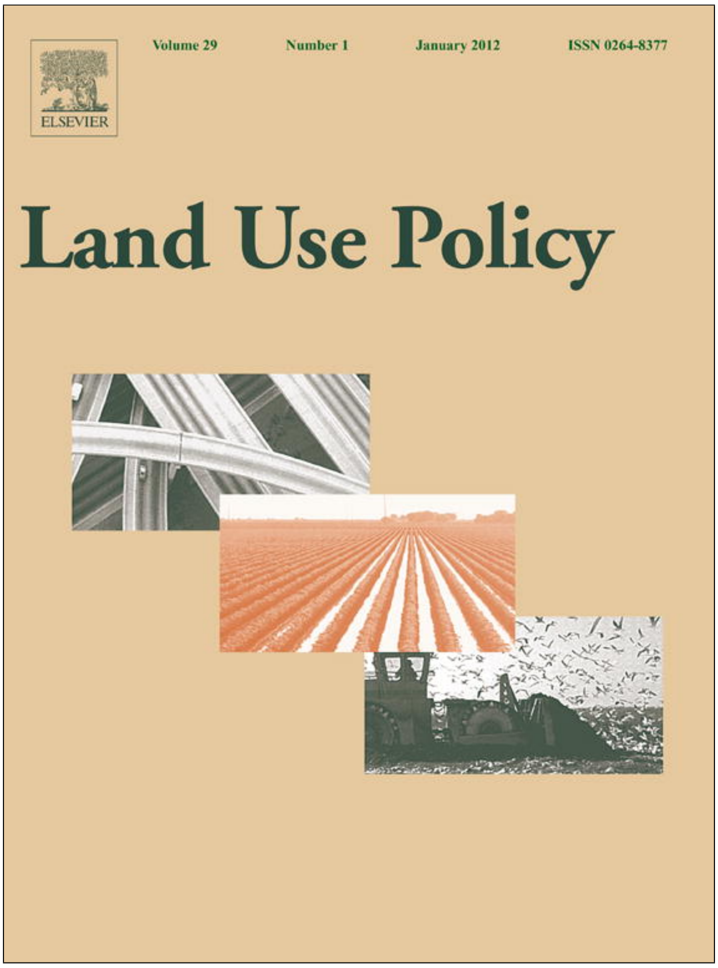
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Factors influencing the use of alternative land cultivation technologies in Swaziland: Implications for smallholder farming on customary Swazi Nation Land

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ABSTRACT

Poor land preparation and late planting are among the factors responsible for the decline in food production on customary Swazi Nation Land (SNL). While efforts are being made to develop an improved national land cultivation programme, this process can be helped by identifying factors that influence farmers to use alternative technologies for land cultivation. Using cross-section data collected in 2009 from a random sample of 210 farmers in Komati, three land cultivation technologies were identified; (i) use of tractors; (ii) use of draught animals; and (iii) use of hand hoes. For a country like Swaziland where human health problems, particularly HIV/AIDS, make manual labour a scarce resource, the use of tractors is regarded as a modern technology that can achieve time and labour savings. The empirical evidence from this study indicates that the use of tractors is significantly influenced by household wealth and size of arable land used by households. However, given that land holdings on customary land are generally small, sparsely distributed and often fragmented, tractor hire service providers face relatively high overhead and transaction costs. Furthermore, investment in mechanised farming by individual SNL households is constrained by the lack of secure tenure. Given these challenges, this study makes recommendations for creating an enabling environment that could promote the adoption of improved land cultivation methods by smallholders on customary SNL.

Introduction

Apart from using tractors for land cultivation, Swazi farmers have been using draught animals (mainly oxen) for many years. Animal traction was initially introduced as an alternative to hand hoes to boost the production of crops while the adoption of improved technology was still at an early stage (Shields et al., 1993). Farm power in African agriculture, especially in Sub-Saharan Africa (SSA), relies to a larger extent on human muscle power, as it is based on operations that depend on hand tools (Mrabet, 2002). However, such tools have implicit limitations in terms of energy and operational output. The use of hand hoes and animal draught power may not be suitable for a country like Swaziland where constraints such as human health problems, particularly HIV/AIDS, and demographic shifts make manual labour a scarce and weak resource (Muwanga, 2002). As a consequence of HIV-related morbidity and mortality, 38.5% of rural households have reduced their area under cultivation, 42% have experienced a change in cropping patterns and 47% a decline in crop yield. In addition, 31% have experienced a diversion of labour to take care of the sick while 39% have experienced a loss of off-farm income (Food and Agriculture Organisation/World Food Programme (FAO/WFP), 2007).

While tractors began to be used by native Africans from around 1945 (Pingali, 2007), this technology was introduced in Swaziland in 1971 through a government initiative known as the Rural Development Area Programme (RDAP) (Funnell, 1982). In line with the national policy of food self-sufficiency (Terry and Ryder, 2007), the aim of the RDAP was to raise the level of food production and consumption for rural households. Prompted by concerns that (1) land tillage was poorly done by farmers on customary Swazi Nation Land (SNL); (2) oxen could not be used on time due to their weakness soon after the winter season, resulting in late planting; and (3) farmers needed knowledge on how best crop production could be achieved with the use of mechanical power, a tractorisation programme was introduced as one of the key components of the RDAP (Government of Swaziland (GoS), 1993). Although the tractorisation programme was initiated for demonstration purposes, the government, prompted by the benefits of the technology, opted to provide this service to customary SNL farmers who could not afford to pay for services provided by the private sector (GoS, 1993). This inadvertently led to the establishment of the Tractor Hire Service (THS), which has hire pools in 20 centres. More than 95% of the 233

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tractors in these centres were supplied by the Japanese government under the 2KR programme[1] (GoS, 2005). Tractors available in these centres are of the medium-size conventional type (40–80 horsepower), the category recommended for local conditions (see FAO, 1981). Despite such assistance, the number of tractors is still very low as farmers from customary SNL still experience delayed soil tilling and often complain that tractors are not available when required (GoS, 2007).

