUC. Spatially-explicit models associate the steepness of terrain to the conversion cost, i.e. the attractiveness of an area for conversion to crop cultivation (López and Sierra, 2010). Moreover, given that potential land productivity is associated with topography, land use often exhibits patterns characterised by farmlands on hill foots, and forest and grasslands on hill slopes and mountain tops (Fu et al., 2000).

Regarding the social milieu, empirical studies show that social capital facilitates land-use conversion through cooperation and litigation mitigation (Libby and Sharp, 2003). Empirical studies also show that farm-level ALUC decisions are governed by social influences (i.e. the influence of behaviour, beliefs and preferences of other people in the farmer's peer group). Based on the innovation diffusion models, studies show that social influence is channelled through knowledge and persuasion that reduce uncertainty about the outcome of land-use conversion, and support optimal management of new technology (Deffuant et al., 2002; Foster and Rosenzweig, 2010; Wuepper et al., 2014).

Methodologically, the empirical and quantitative non-market valuation methods adopted so far can be grouped into two: the behavioural (or indirect) approaches, and SP (or direct) methods (Haab and McConnell, 2002). In the landscape literature, behavioural studies calibrate farmers' attitudes towards ALUC, based on the behavioural theories such as the theory of planned behaviour (Martínez-García et al., 2013; Poppenborg and Koellner, 2013; Zubair and Garforth, 2006). This approach, however, fails to account for "actual" controls (Lynne et al., 1995). To address this setback, studies have increasingly used discrete choice models with flexible substitution patterns, such as the nested logit (NL) (Greiner, 2014; Windle and Rolfe, 2005). Others have adopted the MMNL model (Brey et al., 2007; de Valck et al., 2014; Goibov et al., 2012). The superiority of MMNL over the NL model lies in its capacity to recognise correlated alternatives and preference variations expressed through random parameters (Munizaga and Alvarez-Daziano, 2001).

The studies using the MMNL model often rely on DCE data. However, this approach has some important limitations, such as the potential endogeneity bias (Bhat and Gossen, 2004; Hess, 2012), as well as other common biases in welfare measurement, such as informational and hypothetical biases (Adamowicz et al., 1994). Combining SP and RP data can reduce the biases and improve the consistency of parameter estimates (Whitehead et al., 2008). Although this combination has attracted the attention of researchers in various fields of environmental valuation (Whitehead et al., 2008) and technology adoption (Useche et al., 2009), it has hardly been applied in ALUC modelling.

Inspired by the work of Useche et al. (2009), the present study uses a combined SP-RP technique to the analysis of ALUC. Two alternative approaches to combining SP and RP data exist. Stacking two datasets, one with SP data and another with RP data (Adamowicz et al., 1994) violates the assumption of independent and identically distributed (IID) error terms (Whitehead et al., 2008). The alternative approach that assumes IID error was proposed by Cameron (1992). This approach consists of combining the SP technique with RP methods by using survey instruments that capture information on actual behaviour and respondents' personal evaluation of the attributes/outcomes of various scenarios (e.g. using contingent valuation). The latter approach was therefore used in this study.

3. Conceptual framework

A behavioural household model for ALUC can be constructed by drawing from the utility maximisation framework of the integrated adoption model of technology traits and producer heterogeneity (Useche et al., 2009). Under this non-separable household model, farmer *i* is assumed to maximise his utility U_i by comparing the utility provided by an alternative land use *j* over the current land use *k*. Farmer *i* will adopt land use *j* if $U_{ij} > U_{ik}$ or $\Delta U_{ik} = U_{ij} - U_{ik} > 0$ $\forall j \neq k$. The indirect utility of an alternative land use is assumed to be a linear function of the characteristics *x* of *j* ($U_{ij} = \beta_i x_{ij}$) (Lancaster, 1966). This implies the following behavioural model:

$$\Delta U_{ik} = \beta_i \Delta x_{jk} \tag{1}$$

Due to the potential heterogeneity of the farmers' preferences, the vector of preference parameters (β_i) varies over individuals according to both observable (z_{1i}) and unobservable (υ_i) farm and farmer characteristics, i.e.

$$\beta_i = b + \delta z_{1i} + \phi \upsilon_i \tag{2}$$

Also, farmers with some observable characteristics z_2 (e.g. larger household or farm sizes) may have intrinsic preferences for a specific land use *j* (γ_j) that affect the utility of each of the alternative land uses and the adoption choices, as shown in equation 3 below.

