Journal of Ecosystem & Ecography

Olaleye et al., J Ecosys Ecograph 2016, S5
DOI: 10.4172/2157-7625.S5-001

Research Article Open Access

Likoti Farming under Changing Climate in Lesotho: Agronomic Grain Yield versus Technical Efficiency

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Abstract

Climate Change (CC) and with sub-optimal nutrient contents in the soils of Lesotho is negatively impacting yield and yield components of maize. Often, the grain yield is often ≤ 2.50 t/ha in most cases. One of the ways smallholders in Lesotho try to mitigate the impact of CC and sub-optimal nutrient contents is through the practise of Conservation Agriculture (CA) called *likoti* farming. Data (soil and socio-economic variables) were collected from smallholder farmers practising *Likoti* Farming Systems (LFS) in Lesotho. Surface soil (0-20 cm) samples and socio-economic data were collected between 2012/2013 and 2013/2014 cropping seasons from 105 smallholder farmers in 22 villages. These villages are located in four administrative districts of Lesotho (*Berea*, *Butha Buthe*, *Leribe* and *Maseru*). The socio-economic variables were on inputs (farm size, payment for land, quantity of fertilizer, fertilizer cost, quantity of seeds, man-days, wage rate, quantity of herbicides, price of herbicides and labour cost) and output (grain yield) used by the farmers. In addition, long-term monthly rainfall data (1900-2007) were collected from the Lesotho Metrological Services. Socio-economic data were analysed using means procedure of SAS across the villages. In addition, these same data (i.e., inputs and output) were subjected to Data Envelopment Analysis (DEA) using SAITECH DEA-Solver under constant returns to scale (CRS). Results showed that soils across these villages/ districts had sub-optimal contents of N, P, K and acidic pH (i.e., ≤ 5.0). The mean annual rainfall has been declining steadily over the years. Examination of the grain yields across villages showed that highest grain yield (e.g. 2113.0 kg/ha) was recorded in *Ha-Ts'alemoleka* (*Butha Buthe* District) and the least was about 100 kg/ha in *Ha-Khoeli* village (*Maseru* district). When the DEA method was used to examine the same data set using inputs and output, only four (or 18.20%) of the LFS/Decision Making Units (DMUs) were technically efficient (i.e., efficiency score was 1.0), while the other 18 DMUs (or 81.80%) were not efficient. It was observed that agronomic research using grain yields (i.e., output) as the reason why soil conservation is better in one village/region compared to others may be erroneous. Hence, efforts should be made by researchers (i.e., agronomist, soil scientists, animal scientists, extension agents etc..) to use DEA software to evaluate collected data (i.e., input variables) along with the output(s) arising from such trials to make proper decisions to policy makers.

Keywords: Climate change; Conservation agriculture; *Likoti;* Lesotho; Maize; Soil

Introduction

Climate Change (CC) has become a global issue, which has become one of the major themes of discussions by many scientists and policy makers. It is perceived to negatively impact the yield of crops with attendant decrease in the productivity of agriculture in most countries in Sub-Saharan Africa (SSA) and in the whole world. In Lesotho, "*likoti*" means holes and the farming system was introduced by August Basson, a missionary, who has been living and working in Lesotho for over 30 years. It is a form of Conservation Agriculture (CA) [1]. Since 2005, the Government of Lesotho (GOL) has promoted this farming system as one of the strategies to boost crop production and adapt to the impact of climate change [2,3]. An initial study of *likoti* farming systems (LFS) [4] showed that grain yield of maize from *Likoti* plots were significantly higher than those from conventional farming systems (CFS). Another study sampled 117 *likoti* farmers in Lesotho along with 112 conventional farmers. The results showed that maize yield from *likoti* plots were higher than those from the conventional plots [1]. Also, these authors reported that farmers practising LFS were better-off in socio-economic terms than the latter. For this farming system to be scaled-out, Sicili et al. [5] noted that farmers practising LFS should be properly educated and economic incentives should be provided to such households to help them better adopt the technology. Despite these gains from Lesotho, there has been conflicting results of CA from other parts of the South African Development Community (SADC). For example, these authors Gowing and Palmer [6]; Nkala et al. [7] noted that farmers adopting the CA technologies require higher inputs (e.g. herbicides and fertilizer) to make such technologies profitable in Zimbabwe. Nyagumbo, Nkala et al., Musara et al. [6,8,9] reported that adoption of CA improves yield and soil properties in Namibia and Zimbabwe. However, all these studies only considered just one dimension, that is, agronomic yield, but did not consider other household level covariates (e.g. age, sex, farm size, inputs, education, etc.) in evaluating the yield of crops [10].