The Swaziland government has realised that managing the THS is not economical, as its subsidisation can no longer be sustained by already constrained public resources. Government hire charges, in nominal terms, have remained unchanged for a number of years and besides being about 48% below charges from the private sector, they are far below 'break-even' charges (African Development Bank (ADB), 1989; GoS, 2005). Government tractors charge 130 Emalangeni[2] (E) per hour, whereas private operators charge on average E250 per hour. The inability of the government to finance the regular service, procurement of fuel, and permanent employment for tractor operators has negatively affected the sustainability of the programme and food production in the rural areas (GoS, 2007). It is against this background that the National Agriculture Summit in 2007 called for the privatisation of the THS to try and provide farmers with the best service as and when required (GoS, 2007). While the call for privatising the THS holds, the Ministry of Agriculture is also expected to develop and implement a programme for promoting the use of animal traction as a strategy to reduce agricultural production costs. The animal traction programme is a regional initiative that emanates from the 2004 Southern African Development Community (SADC) declaration on agriculture and food security (SADC, 2004).

In order to develop a strategy that will synchronise both the use of tractors and animal draught, it is important that programme implementers in Swaziland first identify factors that influence farmers' decisions to use alternative technologies for land cultivation. Although various methodologies have been applied in past studies, a review of the literature shows three key factors that influence farmers' choices between tractors and animal draught power; household income or wealth (e.g., Low, 1986; Pingali et al., 1987; Williams, 1997), size of cultivated land (e.g., Akinola, 1987; Shields et al., 1993; Van den Berg et al., 2007) and the number of draught animals owned by the household (e.g., Mbata, 2001). Establishing the economic role of these factors in the Swaziland context would enable policy makers to decide which types of farmers to target for either tractorisation or use of draught animals.

The objective of this study, therefore, is to examine the factors that influence the choice of cultivation methods by smallholder farmers on customary SNL, using maize as a reference crop. Maize is Swaziland's staple crop and is produced by over 90% of smallholder farmers (Food, Agriculture and Natural Resource Policy Analysis Network (FANRPAN), 2003; Terry, 2007). The importance of maize to the livelihoods of rural producers in Swaziland is highlighted in Rauniyar and Goode (1996), while Peter et al. (2008) noted that apart from sugarcane, which is produced in large areas through farmer associations, individual farmers on SNL in the Komati Downstream Development Project (KDDP) produce maize as their main household agricultural enterprise. Hence, this study is based on farmers located in the KDDP, which falls within the Lowveld, one of Swaziland's driest and poorest agro-ecological zones (FAO, 2008). The Swaziland government commissioned the KDDP in 1999 as an innovative development intervention aimed at increasing rural living standards, using water from Maguga dam.

A socio-economic survey conducted in 2009 (Swaziland Water and Agricultural Development Enterprise (SWADE), 2009) indicated that farmers in the KDDP use tractors, draught animals or hand hoes as alternative means of land cultivation. Apart from Low (1986) and Shields et al. (1993), who studied factors that influence the use of tractors as opposed to oxen in Swaziland, to the authors' knowledge, no empirical study has been conducted which considers the use of hand hoes as a third alternative means of land cultivation in Swaziland. More importantly, these studies did not make recommendations to address the current research problem. This study also differs from previous research (e.g., Akinola, 1987; Mbata, 2001) by focusing on farmers who produce irrigated and non-irrigated maize.

The KDDP farmers are not the only smallholder farmers in Swaziland affected by major investment made by the government to try and improve rural livelihoods and food security through irrigated farming (Atkins, 1999; Terry and Ryder, 2007). For instance, Lavumisa and Siphofaneni are among other rural areas where farmers have an option to produce irrigated maize and other crops. Development in Siphofaneni is currently the largest investment covering 11,500 ha of irrigated land, which is almost twice the size of KDDP. Although sugarcane is the main crop produced in these areas (through farmer associations), part of the land is still used by individual households just like in any other rural setting on SNL to produce food crops (Peter, 2011). With more resources being committed towards expanding smallholder irrigation agriculture in Swaziland, and the Southern African region at large (see SADC, 2009, 2010), it would be remiss of current researchers to make policy recommendations without considering such developments. For this reason, the lessons drawn from this study may not only apply to the Swaziland situation, but the Southern African region at large where similar irrigation projects are being implemented.

The rest of the paper is organised as follows: The next section discusses the land tenure system in Swaziland, followed by a review of the literature related to land cultivation technology adoption. The third section presents the methodology, which outlines the sampling method, data collection procedure and empirical model. Empirical results are presented thereafter followed by conclusions and policy recommendations.

Land tenure system in Swaziland

Past studies (e.g., Feder and Onchan, 1987; Smith, 2004; Deininger and Jin, 2006) have shown that property rights which govern the use of a particular plot of land affect farmers' adoption and subsequent use of different technologies on that land. This section presents an overview of the land tenure system in Swaziland, highlighting the distinctive attributes of customary SNL compared to other forms of tenure.

The present land tenure system in Swaziland has been shaped by national decisions made since 1875 (see Simelane, 1991; Mhlanga et al., 1998). While there is considerable evidence that the land tenure system has a substantial impact on the ability of rural-based smallholder farmers to increase agricultural production, no meaningful efforts have been invested in the task of providing solutions (Hughes, 1962; Mkhabela, 2006). Attempts to formulate a national land policy, which began in 1993, have not yielded results thus far, implying that agricultural problems linked to the land tenure system will continue. Table 1 shows that the land tenure system in Swaziland is characterised by three main types; Title Deed Land (TDL); SNL and Crown land. The TDL, which accounts for about 25%, can be held by freehold or concession. However, since the

[1] This is a grant assistance programme provided by the Government of Japan to developing countries. The 2KR programme was started in 1977 with the purpose of assisting underprivileged small-scale farmers improve food production by providing agricultural machinery.

[2] "E" denotes Emalangeni, the Swaziland currency. 1US$ = E8.31 in 1st October 2012 (Central Bank of Swaziland, 2012).

Table 1
Land tenure types in Swaziland.