$$U_{ij} = \beta_i x_{ij} + \gamma_j z_{2i} \text{ or } \Delta U_{ik} = \beta_i \Delta x_{jk} + \gamma^*_{jk} z_{2i} \quad (3)$$

where $\gamma^*_{jk} = \gamma_j - \gamma_k$

Substituting equation 2 into equation 3 yields:

$$\Delta U_{ik} = (b + \delta z_{1i} + \phi \upsilon_i)\Delta x_{jk} + \gamma^*_{jk} z_{2i} \quad (4)$$

Equation 4 depicts a behavioural model of ALUC as a function of land-use attributes (x_{ij}) (which vary across individuals *i* and land use *j*), given farmers' own preferences for land use, based on perceived outcome (β_i) and intrinsic preferences for a specific alternative (γ_j) and own farm and farmer characteristics (z_i).

4. Empirical model

The MMNL model provides a practical econometric approach for analysing discrete choices arising from utility maximisation frameworks (McFadden and Train, 2000). The MMNL choice probabilities are:

$$P_{ij} = \int \frac{\exp(\beta' x_{ij} + \gamma_j z_i)}{\sum_k \exp(\beta' x_{ik} + \gamma_j z_i)} f(\beta) d\beta \quad (5)$$

for $i = 1, \ldots, I$, and $j, k = 1, \ldots, J$

There are two statistical procedures of simulating MMNL: the maximum simulated likelihood estimation and the method of simulated moments (McFadden and Train, 2000). This study used a Stata® module written by Hole (2007) to fit the MMNL model by using a maximum simulated likelihood approach.

The expected utility (EV) from the LUFs is estimated as follows:

$$EV_i(Ac) = \alpha_{Ac} + \beta_{i1} EY_{Ac} + \beta_{i2} EQ_{Ac} + \beta_{i3} EF_{Ac} + \beta_{i4} EL_{Ac} + \beta_{i5} ES_{Ac} + \sum_{k=1}^{7} \gamma^k_{Ac} z_{ki} \quad (6)$$

$$EV_i(Sc) = \alpha_{Sc} + \beta_{i1} EY_{Sc} + \beta_{i2} EQ_{Sc} + \beta_{i3} EF_{Sc} + \beta_{i4} EL_{Sc} + \beta_{i5} ES_{Sc} + \sum_{k=1}^{7} \gamma^k_{Sc} z_{ki} \quad (7)$$

$$EV_i(Tc) = \alpha_{Tc} + \beta_{i1}EY_{Tc} + \beta_{i2}EQ_{Tc} + \beta_{i3}EF_{Tc} + \beta_{i4}EL_{Tc} + \beta_{i5}ES_{Tc} + \sum_{k=1}^{7}\gamma_{Tc}^{k} z_{ki} \qquad (8)$$

In the empirical models above, Ac, Sc and Tc represent three alternative land uses (*viz.* annual crops, sugarcane and tree plantations). A constant specific to each alternative is represented by α which captures the average effect of unobserved factors for an alternative with respect to all others. *EY*, *EQ*, *EF*, *EL* and *ES* are expected values attached to the five indicators of LUFs, i.e. income generation (*Y*), crop productivity (*Q*), food availability (*F*), labour requirement (*L*) and soil loss mitigation (*S*). Based on standard microeconomic principles, as well as the review of literature in Section 2, the demand for ALUC was expected to increase in *Y, Q, F*, and *S*, but decrease in *L*.

Vector *z* depicts farmer, household, farm and social characteristics. Based on the literature review in Section 2, the selected independent variables are as follows:

- z_1 captures the female gender of the household head (GENDER);
- z_2 represents the attitudes towards investment by using the age of the household head (AGE);
- z_3 indicates the levels of skills and liquidity constraints (i.e. access to labour and financial markets) by using the number of years the head of household spent in formal education (EDUCATION);
- z_4 represents household consumption and labour force by using the number of adult-equivalent members of the household (ADULT)[1];
- z_5 uses the operated hectares (LAND) as a proxy of farm size;
- z_6 measures access to physical markets (an indicator of land rent) in the model, based on average walking distance (in minutes) to the nearest tarred road (ROAD);
- z_7 measures the distance to the nearest river/dam (in walking minutes) (WATER) to portray access to irrigation water;
- z_8 measures the generalised level of trust (TRUST) to represent the effects of civic society, quality of institutions, culture and values, and ethnic heterogeneity in the community (Nannestad, 2008; Rothstein and Stolle, 2008);
- z_9 captures social influences by using the proportion of households that have converted land use to sugarcane and forestry plantations in the ward (PROPORTION) (Walker et al., 2011); and
- z_{10} is a dummy variable of Windy Hill Mistbelt region (AGRO-ECOLOGY) for controlling the