"*Likoti*" practices have been associated with yield gain of maize planted; there is compelling interest to measure and understand the technical efficiency of this technology in the face of declining agricultural productivity among selected smallholder maize farmers in Lesotho. The production of crops, whether under conventional tillage, CA or *likoti* farming utilizes large quantities of inputs either directly or indirectly in the form of machinery, seeds, fertilizer, manure, chemicals

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Received December 05, 2015; **Accepted** February 09, 2016; **Published** February 17, 2016

Citation: Olaleye AO, Tambi E, Bangali S, Odularu GOA (2016) *Likoti* Farming under Changing Climate in Lesotho: Agronomic Grain Yield versus Technical Efficiency. J Ecosys Ecograph S5: 001. doi: 10.4172/2157-7625.S5-001

(i.e., herbicides) water, farm size and so on. Excessive utilization of any of these inputs may result in environmental hazards directly or indirectly if used over a long period of time. In addition, some of these inputs are becoming very expensive and often are not available to farmers during the production seasons either due to excessive cost or unavailability. Therefore, efficient utilization of these inputs will reduce environmental hazards, prevent the destruction of natural resources, ensure agricultural sustainability and enable smallholder farmers to utilize agricultural inputs judiciously.

Calculating efficiency and optimizing performance can be achieved using parametric (Stochastic Frontier Analysis- SFA) and non-parametric (Data Envelopment Analysis (DEA) or Free Disposable Hull (FDH) methods. The Data Envelopment Analysis (DEA) was developed by Charnes et al. [11] as an optimization tool to calculate efficiency. The method has been used to estimate the efficiency in several organizations units in several areas [12] and across several fields - Agriculture, Health [13] and Management [14-17]. The advantage is that it places less structure on the shape of the efficient frontier [18]. According to Farrell [19], the DEA involves the concept of efficiency, which is defined as the ratio of output(s) to input(s). The DEA is a non-parametric method to calculate efficiency, and it involves the use of technical linear programming tools to construct a non-parametric piecewise surface (or frontier) over a given set of data for it to be able to estimate efficiency relative to that specific surface [20]. The DEA develops efficiency by optimizing the weighted output/ input ratio of each Decision Making Units (DMU), subject to the condition that this ratio can be equal, but never exceed, unity for any provider/ in a given data set [11]. Thus, any farm below the frontier is considered to be inefficient (i.e., the scale efficiency is ≤ 1.0). The DEA often constructs a "best-practice" benchmark from data of inputs and outputs supplied [21]. The efficiency score of the best performing technology (i.e., the benchmark) in any given evaluation will only represent the organisation or technology in question considered in the analysis. According to Ozcan [13], though the DEA can clearly identify improvement strategies for those non-top-performing technologies, further improvements of top performers depend on factors such as new technologies and other changes to such technologies, the price of inputs or the scope of the production process (i.e., scale).

Many studies have reported that LFS improves grain yield of maize, and it also increases the amount of carbon fixed into the soil compared to conventional methods. Despite these gains, there is sparse literature on the technical efficiency of LFS in Lesotho when compared to agronomic yield. The objective of this investigation was to compare the agronomic yield of maize of 105 *likoti* farmers in 22 villages located in four Districts of Lesotho with results from the efficiency analysis using DEA solver[1].