Land tenure type	Percentage of total land	
SNL		
Leased to private companies and estates	6.5	
Under Ministry of Agriculture	6.8	
Under National Trust Commission	2.6	
Under Tibiyo/Tisuka TakaNgwane	2.9	
Customary land under chiefs	49.6	74.2
TDL		
Urban area	0.7	
Rural area	24.4	25.1
Crown land	0.4	0.4
Water reservoirs	0.2	0.2
Total	100	100

Source: Swaziland Environment Authority (SEA) (2002).

inception of Swaziland's Constitution in 2005, all concessions are vested in the King in trust for the nation. Crown land, the smallest (0.4%) category of land tenure, is land owned by government. It is mainly used to construct public structures, including offices and residential houses for public servants (Armstrong, 1986).

The SNL, which accounts for about 74% of total land area, is divided into three sub-categories, all registered in the King's name in trust for the nation. The first category, which covers about 7% of total land, is leased to large private companies (mainly of foreign origin) engaged primarily in agribusiness and timber production. This land is characterised by a large number of highly capital intensive and well managed estates which specialise in export commodities such as sugarcane, pineapple, citrus, beef, dairy, poultry and timber. Agricultural production in this category provides the basis for most of Swaziland's manufacturing activity.

The second category of SNL, which accounts for 12% of total land area is land that was reclaimed by Swazis from concessionaries through land purchase programmes, implemented before and after independence in 1968 (see Levin, 1997; Mhlanga et al., 1998). Instead of being used for human settlement under traditional control of chiefs, this category of SNL was allocated for agricultural and conservation programmes implemented by the Ministry of Agriculture and the National Trust Commission, respectively. Land under the Ministry of Agriculture is used for crop demonstration purposes and the management of livestock 'sisa' and fattening ranches. These livestock programmes were initiated for the purpose of improving livestock breeds while relieving grazing pressure on communal lands. Other agricultural projects are implemented by Tibiyo and Tisuka TakaNgwane, two investment corporations established by the King in 1968 to complement Government's national development efforts (Armstrong, 1986; Terry, 2007). Tibiyo and Tisuka TakaNgwane have also invested in a number of private companies, including sugar estates and sugar mills in Swaziland.

The third category of SNL, which comprises about 50% of total land area, is held under customary tenure and contains the majority of the rural population. The King is technically the ultimate authority regarding land distribution, but in practice this power is vested in the subordinate territorial authorities who are the local chiefs. Land on customary SNL is acquired through inheritance or the traditional practice of *kukhonta*, whereby the male head of a household pledges allegiance to the chief and, in return, is given a piece of land to build homestead structures, a field to cultivate crops and access to communal grazing land. The acquired land cannot be bought, mortgaged, leased or sold. Once an individual has been allocated land, he is allowed to pass it on to his children. Households can only use the land, but do not own it, implying a lack of secure tenure. The chief has the power to allocate land, but he also has the power to take it away from an individual. Households are also occasionally resettled by the chief, especially in favour of community development projects (Armstrong, 1986). Although the chief rarely exercises the power of banishment, both banishment and the threat of resettlement can instill a sense of insecurity among community members and may act as a constraint on investments that might increase land productivity (Mkhabela, 2006).

One of the most common criticisms of customary tenure is the lack of immovable assets to pledge as collateral for loans, which constrains access to commercial credit, and hence to investment and productivity increases (Mkhabela, 2006; Pingali, 2007). The very low contribution of customary SNL to Swaziland's annual GDP has been a concern even before independence in 1968 (Hughes, 1962; Terry, 2007). Maize is the leading crop and over 80% of locally produced maize comes from farmers located in such areas (FANRPAN, 2003). Other major crops include cotton and legumes. Farmers living on customary SNL also account for about 81% of the total cattle herd in Swaziland (Mkhabela, 2006). The average land holdings are small (1.94 ha) (Terry, 1997), sparsely distributed and often fragmented. As a consequence, farmers travel considerable distances to cultivate their land. This travel time has a negative effect on utilisation efficiency, regardless of whether the farmer uses human, animal or mechanical power (FAO, 1981).

Considering Swaziland's increasing population and the land acquisition process on customary SNL, it is difficult to visualise how the current generation will be able to further subdivide land for future generations and produce enough to attain food self-sufficiency or at least generate substantial farm income. As the land becomes more fragmented, the implications for the promotion and adoption of improved land cultivation methods must be considered, particularly as manual labour to drive draught animals and use hand hoes may not be a sustainable option for a country that is affected by human health problems. The following section discusses other important factors that may influence the use of different land cultivation methods by smallholder farmers.

Factors affecting the choice of land cultivation technology

Comparing the use of tractors and animal draught power, the former can be regarded as a modern technology that can be used for power-intensive farm operations (Pingali et al., 1987). Tractors are known to achieve the greatest savings in terms of time and labour, but with relatively substantial expenses (Gosh, 2010). Although most farmers wish to benefit from tractorisation, this is often an unrealistic expectation for rural-based, resource-poor farmers (Lawrence and Pearson, 2002). Gosh (2010) argues that individual tractor ownership is seldom possible for farmers with small areas of cultivation, and as such, tractors tend to be more appropriate for large-scale commercial farming (Van den Berg et al., 2007). However, considering the issue of timeliness and improved cultivation for the purpose of increasing productivity, the use of tractors can benefit both smallholder and large-scale producers alike (Pingali, 2007).

Although the incorrect use of cultivation methods has the potential to destroy soil structure and sometimes lead to degradation (Islam and Weil, 2000; Holland, 2004), the aim of cultivation is to turn the soil into a fine tilth in order to enhance seed germination and root development. Cultivation can also improve soil moisture retaining capacity (Gupta et al., 2010) and weed management (Boydston and Vaughn, 2002), and reduce the incidence of soil-borne diseases. These diseases can be problematic in soils where crops are planted using conservation tillage,[3] particularly

[3] The classical definition of conservation tillage is any tillage operation which leaves a minimum of 30% of the soil surface covered with crop residues (Kassam *et al*., 2009). This results in planting or sowing through the previous crop's residues that are purposely left on the soil surface. Conservation tillage is a component of

direct drilling or zero tillage (Bockus and Shroyer, 1998). Conservation tillage, however, has the potential to increase soil organic matter content and enhance soil aggregation, creating a fertile surface layer that reduces soil erosion (Mrabet, 2002).