As proposed by Cutler and Katz (1992), adult-equivalents (*E*) is computed as $z_4 = (N_A + cN_C)^{\theta}$, where N_A and N_C represent the number of adults and children in the household, respectively, *c* is a constant reflecting the resource cost of a child, relative to that of an adult, and θ measures the overall economies of scale within the household. Following previous key empirical studies in South Africa (May et al., 1995; Woolard and Leibbrandt, 2006), *c* was set to 0.5, and θ was set to 0.9 (Streak et al., 2009).

fixed effects of differences in agro-ecological conditions, such as rainfall and topography.

This specified model, however, suffers from potential endogeneity bias. Farmers living in the same community (i.e. ward), or in the same agro-ecological area, face the same attribute of alternative land use (e.g. crop productivity) and constraints (e.g. access to water). Therefore, both observed and unobserved factors (e.g. aesthetic value of the landscape) will be similar for the farmer and his neighbours. Disregarding such endogeneity, caused by locational effect, could lead to a considerable flaw in the estimation of the true population parameters (Louviere et al., 2005).

To address this potential bias, the Berry-Levinsohn-Pakes (BLP) approach was used (Berry et al., 1995). The BLP approach is a three-step estimation procedure:

(i) estimating the location-specific constants from the choice model;
(ii) using a two-step instrumental variable (IV) approach to obtain the coefficient estimates for location-specific variables; and
(iii) manually inserting the estimated coefficients into the results of the first stage to portray endogeneity-corrected results.

According to Walker et al. (2011), the land-use shares in an area is socially influenced by land-use shares in adjacent zones, due to spatial continuity of social structures. Following Walker et al. (2011), an assumption of spatial continuity was made, and average land-use share in adjacent wards was defined as an instrument of land-use shares in the respective ward. Regarding agro-ecological conditions, the ward-level population density that was based on the 2011 population census data published by Statistics South Africa (2013), was used as an instrument for agro-ecological location. The instrumentation was based on a rich literature linking agro-ecological factors (e.g., productivity and proximate environmental hazards) to residential choices and human population density (Hunter, 2005; Vačkář et al., 2012). With six communities and two agro-ecological groups, 14 constants were estimated for these groups: six community-sugarcane constants, six community-timber constants, one agro-ecology-sugarcane constant (one group was constrained for identification), and one agro-ecology-timber constant (again, one group was constrained).

5. The data

The empirical investigations in the study were conducted in the Midlands region of KZN, an inland area stretching between the low-lying coastal strip of the Indian Ocean and the high altitudes of the Drakensberg escarpment. Around 80% of the 1.6 million inhabitants are small-scale farmers, the majority of whom are subsistence farmers engaged in maize production (Hitayezu et al., 2014). This region is a major hotspot of climate change in South Africa (Warburton et al., 2005). Whilst climate change is negatively affecting maize productivity (Abraha and Savage, 2006), it is turning the region into an optimum agro-ecology for sugarcane and forest plantation (Schulze and Kunz, 2010a, 2010b). Land-use conversion towards sugarcane and forestry is also driven by the land-use policies mentioned in the introductory section.

The land-use categories and salient LUFs that critically influence small-scale farmers' decision making (as mentioned in the previous section) were identified through a consultative process (Greiner and Ballweg, 2013). Based on the literature review, two long lists of agricultural land uses and LUFs were compiled. The lists were refined through a participatory rural appraisal (PRA) conducted in May 2013. This information allowed the authors to categorise agricultural land use into three areas:

(i) annual cropping (Ac), if the farmer continues to cultivate traditional annual crops such as maize, beans, potatoes and taro;
(ii) sugarcane farming (Sc), if the farmer has planted sugarcane; and
(iii) forest plantation (Tc), if the farmer has cultivated trees.

The salient beliefs about LUFs unveiled during the PRA phase comprised the five indicators of land-use sustainability in Table 1.

[Table 1 about here]

Based on the PRA information, 15 different questions about perceived outcomes of the three land uses were constructed for a structured survey questionnaire. Following Vagias (2006), Likert-type scale response anchors were provided for each question as follows: (1) extremely unlikely, (2) unlikely, (3) neutral/not sure (4) likely, (5) extremely likely. The "neutral" or "not sure" option was meant to reduce the cognitive burden to the interviewee, increase participation (i.e. reduce the problem of attrition), and reduce the problem of misreporting behaviours based on social desirability/sensitivity. For outcome beliefs, however, farmers were asked to provide their responses based on personal experience and available information from 2011, whilst the questionnaire recorded actual land-use choices in the 2012-2013 agricultural season. This technique further allowed the reduction of the scope of endogeneity with self-reported performances (Useche et al., 2009). The questionnaire also captured farmer, household and farm characteristics.