Several factors do, however, confer a great deal of comparative advantage on the use of animal traction in SSA. First, because most farmers are engaged in mixed farming, livestock production forms an integral part of their farming system (O'Neill et al., 1999). This means that animal power would be readily available as an alternative and relatively lower cost source of draught power. Secondly, because animal-drawn implements can be manufactured relatively easily by rural dwellers, they are less capital-intensive and, therefore, could become a source of increased economic activity for the poor rural-based dwellers (Mbata, 2001). They also have the added advantage of providing a less expensive source of fertiliser in the form of organic manure, which is more environmentally friendly than inorganic fertilizers (Guthiga et al., 2007). Furthermore, cattle can provide households with meat, milk and skins (O'Neill et al., 1999) and act as a store of wealth for the household (Doran et al., 1979). Despite having some advantages, cattle may also become a drain on producers' resources, especially during times of disease outbreaks or drought (Pearson, 1993; Teweldmehidin and Conroy, 2010).

Past studies have shown that having substantial levels of income or wealth may enable farmers to meet capital costs required to use improved technology such as tractorisation (Pingali et al., 1987; Williams, 1997; Savadogo et al., 1998). Given the importance of household income or wealth, and the disproportionate distribution of productive assets among households within a community, adoption behaviours are expected to differ across socio-economic groups. Phiri et al. (2003) concluded that within a given farming community, households with relatively more wealth are most likely to adopt new technologies because of their relatively secure economic positions and better capacity to absorb potential risk. Low (1986) and Shields et al. (1993) argue that increasing off-farm job opportunities and wage rates could incentivise household members to seek and adopt time-saving crop production technologies such as the use of tractors for land cultivation as opposed to using animal draught power or hand hoes, both of which are time consuming. Therefore, with a comparatively high off-farm wage, a household could either own a tractor or afford to pay other providers for tractor services.

The size of arable land cultivated has also been identified as an important factor which influences the farmer's ultimate technology adoption decision (Gosh, 2010). Additional fixed costs associated with tractorisation often impede adoption on smaller farms, as low levels of output lead to higher average fixed costs (Akinola, 1987). Thus, larger farms are able to spread fixed costs over a greater number of units of output and are more likely to use tractors for cultivation than smaller farms (Van den Berg et al., 2007). Another important finding (O'Neill et al., 1999) is the positive relationship between the number of work animals and the likelihood of using animal traction technology. Farmers who own a relatively large number of work animals are more likely to use animal traction than any other technology (Mbata, 2001). The next section presents the sampling methods and empirical model used to analyse the influence (if any) of the factors discussed above on the choice of land cultivation methods by maize producing households in Komati.

conservation agriculture (CA), one of the technologies used to mitigate the effects of climate change in developing countries. Other components of CA include the maintenance of permanent soil cover and practicing crop rotation. In Swaziland, CA was introduced in 2003 with the support of government and non-governmental organisations.

Methodology

Sampling and data collection

The study used a database developed by SWADE from a socio-economic survey conducted in the Komati area in July 2009. The overall objective of this survey was to assess whether the livelihoods of rural households living in the Komati area had changed since the KDDP was commissioned in 1999. Using a list of households (the unit of enumeration) located within the Project Development Area (PDA), random and systematic sampling techniques were applied to draw a 20% sample from the total population of 3997 households. For the nine PDA communities, one random number between one and five was generated per community, and subsequently used as a starting point for a systematic sampling of every fifth household in the list until 798 households were sampled.

Information from respondents was gathered using a questionnaire through direct interviews with household heads. Questions were designed to obtain data on household demographics, health and nutrition, agriculture, poverty and behavioural issues. Using the database generated from the nine communities, this study randomly selected Malibeni, which had 210 respondents, to study the socio-economic factors which influence the choice of land cultivation technologies used by households. This relatively homogeneous area was considered appropriate, as selecting one community was expected to reduce the effects of uncontrollable factors on the choice of land cultivation technology. These factors, which include topography, slopes, soil types and rainfall patterns (see Logan et al., 1991), may influence the selection of alternative cultivation methods in a particular area.

Empirical model

Rogers (2003) describes an innovation (or improved technology) as a new idea, object or practice introduced in response to a certain need. The use of tractors for land cultivation in Swaziland, therefore, is conceptualised as improved technology because of its ability to achieve time and labour savings. Given that the study sample has three distinct categories of the dependant variable (cultivation methods), a Multinomial Logit (MNL) model was used for analysis. The MNL is commonly used for analysing polychotomous choice options and is popular among researchers because of its ease of estimation and interpretation (Long, 1997).

Let P_j denote the probability associated with the choice of cultivation technology by the ith farm household with $j = 1$ if the farm household uses a tractor, $j = 2$ if the farm household uses animal draught power, and $j = 3$ if the household uses hand hoes. The MNL model (Long, 1997) is given by:

$$P_{ij} = \frac{e^{(\beta x_{ij})}}{\sum_{j=1}^{3} e^{(\beta x_{ij})}} \tag{1}$$

where β represents the parameters to be estimated and x_{ij} represents the set of explanatory variables. The use of tractors was selected as the reference category in the MNL as it was the most common means of land cultivation for the interviewed households (see Section "Descriptive statistics for variables used in the MNL model"). Setting the βs to zero for the base category, the conditional probability of a household using any of the three cultivation technologies (Long, 1997) is expressed as:

$$P(j = 1|x_i) = \frac{1}{\sum_{j=1}^{3} e^{(\beta x_{ij})}}$$

and

$$P(j \geq 2|x_i) = \frac{e^{(\beta x_{ij})}}{\sum_{j=2}^{3} e^{(\beta x_{ij})}} \quad (2)$$

The model parameters were estimated using the method of maximum likelihood where the marginal effects of the explanatory variables on the probability of a household being in one of the three categories (see Long, 1997) were computed as:

$$\frac{\partial P_j}{\partial x_i} = P_j = \left[\beta_{ij} - \sum_{k=0}^{J} P_k \beta_k\right] = P_j[\beta_j - \bar{\beta}] \quad (3)$$