Focusing on the uMshwati Local Municipality, farm households were selected for survey interviews by using a stratified two-stage random sampling procedure. During the first stage, two clusters were selected, based on two contrasting homogeneous agro-climatic zones in the Midlands (see Table 2): *Mthuli* area in the wetter and hilly Windy Hill Mistbelt region, and *Gcumisa* in the warmer and dryer Wartburg/Fawnleas zone (Bezuidenhout and Gers, 2002). These two areas cover six wards with a high concentration of small-scale farming (see areas with downward diagonals in Figure 1). During the second stage, a simple random sampling was used to select interviewees, by using farmer lists provided by the agricultural extension officers in the respective areas. In order to account for the difference in the size of farmer populations in the two areas, farmers were randomly sampled with probability proportional to size. In total, 152 farmers were selected and interviewed during June and July 2013.

[Table 2 about here]

[Figure 1 about here]

Based on the household survey data, Table 3 shows the interviewed farmers' general belief that:

(i) annual crops demand more family labour and secure more food for the family;
(ii) adding sugarcane to the annual cropping portfolio increases crop productivity and farm income; and
(iii) planting trees reduces the demand for family labour and soil loss mitigation.

[Table 3 about here]

Table 4 shows that the majority of interviewed households were headed by women and 58 year-old farmers that had completed primary school (six years). An average household had five adult-equivalent members. The landholding size in the interviewed communities was positively skewed, with an average of 1.5 ha per household, and a minimum of 0.1 ha (mainly home gardens)[2] and a maximum of 10.5 ha. A farmer walked 12 minutes on average to arrive at the nearest tarred road and 43 minutes to arrive at the nearest river/dam. On average, a farmer believed that the majority of his neighbours are not trustworthy. About 62% of farmers in a ward had converted their land use, although, in some wards, all or none of the farmers had converted. The majority of interviewed

[2] Home gardens were mainly observed among sugarcane farmers. Such non-negligible boundary observations vindicate the adoption of discrete choice models prior to fractional analyses (Cook et al., 2008; Xiong, 2014).

farmers were located in the dryer Wartburg/Fawnleas agro-climatic zone.

[Table 4 about here]

6. The results and discussion

The results of the MMNL estimation are presented in Table 5. Model 1 presents the results without accounting for endogeneity, and Model 2 gives the results of the third step of the BLP procedure. In Model 1, three LUFs variables (crop productivity, food availability and labour requirement) have the expected signs. Crop productivity and food availability are significant indicators, suggesting that they are the most prioritised LUFs. The magnitudes of estimated coefficients suggest that crop productivity explains more of the heterogeneity in land use than labour availability. Farm income and soil loss mitigation do not have the expected signs, but their estimated coefficients are not significant in the model.

[Table 5 about here]

Most of the estimated coefficients of farmer, household, farm, social and locational characteristics have the expected signs. The exception is the coefficient of operated hectare on tree farming, although it is not significant. In Model 1, adult-equivalents and distance to road have negative and significant estimated coefficients in tree choice, whilst operated hectares and trust are positive and significant for sugarcane choice. The estimated coefficients of proportion of land-use changes in the ward and agro-ecology are also positive and significant for tree and sugarcane choices. However, the significant and negative coefficients of alternative-specific constants mean that unobserved factors reducing the preference for sugarcane and tree cultivation are not well explained by the socio-economic factors in the model.

As mentioned in the previous section, the proportion of ALUC in the peer group and agro-ecological effect are suspected to be correlated with the error term. This correlation could create inconsistency in the parameter estimates of these factors and potentially other variables in the model. The results of Model 2 in Table 5 represent the outcomes of the third step of the BLP approach. The results of the second stage are also presented in Table 6. They show that the instrumental variables (in Models 2a and 2c) worked well, as they are both significant and reflect the expected signs. The results in Table 5 show a decrease in the magnitude of the effect of ALUC proportions in the peer group and agro-ecological conditions (as estimated from Models 2b and 2d in Table 6). This outcome suggests that the parameter estimates of peer pressure and agro-ecological conditions in Model 1 were biased upward, overemphasising their actual affects. Nevertheless, the effects of both variables remain significant after correcting for endogeneity.