Although the MNL is relatively easy to estimate and interpret, its major disadvantage is the inherent assumption of the independence of irrelevant alternatives (IIA) (Amemiya, 1985). This assumption requires that the inclusion or exclusion of any category (e.g., use of hand hoes) does not affect the relative risks associated with the regressors in the remaining categories (use of tractors and animal drought power). The Hausman test (see Hausman and McFadden, 1984) was performed to check whether or not the IIA assumption was violated in this study. The process involves estimating a full model that includes all j categories and a restricted model where one category is eliminated. A statistically significant difference between the two models' estimates would indicate a violation of the IIA assumption. In this case, the null hypothesis of independence could not be rejected as the difference between the full and restricted models' estimates [$\chi^2 = 0.31$ (10 degrees of freedom)] was not statistically significant ($p > 0.1$), suggesting that the use of MNL was appropriate. Based on field observations and the factors identified in Section "Factors affecting the choice of land cultivation technology", the following explanatory variables were specified in the MNL model to analyse whether they influence the choice of land cultivation technology by smallholder maize farmers in the KDDP:

Age: Younger smallholder farmers are expected to be relatively more progressive and receptive to new ideas, and perhaps better understand the potential benefits of mechanised farming (Sanni, 2008). In most cases, older farmers tend to view farming as a way of life and have a strong emotional connection with the use of traditional farming methods (Akinola, 1987). Age was included in the model as a continuous variable.

Gender: The general belief is that African women play a prominent role in agriculture; hence, they are relatively more receptive to innovations than men (Chipande, 1987). However, Doss and Morris (2001) found that farmers' production decisions depend primarily on access to resources rather than on gender per se. If, for instance, the use of tractors depends solely on knowledge gained through training, and if in a particular community only men are permitted to undergo training, then in that context the use of tractors will not benefit men and women equally. To study whether gender has an effect on the choice of land cultivation technology, the variable was captured as a dummy where males were accorded a value of one and females zero.

Level of formal education: Without ignoring the importance of indigenous knowledge, the level of formal education attained is used as a proxy for the farmer's ability to acquire and effectively use information gathered from different sources (Strauss et al., 1991). Human capital is an important asset influencing technology adoption and an educated farmer is more likely to accept new agricultural innovations (Rahm and Huffman, 1984). The assumption is that education facilitates learning, which in turn is presumed to instil a favourable attitude towards the use of improved farm practices (Singh, 2000). Given that over 65% of the respondents hardly went beyond primary education, this variable was captured as a dummy where household heads with at least primary education have a value of one, and for those who did not reach this level, a value of zero.

Number of oxen: A positive relationship is expected between the number of work animals owned and the likelihood of using animal traction technology. Farmers who own a relatively large number of oxen find it relatively cheaper to use animal traction than any other technology (Mbata, 2001). The number of draught animals was captured as a continuous variable.

Household labour availability: Land cultivation using either draught animals or hand hoes requires relatively more labour units. Therefore, households with a relatively large number of household members (in man-equivalents) are more likely to use either draught power or hand hoes for land cultivation (Savadogo et al., 1998). Following Langyintuo and Mungoma (2008), man-equivalents were computed as follows: household members less than 9 years = 0; 9–15 = 0.7; 16–49 years = 1; above 49 years = 0.7. The concept of man-equivalents was adopted to account for labour contribution differences among the different household members (Eicher and Barker, 1992), particularly with the use of hand tools or implements (Rwelamira, 1990). The inclusion of all household member categories (even school-attending children) is based on the general observation in rural Swaziland that most production activities (ploughing, weeding and harvesting) are performed in the early hours of the day. Children who attend school normally participate in these activities, only to be released by their parents or guardians to attend classes during school hours.

Size of arable land: This variable refers to the total area of arable land (hectares) that a household uses to produce maize. The use of maize area (instead of total arable land) in the MNL was influenced by the observation that maize was produced by every respondent and occupied over 80% of total arable and cultivated land. This also made it easier to study farmers' choices of cultivation technologies in producing the same crop. Additional fixed costs associated with use of improved technologies impede adoption on smaller farms, as low levels of output lead to higher average fixed costs. Thus, larger farms can spread fixed costs over more units of output and are more likely to use tractors compared to smaller farms (Van den Berg et al., 2007).

Access to irrigation: Although this variable has not been used widely in similar studies, research on irrigation and poverty has noted that farmers producing under irrigation have an opportunity not only to increase productivity, but are also more likely to adopt improved farming technologies (Shields, 1985; Tesfaye et al., 2008). Access to irrigation was captured as a dummy variable where irrigating farmers score one and non-irrigating farmers a zero.

Household wealth and income: Having relatively high levels of wealth may enable farmers to more readily meet capital costs required to manage or hire tractors (Savadogo et al., 1998). Past studies (e.g., Williams, 1997; Adesina et al., 2000; Mbata, 2001; Gosh, 2010) have shown that household income positively influences adoption of new agricultural innovations or technologies. Given that some of the sampled households were not willing to share information on monthly income, the study used a proxy variable in the form of household wealth. Following Langyintuo and Mungoma (2008), a wealth index was estimated using Principal Component Analysis (PCA) for each household based on the number of television sets, satellites/decoders, cellphones, refrigerators, radios and cars owned, and wall material for the main house,[4]

[4] For wall material, houses constructed in bricks and cement were accorded a score of 5, blocks and cement = 4, stone and cement = 3, stick and mud = 2 and wood off-cuts = 1.

floor type[5] and main source of energy for cooking[6]. The PCA was applied using a correlation matrix as these variables were measured in different units (Krzanowski, 1987). Terry (2012) used some of these variables to develop wealth categories for a neighbouring rural community in Nyakatfo. Household wealth is expected to be positively associated with the use of tractors by the sampled households.

Although information on income figures could not be obtained, respondents were prepared to indicate their main sources of income. From the over ten sources indicated (see Fig. 2), at least 60% of the households identified remittances as their major source of income. A dummy variable was, therefore, computed scoring one for households with remittances as their major source of income and zero otherwise. This variable was included in the MNL to study whether the adoption and use of land cultivation technologies is linked to off-farm income, as found by Low (1986) and Shields et al. (1993). Given the above discussion on sample data issues and the MNL, the next section presents the study's empirical results.

Empirical results

This section has four sub-sections: the wealth index computed from household assets using PCA is presented first, followed by descriptive statistics for the variables used in the MNL model. The third sub-section presents a discussion of a correlation matrix for these variables, while the final sub-section presents the empirical MNL.

Wealth index for households in Malibeni

Using the Kaiser criterion (Kaiser, 1960), PCA results indicated that the first three principal components (PCs) had eigenvalues greater than one and together accounted for about 55.6% of total variation in the original variables. The first principal component (PC_1) had an eigenvalue of 2.477 and accounted for some 27.5% of the total variance. The second and third PCs had eigenvalues of 1.432 and 1.094, and explained 15.9% and 12.2% of total variance, respectively. All estimated coefficients for PC_1 had positive signs, implying that as their values increase (in rank and quantity), the wealth index for the *i*th household also increases. It was, therefore, decided to use PC_1 to compute a wealth index for each sampled household.

Retaining coefficients with PC loadings greater than $|0.30|$, as proposed for samples with greater than 50 observations (Koutsoyiannis, 1992), PC_1 was computed using a correlation matrix and standardised variables as:

$$\begin{aligned}\text{WEALTH} = {} & 0.603\text{TVsets} + 0.595\text{Cellphones} + 0.561\text{Refrigerators} \\ & + 0.560\text{Radios} + 0.527\text{Cars} + 0.399\text{Energy source} \\ & + 0.490\text{Walls} + 0.595\text{Floors} + 0.317\text{Satellites} \qquad (4)\end{aligned}$$

As indicated in Section "Empirical model", households that score highly on this index are more likely to use tractors for land cultivation.

Descriptive statistics for variables used in the MNL model

Fig. 1 shows the three main technologies (means of land cultivation) used by households in Malibeni. Tractors were used by 51.4% of respondents, draught animals by 27.1% and hand hoes by 21.4%. None of the farmers used a combination of any of these technologies. Of the 51.4% of respondents who used tractors, only 11.4% owned a tractor.

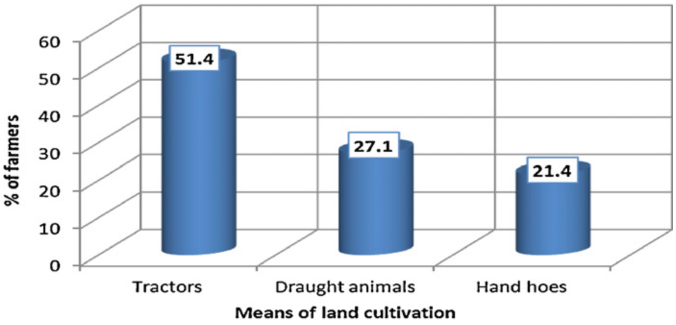

Fig. 1. Means of land cultivation used by sample farmers in Malibeni, 2009 ($N = 210$). *Source*: Survey data (2009).

The nearest government tractor hire pool(s) to farmers in the study area are found in either Mayiwane or Madlangempisi. However, because these areas are over 15 km away and have few tractors available for hire (11 in each centre), farmers in Komati often rely on tractors owned by farmer associations and individuals whose charges range between 41% and 48% above the subsidised government hire fees. Table 2 presents a summary of the descriptive statistics for the explanatory variables used in the MNL.

Most household heads (67%) were men, of whom 57% used tractors for land cultivation. Only about 20% of households produced irrigated maize (again mainly tractor users), all of whom used sprinkler irrigation, which is less costly and less efficient than drip irrigation (Dlamini, 2005). The average age of household heads was 48 years, which did not differ markedly by type of land cultivation method. Household labour availability (in man-equivalents) was statistically significantly higher for households using animal draught power and hand hoes.

The size of arable land used to produce maize was statistically significantly higher for tractor users. Proponents of agricultural mechanisation argue that the exclusive use (or ownership) of standard tractors (40–80 horsepower) on farms measuring less than 2 ha would be uneconomical, particularly if the fields are irregularly shaped and fragmented (see FAO, 1981). Although the MNL uses a variable for land area under maize production (for reasons given in the Introduction and Section "Empirical model"), the average total arable land (proxy for total farm size) in the study area was 1.96 ha. About 49% of the farmers had total arable land below the threshold of 2 ha and 45% of them used tractors, 24% used animal draught power, and 31% used hand hoes to cultivate their land for maize production. The number of oxen per household was statistically significantly greater for users of animal draught power. The WEALTH index scores were statistically significantly higher for tractor users, while the heads of these households also had a relatively higher level of formal education.

Non-agricultural economic activities were the most important income sources for over 80% of the respondents with remittances being identified by over 60% of the households (see Fig. 2). Income from agricultural-related sources, such as earnings from sugarcane production, crop and livestock enterprises, was reported by less than 10% of sampled households for each respective alternative.

Correlation of explanatory variables used in the MNL model

Estimated correlation coefficients for the variables specified in the MNL are presented in Table 3. The dependent variable (Cultivation method) was significantly positively correlated with

[5] For floor material, houses with tiles were accorded a score of 5, cement = 4, planks = 3, soil covered in cow dung = 2 and just soil = 1.

[6] For source of power for cooking, households that use electricity were accorded a score of 5, solar = 4, handigas = 3, paraffin = 2 and wood = 1.

Table 2
Descriptive statistics for variables used in the MNL ($N = 210$).