[Table 6 about here]

Most other parameter estimates and their significances did not change substantially as a result of BLP procedure. Exceptions are the increased significance of family labour employment, as well as the reduction in the significance of trust and distance to the road. These variables are affected probably due to their respective collinearity with peer group and agro-ecological conditions. The log-likelihood has obviously increased, as a large number of constants was estimated in Model 2.

The results of Model 2 in Table 5 suggest that social sustainability outcomes of land use dominate pure income generation and ecological incentives, these incentives being the frequent focus in agricultural policy in South Africa. This predominance of social motives over financial incentives, however, is not new in the ALUC literature (Purushothaman et al., 2013). The strong appeal for cropland productivity was also found in other study cases (Martínez-García et al., 2013). In the KZN Midlands, this strong appeal could be a reflection of the limited access to alternative livelihood assets in the region, as noted by a recent review by Hitayezu et al. (2014). Also, productive use of land is an important means of preserving land rights and ensuring tenure security in communal land areas in South Africa (Armitage et al., 2009; Cairns, 2000).

Food availability is also a priority function of land use in the KZN Midlands. This is partly because most households are producing mainly for their household consumption and not for the market. This finding is consistent with the results of other studies such as Purushothaman et al. (2013) in India. The critical importance of the food provisioning function of land use in the KZN Midlands is accentuated by other pillars of food security, such as food access and utilisation that are not manifest in the region. For example, Sinyolo et al. (2014) found that, on average, farm households spend only R5 990 (equivalent to USD550) per adult-equivalent per annum. Misselhorn (2009) also reported that small-scale farm households have lower scores of dietary diversity. Therefore, food availability is the backbone of food security in the region.

The stated preference for labour saving is also consistent with the findings of previous economic studies (Useche et al., 2009). The heightened demand for labour-saving land uses could be explained by the staggering emigration trends in the region. In the KZN Midlands, many economically active men leave communal land areas to work in major urban centres, leaving women, children and the elderly to work on the land (Hitayezu et al., 2014).

Interestingly, the fourth column of Table 5 shows that the standard deviation of the coefficient (St. Dv. β) is significant for some indicators, suggesting that the preferences for outcomes are heterogeneous and significantly different from the average preferences. These results show the extent to which diverse interests in LUFs create some trade-offs at household level. For example, although 82% of the farmers prefer labour-saving land use, the remaining 18% are willing to adopt labour-intensive land uses, provided they can secure other benefits such as food production or higher yield[3]. This trade-off explains the extent to which household-level agricultural land uses are often diversified.

The hypothesis that household size influences ALUC is confirmed for tree farming. In line with the Chayanovian model, the results infer that households engage in on-farm tree cultivation when their consumption needs are lower. Similar findings were reported in shifting cultivation in Brazil (Klemick, 2011).

Consistent with the findings of previous studies (Masuku et al., 2001), the results further suggest that the utility gained from planting sugarcane increases with farm size. This finding vindicates Just and Zilberman's (1983) ALUC model, showing that high fixed costs of sugarcane cultivation imply that only farmers owning large tracts of land would prefer to adopt sugarcane planting, since they are able to spread those costs and take advantage of economies of size. Previous studies (Mbowa and Nieuwoudt, 1998) have also documented the extent of economies of size in sugarcane plantation in South Africa.

The positive influence of proportion of ALUC in a farmer's peer group suggests that farmers benefit from the cumulative experience of other farmers in the community. This result is in line with the findings of various case studies cited in Foster and Rosenzweig (2010). This result is not surprising, given that timber and sugarcane farming are relatively new enterprises to the majority of small-scale farmers in South Africa. In many cases, the outcomes have been very uncertain, and many small-scale growers continue to lack the necessary managerial skills (Cairns, 2000; Dubb,

[3] The trade-off is calculated based on the normal distribution of the coefficient of the family-labour requirement (with a mean of -0.933 and standard deviation of -0.545). Following Hole (2007), the percentage of people preferring land-saving land use is obtained by multiplying the cumulated standard normal distribution with the ratio of 0.933/-0.545.

2014; Howard et al., 2005).

The finding that land-use change is controlled by agro-ecological conditions (e.g., rainfall variability, slopes, etc.) is not new. Similar findings are reported from other regions (Arslan et al., 2014; López and Sierra, 2010; Nahuelhual et al., 2012). Farmers in the Windy Hill Mistbelt region could face high costs intensifying with annual crop cultivation. Acute soil erosion due to the combination of steeper slopes and higher rainfall variability could also be more pronounced. Therefore, hilly and wetter regions provide fewer opportunities for alternative land uses.

7. Conclusions

The spatial expansion of small-scale and subsistent farming (often involving land-mining agricultural practices) in post-apartheid South Africa entails considerable detrimental environmental impacts that undermine the future productivity of land. However, empirical evidence on farm-level determinants of ALUC, needed to inform land-use policy in South Africa, remains scanty. Against this backdrop, this study was set out to investigate farmers' attitudes towards land-use change, and the constraints they face in their land-use decision-making process. To that end, this study employed a combination of SP and RP data collected in the Midlands region of KZN by means of a MMNL model.

After correcting for potential endogeneity in locational/spatial factors, the MMNL estimation results suggest that small-scale farmers prioritise higher crop yield, increased food availability and labour-saving functions of land use. The results also revealed a trade-off between the priority LUFs. The findings further suggest that the utility of planting sugarcane increases with farm size, whilst the preference for forest plantation decreases with household size. ALUC is also controlled by peer group influence and agro-ecological conditions.

These results can serve as guidelines for the development of more effective policy interventions to promote sustainable agricultural land use in the rural areas of South Africa, taking farmers' perceptions and needs into account. Aligning the private incentives with public goals would support the promotion of timber-based agro-forestry systems (agri-silviculture) as an alternative to the current timber monoculture. Policymakers should invest more efforts into research and extension of inter-crop systems that optimise both timber and food crop productivity, secure higher returns on labour, and maintaining the quality of the soil. The significantly negative effect of labour in the afforestation model infers that incentive-based schemes (e.g. payment for ecosystem services) should be designed on a per-capita or equivalent-consumption basis.

For a zoning approach to agricultural land-use planning, the significance of agro-ecology-fixed effects suggests that afforestation policies should target farmers in sloping landscapes or in areas with higher rainfall variability. For areas zoned for sugarcane cultivation, the significance of farm size underscore the relevance of strategies, such as land-use consolidation and cooperative farming. To leverage on the significance of peer group influence, a policy emphasis on innovation diffusion and community-based agricultural extension models (e.g. using farmer field schools) can be effective. Subsidising experimentation at village-level could reduce the scope of free-riding behaviour that can undermine the efficient provision of information on agro-forestry.

The empirical basis of these recommendations, however, needs to be reassessed. Although the BLP approach has helped correcting for the endogeneity bias pertaining to spatial factors, the endogeneity bias caused by biases in self-reported measures of outcome beliefs (e.g. attrition bias, misreporting behaviours based on social desirability/ sensitivity) remains at large. A formal test for such non-negligible endogeneity requires techniques, such as multiple imputations that use auxiliary or longitudinal data, which is an important avenue for future research.

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Table 1. Indicators of perceived farm-level sustainability impacts of ALUC in the KZN midlands

Sustainability dimension	Land-use function	Indicator
Economic sustainability	Economic production	Farm income generation (Y)
	Land-based production	Crop productivity/suitability (Q)
Social sustainability	Food security	Food availability (F)
	Provision of work	Family labour employment (L)
Ecological sustainability	Provision of abiotic resources	Soil loss mitigation (S)

Source: Authors' PRA (2013)

Table 2. Characteristics of agro-ecological zones in the uMshwati Local Municipality, South Africa

Zone	Area (km^2)	Mean annual solar radiation ($MJ.m^{-2}$)	Mean annual heat units (°C.d.)	Mean annual precipitation (mm)	Mean coefficient of variation (%)
New Hanover	458	8095	2760	977	5.0
Wartburg/Fawnleas	561	7890	2772	867	2.4
Windy Hill Mistbelt	244	7720	2668	981	5.3
Hilton / Umgeni Valley	174	8001	2970	892	2.2

Source: Extracted from Bezuidenhout and Gers (2002)

Table 3. Descriptive statistics for attitudinal data used in the MMNL model

Outcome beliefs (LUF indicators)	Mean	Std. Dev	Min	Max
Farm income generation from Ac	1.203	0.648	1	3
Farm income generation from Sc	3.532	0.585	1	5
Farm income generation from Tc	1.815	0.493	1	4
Crop productivity from Ac	1.421	0.776	1	4
Crop productivity from Sc	3.572	0.705	1	5
Crop productivity from Tc	1.519	0.660	1	4
Food availability from Ac	4.131	0.903	2	5
Food availability from Sc	1.756	0.983	1	5
Food availability from Tc	2.003	0.908	1	4
Family labour employment from Ac	3.943	1.006	2	5
Family labour employment from Sc	1.45	0.823	1	5
Family labour employment from Tc	1.015	0.937	1	2
Soil loss mitigation from Ac	1.776	0.621	1	3
Soil loss mitigation from Sc	2.065	0.547	1	3
Soil loss mitigation from Tc	4.559	0.638	3	5