Categorical variables						
Variable	Unit	% of total sample ($N = 210$)	% from tractor users ($N = 108$)	% from users of animal draught ($N = 57$)	% from users of hand hoes u ($N = 45$)	χ^2-Value
Gender of household head (GENDER)	Male	67.1	57	30	13	4.301
	Female	32.9	49	25	26	
Is maize irrigated? (IRR)	Yes	19.5	75.6	14.6	9.8	11.969***
	No	80.5	45.6	30.2	24.3	
Major source of household income (INC_SOC)	Remittances	64.8	53	22	25	2.003
	Non-remittances	35.2	51	25	24	
Continuous variables						
Variable	Unit	Mean total sample ($N = 210$)	Mean tractor users ($N = 108$)	Mean users of animal draught ($N = 57$)	Mean users of hand hoes ($N = 45$)	F-value[b]
Age of household head (AGE)	Years	48	47	49	50	0.656
Household size (MAN_EQUIV)	Man-equiv.	6.56	4.77	6.23	7.29	13.942***
Total maize area (MAIZE_AREA)	Hectares	1.53	1.76	1.51	1.02	12.187***
Number of work animals (DRA_ANIM)	Number of oxen	5.16	4.84	8.5	3.47	11.104***
WEALTH	Principal Component score	0.0	0.179	0.102	−0.561	2.132**
Ordered variables						
Variable	Unit	Mode total sample ($N = 210$)	Mode tractor users ($N = 108$)	Mode users of animal draught ($N = 57$)	Mode users of hand hoes ($N = 45$)	χ^2-value
Education level of H'hld head (EDUC)	Highest level of education attained[a]	0	1	0	0	9.473

Source: Survey data (2009).
[a] 0 = no formal education; 1 = primary education; 2 = secondary education; 3 = high school; 4 = college; and 5 = university.
[b] Generated from one way ANOVA.
** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

labour endowment (MAN_EQUIV), and significantly negatively correlated with MAIZE_AREA, production of irrigated maize (IRR) and the wealth index (WEALTH). Furthermore, some evidence of statistically significant relationships between MAN_EQUIV and MAIZE_AREA ($p < 0.01$), level of education (EDUC) and IRR ($p < 0.01$), MAIZE_AREA and WEALTH ($p < 0.01$), and IRR and EDUC ($p < 0.01$) were detected.

AGE was also significantly correlated with GENDER and EDUC ($p < 0.01$), MAN_EQUIV, MAIZE_AREA and WEALTH ($p < 0.05$). However, given that the highest correlation coefficient was $|0.319|$, these relationships between the explanatory variables were not considered an issue in obtaining reliable parameter estimates from the MNL as the variables were reasonably independent of one another. The empirical MNL results are presented in the next sub-section.

MNL model results

The MNL model was estimated with robust standard errors using STATA 11 software programme (Long and Freeze, 2006) and the results are presented in Table 4.

The results show a statistically significant ($p < 0.01$) Wald χ^2 of 63.42, suggesting that the explanatory variables explain variation in household choice of land cultivation technology quite well. The estimated MNL correctly predicted about 93%, 83%, and 87% of farmers' preferences for using tractors, animal draught power

Table 3
Correlation matrix of variables used in the MNL model ($N = 210$).

	Cultivation	AGE	GENDER	EDUCATION	MAN_EQUIV	MAIZE_AREA	DRA_ANIM	IRR	WEALTH	OFF_FARMINC
Cultivation	1.0									
AGE	0.079	1.0								
GENDER	0.118	−0.212***	1.0							
EDUC	−0.013	−0.224***	−0.224	1.0						
MAN_EQUIV	0.221***	0.149**	0.149**	−0.096	1.0					
MAIZE_AREA	−0.319***	−0.150**	−0.037	0.072	−0.215***	1.0				
DRA_ANIM	0.104	0.007	−0.005	−0.011	−0.095	0.048	1.0			
IRR	−0.221***	0.016	−0.065	−0.232***	−0.097	0.069	−0.072	1.0		
WEALTH	−0.268***	−0.144**	0.009	0.045	−0.186***	0.082	0.103	0.122	1.0	
INC_SOC	−0.003	−0.066	0.036	0.025	0.017	−0.096	−0.059	−0.014	0.067	1.0

Source: Survey data (2009).
** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

Table 4
MNL estimates of factors that influence the use of alternative land cultivation technologies in Malibeni, Swaziland, 2009.

Variables	LR test χ^2-value (2df)	$\ln(P_2/P_1)$ Animal draught power vs tractor[b]				$\ln(P_3/P_1)$ Hand hoe vs tractor[b]			
		Coeff.	Marginal values			Coeff.	Marginal values		
			$\partial y/\partial x$	Std. error	z-Value		$\partial y/\partial x$	Std. error	z-Value
Constant		−3.485				−4.720			
AGE	0.015	−0.002	−0.00045	0.0034	−0.13	0.001	0.00007	0.0008	0.09
GENDER[a]	1.095	−0.575	−0.1203	0.1011	−1.19	−0.579	−0.0130	0.0405	−0.32
MAN_EQUIV	77.250***	0.403	0.0769	0.0299	2.58***	0.933	0.0259	0.0113	2.29**
EDUCATION[a]	2.639	0.866	0.1802	0.1643	1.10	1.057	0.0277	0.0407	0.68
MAIZE_AREA	10.091***	−0.666	−0.1188	0.0821	−1.45	−2.342	−0.0687	0.0305	−2.25**
DRA_ANIM	104.578***	0.330	0.0716	0.0199	3.59***	−0.053	−0.0052	0.0028	−1.86*
IRR[a]	3.031	−1.250	−0.2193	0.1077	−2.04**	−1.019	−0.0185	0.0193	−0.96
WEALTH	4.816*	−0.159	−0.0261	0.0534	−0.49	−0.775	−0.0234	0.0137	−1.71*
INC_SOC[a]	0.361	−0.145	−0.0264	0.1092	−0.24	−0.442	−0.0135	0.0258	−0.52
Observations = 210; Wald χ^2 (18df) = 63.42***; pseudo R^2 = 0.65; Log pseudolikelihood = −74.36									
Correct prediction: tractor use = 92.6%; animal draught power = 82.5%; use of hand hoes = 86.7%; overall model = 88.6%;									

Source: Survey data (2009).
[a] $\partial y/\partial x$ is for discrete change of dummy variable from 0 to 1.
[b] Reference category is use of tractor (P_1).
* Statistical significance at the 10% level.
** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

and hand hoes, respectively. The overall correct prediction rate of the model was almost 89%. The marginal effects show that for households which use either draught animals or hand hoes, proper cultivation would be possible if sufficient labour is available to drive the animals during cultivation in category 2 and for using hand hoes in category 3.

The positive, statistically significant coefficients for MAN_EQUIV indicate that the likelihood of using either draught animals or hand hoes, as opposed to using tractors, increases as the number of family members (in man-equivalents) for the *i*th household increases. Savadogo et al. (1998) noted that households with four or less members may find it difficult to use traction equipment, particularly when using draught animals. However, considering Swaziland's extremely high HIV/AIDS infection rate, reliance on such cultivation methods could lead to increased levels of food insecurity among rural households. Although this was outside the scope of the study, Muwanga (2002) found that such labour demanding activities place severe limitations on the amount of land that can be cultivated by affected household. They further reduce the timeliness and efficacy of farm operations such as cultivation and weeding.

The negative, statistically significant MAIZE_AREA coefficient suggests that as the size of arable land (in hectares) cultivated by the *i*th household increases, there is a higher probability that the household will use a tractor for land preparation as opposed to hand hoes. These results are consistent with a priori expectations as the work rate human beings or even animals do not compare to that of tractors. This could also result from comparatively larger farms being able to spread fixed costs over a greater number of units of output. The use of draught animal power for land cultivation is more likely by households that own relatively large numbers of draught animals. Although the study did not explore the relative profitability of using alternative cultivation technologies, the implication is that these households find it relatively cheaper to use resources at their disposal than to incur financial tractor hiring costs and the opportunity cost of waiting for a service that may be offered after the onset of annual rains. The negative, statistically significant IRR coefficient also suggests that households who produce maize under irrigation are more likely to use improved cultivation methods. This could perhaps be attributed to farmers' objectives to increase productivity in their respective plots. While use of irrigation could be influenced by other factors outside the scope of this study, these results support other findings (e.g., Shields, 1985; Tesfaye et al., 2008) that investment in irrigation is likely to improve the adoption of complementary technologies.

Despite over 60% of sampled households relying on remittances as their major source of income, in contrast to previous findings by Low (1986) and Shields et al. (1993), the non-significant coefficient estimates for INC_SOC implies that use of tractors and off-farm income are not related. The marginal effect for WEALTH was negative in both contrasts, but only statistically significant in the contrast between hand hoes and tractors. This suggests that the likelihood of using hand hoes as opposed to using tractors decreases with an increase in household wealth. Wealthy farmers are either capable of owning a tractor or can more readily afford to pay for tractor hire services.

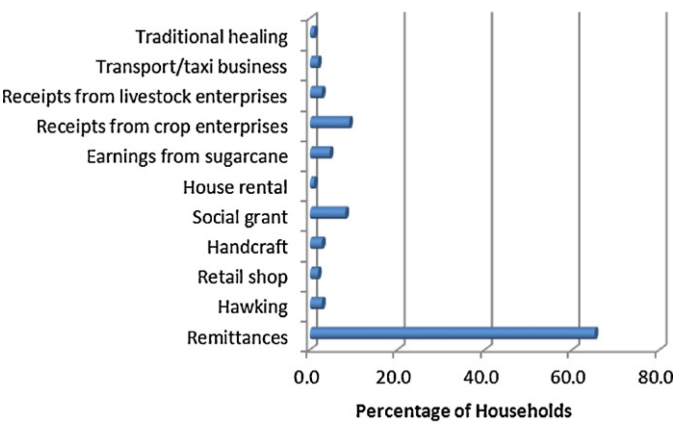

Fig. 2. Major income sources for sampled households in Malibeni, 2009 (N = 210).
Source: Survey data (2009).

Conclusions and policy recommendations

The empirical results imply that several factors need to be considered in developing a comprehensive land cultivation programme to improve the prospects of early planting and ultimately increasing food production on customary SNL. Since the Swaziland government currently has very few tractors available for hire, in the short-term, farmers who own relatively larger numbers of draught animals should be encouraged not to rely on tractors. Although the use of animal draught power requires relatively more labour for land cultivation than tractors, these farmers could avoid production losses by using resources at their disposal than to incur tractor hiring costs and the opportunity cost of waiting for services that may be offered long after the onset of rains. Note, however, that the limited availability of labour, especially given the HIV/AIDS pandemic in Swaziland, could constrain the use of this technology.

While the concept of privatising the THS implies the withdrawal of government subsidies, the intention is to improve service delivery, which may ultimately lead to an increase in hire charges. With the national average land holding on customary SNL being around 1.9 ha, where most farmers produce under rain-fed conditions and fall in the lowest continuum of the wealth index, there is a possibility that prospective service providers may not have sufficient demand to sustain their business ventures. Providing services which have a seasonal demand to a large number of fragmented smallholder producers may increase overhead and transaction costs of managing the THS. Furthermore, it appears that venturing into business in this sector requires not only a sizeable investment in machinery and human capital, but also the assurance of a reliable support service for implements and spare parts.

Given the difficulties likely to be encountered in privatising the THS under the current situation, the study recommends a thorough review of the land tenure system in Swaziland. While the study results indicate that improved technologies are likely to be adopted by farmers producing on larger arable land holdings, the option of simply availing more land to customary SNL producers may not be a lasting solution considering the country's increasing population. In order to attract meaningful investments from producers, which may also increase agricultural productivity on customary SNL, the review of the land tenure system could consider allowing customary SNL producers more definite land use rights, perhaps through long-term lease arrangements. This option would augment efforts to commercialise production on SNL, as farmers would be allowed to use lease contracts as collateral for credit to improve productivity through mechanised farming. This does not imply that all producers should own tractors; however, those who may not find it economical could indirectly benefit from their neighbours who may utilise such an opportunity to invest in farm machinery. Through entrepreneurship, tractor owners may offer services in the communities they live in and possibly improve accessibility during or even beyond peak planting periods.

However, in order to improve the likelihood of SNL farmers benefiting from a change in tenure arrangements, this process could to be complemented by other agricultural sector policies that promote commercialisation. Otherwise, if production costs are such that commercial production does not provide returns commensurate with off-farm opportunities, few households will be willing to acquire land for commercial production and it will continue to be used primarily for non-market purposes.

One major limitation of this study is the use of cross-section data that were collected at a time when some sampled farmers were in the process of harvesting their maize. This meant that no data were available on total annual production, preventing analysis of the impact of different cultivation technologies on household maize yield. This is an area that could perhaps be considered for future research.

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