Note: number of observations (n) = 152
Source: Authors' survey data (2013)

Table 4. Descriptive statistics for structural variables used in the MMNL model

Structural variable	Variable/value description	Mean	Std. Dev	Min	Max
GENDER	1=Female-headed household; 0=otherwise (dummy)	0.532	0.400	0	1
AGE	Age of the household head in years (continuous)	58.940	12.834	33	88
EDUCATION	Years spent by the household head in the formal education system (continuous)	6.552	3.951	0	16
ADULTS	Number of adult-equivalent members of the household (count)	5.105	2.591	1	13.481
LAND	Total operated area in hectares (continuous)	1.596	1.515	0.1	10.5
ROAD	Minutes taken on arrive at the nearest tarmac road (continuous variable)	12.559	17.735	0	120
WATER	Walking distance (in minutes) to the nearest river/dam (continuous)	43.723	32.725	0	240
TRUST	1= don’t trust anyone, 2= the majority are not trustworthy, 3=the majority are trustworthy, 4=everyone is trustworthy (categorical)	2.743	0.766	1	4
PROPORTION	Proportion of interviewed households that have cultivated sugarcane or trees in a ward	0.62	0.31	0	1
AGRO-ECOLOGY	1 = Windy Hill Mistbelt agro-ecology (Mthuli); 0 = Wartburg/Fawnleas agro-ecology (Gcumisa) (Dummy)	0.243	0.430	0	1

Note: number of observations (n) = 152
Data source: Household survey data (2013)

Table 5. Mixed multinomial logit (MMNL) estimation results, uMshwati local municipality, 2013

	Model 1 (without accounting for endogeneity)		Model 2 (corrected for endogeneity)			
	Average β	S.E.	Average β	S.E.	St. Dv. β	S.E.
Preferences for attributes (LUFs)						
Farm-income generation	-0.029	(0.939)	-0.035	(0.943)	-0.039	(1.327)
Crop productivity	2.546***	(0.570)	2.500***	(0.566)	2.063***	(0.690)
Food availability	0.272**	(0.136)	0.281**	(0.132)	0.641**	(0.251))
Family labour employment	-0.172	(0.108)	-0.193*	(0.112)	-0.453**	(0.202)
Soil-loss mitigation	-0.658	(1.308)	-0.745	(1.299)	-0.125	(1.311)
Intrinsic utility effect of farmer, household, farm and locational characteristics						
GENDER (Sc)	-0.590	(0.422)	-0.606	(0.431)	–	–
GENDER (Tc)	1.139	(0.900)	1.104	(0.882)	–	–
AGE (Sc)	0.030	(0.022)	0.028	(0.021)	–	–
AGE (Tc)	0.048	(0.050)	0.043	(0.047)		
EDUCATION (Sc)	0.087	(0.059)	0.079	(0.055)	–	–
EDUCATION (Tc)	0.108	(0.121)	0.098	(0.119)	–	–
ADULTS (Sc)	0.099	(0.859)	0.102	(0.823)	–	–
ADULTS (Tc)	-0.429**	(0.218)	-0.488**	(0.225)	–	–
LAND (Sc)	1.005***	(0.117)	0.996***	(0.113)	–	–
LAND (Tc)	-1.301	(0.873)	-1.327	(0.880)	–	–
ROAD (Sc)	-0.192	(0.741)	-0.200	(0.749)	–	–
ROAD (Tc)	-0.131*	(0.079)	0.127	(0.086)	–	–
WATER (Sc)	-0.111	(0.081)	-0.119	(0.077)	–	–
WATER (Tc)	0.315	(0.203)	0.307	(0.199)	–	–
TRUST (Sc)	1.029*	(0.620)	1.007	(0.618)	–	–
TRUST (Tc)	0.278	(0.773)	0.254	(0.769)	–	–
Location-specific effects						
PROPORTION (Sc & Tc)	2.425***	(0.151)	1.290**	(0.645)	–	–
AGRO-ECOLOGY (Sc & Tc)	3.792***	(0.896)	0.668*	(0.403)	–	–
Alternative-specific constants						
Sc	-5.559**	(2.822)	–	–	–	–
Tc	-3.293*	(1.996)	–	–	–	–
Number of estimated location-specific constants	–		14			
Number of cases (= n x 3)	456		456			
Log-likelihood at convergence	-42.603		-37.152			

Note: *** = significance at 1% level, ** = significance at 5% level, * = significance at 10% level
Data source: Authors' survey data (2013)

Table 6. Second stage of BLP approach (two-step IV regression)

Model 2a (Dependent variable: Proportion of ALUC in a ward)			Model 2c (Dependent variable: location in Windy Hill Mistbelt agro-ecology)		
	β	S.E.		β	S.E.
Intercept – sugarcane plantation	-0.109	0.182	Intercept – sugarcane plantation	1.873*	0.101
Intercept – tree plantation	0.187**	0.098	Intercept – tree plantation	0.914***	0.293
Average proportion of ALUC in surrounding wards	0.745***	0.275	Ward's population density	-0.009***	0.003
Adjusted R Square	0.559		Adjusted R Square	0.967	

Model 2b (Dependent variable: Ward - specific constants)			Model 2d (Dependent variable: Market specific constants)		
	β	S.E.		β	S.E.
Intercept – sugarcane plantation	0.201**	0.099	Intercept – sugarcane plantation	-0.455	1.123
Intercept – tree plantation	0.087*	0.051	Intercept – tree plantation	0.097	0.769
Fitted value of proportion of ALUC (from model 2a)	1.290**	(0.645)	Fitted probabilities for locating in Windy Hill Mistbelt agro-ecology	0.668*	(0.403)
Adjusted R Square	N/A		Adjusted R Square	N/A	

Note: *** = significance at 1% level, ** = significance at 5% level, * = significance at 10% level number of observation n=152.

Data source: Household survey data (2013)

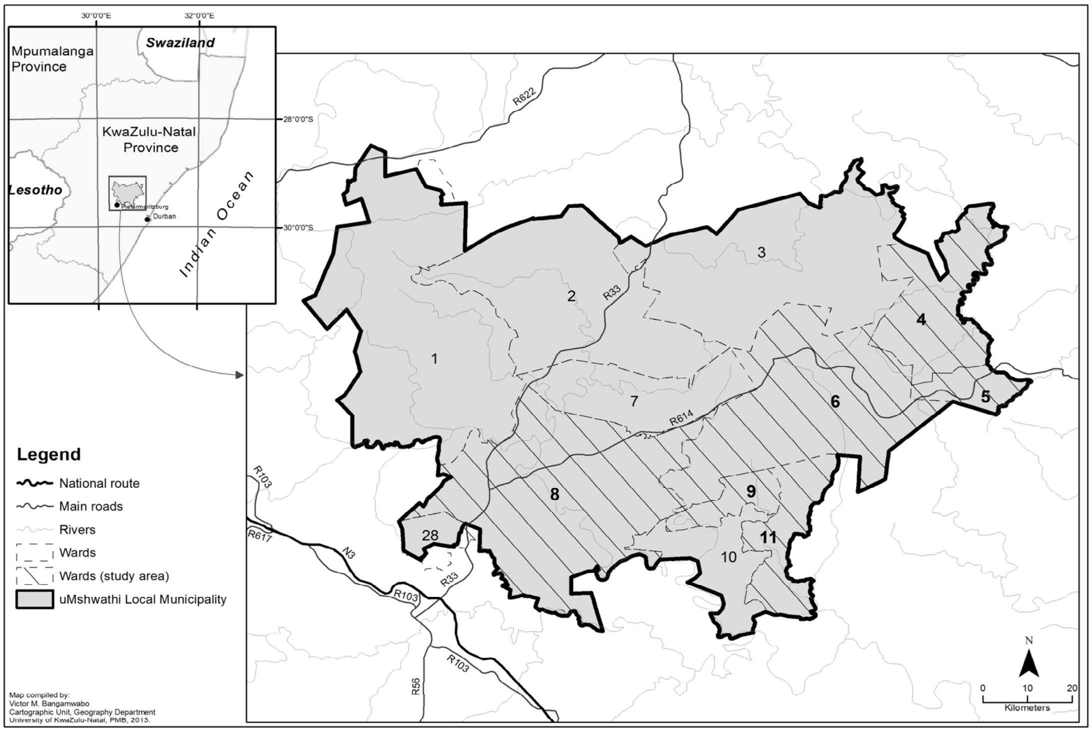

Figure 1. Administrative map of uMshwathi local municipality, South Africa, showing sampled wards

Source: Based on shapefiles provided by Municipal Demarcation Board (http://www.demarcation.org.za/)