Materials and Methods

Study sites description

Lesotho is land locked and surrounded only by the Republic of South Africa (Figure 1). It is situated approximately between 28^{0}S and 31^{0}S latitudes and longitude 27^{0}E and 30^{0}E. The total land area is about 30, 355 km^2 of which about 12% is arable. It is divided into four Agro-Ecological Zones (AEZ): the Lowland, Senqu River valley, Foot-Hills and mountains (Table 1).

[1]Agronomic yield (i.e. the grain yields) and DEA results were presented across villages.

Data collection

Between 2012/2013 and 2013/2014 cropping seasons, socio-economic survey was conducted using structured questionnaires to elicit information from 105 smallholder farmers located in 22 villages practising *likoti* farming. Data (2010-2015) were collected from these farmers on grain yields (t/ha), amount paid for renting land (Loti[2]), quantity of fertilizer used (kg/ha), amount spent on purchasing fertilizer (Loti[2]), quantity of seeds used (kg/ha), man-day spent on the field (hrs), quantity of herbicides used (litres/ha), and cost of herbicides (if any) (Loti). These data were collected using post-graduate students of the National University of Lesotho (NUL) and extension agents working in the Ministry of Agriculture, and those with non-governmental organisations in Lesotho. In addition, surface soil samples (0-15 cm) were collected randomly from 22 of these farmers during the survey (i.e., 2012/2013 - 2013/2014 cropping seasons). These smallholder farmers were located in four administrative districts of Lesotho (i.e., *Berea*, *Butha Buthe*, *Leribe* and *Maseru*). The soil samples were labelled and bulked together and representative samples were taken for routine laboratory analyses. The soil samples were air-dried for 48 hours and crushed to pass through a 2 mm sieve. The soil samples were analyzed for the following parameters: particle size analysis [22], Soil pH (water), Organic Carbon (OC) [23], available Phosphorus (P) [24], available Nitrogen (N), Bulk Density (BD) was calculated using American Bulk Density Calculator and Soil Organic carbon pool (C-pool) was calculated using relation as given by Wairiu and Lal [25]:

$$\text{C-pool} = d \times BD \times \text{C-content} \quad (1)$$

Where, C-pool (kg Cm^{-2}), d: soil layer thickness (m), BD: bulk density (kg m^{-3}), C[3]-content (g g^{-1}). The cation exchange capacity (CEC) was determined using Ammonium acetate at pH 7. The base cations (Ca^{2+}, Na^+, Mg^{2+} and K^+) were extracted using 1N NH_4OAc and read on Atomic Absorption Spectrometer. Long-term monthly rainfall data (1900 - 2007) were collected from the Lesotho Meteorological station (Figure 2) and annual means of these were calculated for 100 years.

Estimating the efficiency of *Likoti* farming using DEA

Data Envelopment Analysis (DEA) is a widely used mathematical programming approach for comparing the inputs and outputs of a set of homogenous Decision Making Units (DMUs) [14,15]. The DEA evaluates the performance of DMUs based on evaluating the relative efficiencies of comparable DMUs by estimating an empirical efficient boundary [26]. A DMU (in this case, a farmer/village) is said to be efficient when a comparable DMU can produce more outputs using an equal or lower amount of inputs (e.g. fertilizer, herbicides, man-days etc.). The DEA also provides efficiency scores and reference units for inefficient DMUs. Details of the DEA can be seen elsewhere [13-15,17]. DEA can either be input oriented or output oriented. In the former, the DEA method defines the frontier by seeking the maximum possible proportional reduction in input usage, with output levels maintained at a constant level for each farm. However, in the output orientation, the DEA method seeks to the maximum equiproportional increase in the output production with input levels fixed. Since *likoti* farming relies on finite and scarce resources; therefore, the input-orientation DEA model was used as it is more appropriate to reduce the amounts of inputs consumed to produce a certain amount of yields of maize [18,27]. As such, the input-orientation method was used to access the efficiency of *likoti* farming in Lesotho. Thus, the DEA model assume (k=1……, K) decision making units (DMUs), operating in a technology subset T denoted by $x = (x_1, \ldots\ldots\ldots x_N) \varepsilon \Re^{N+})$ vector inputs produce a

[2]15.89 Loti = US$ 1:00

[3]C= carbon contents

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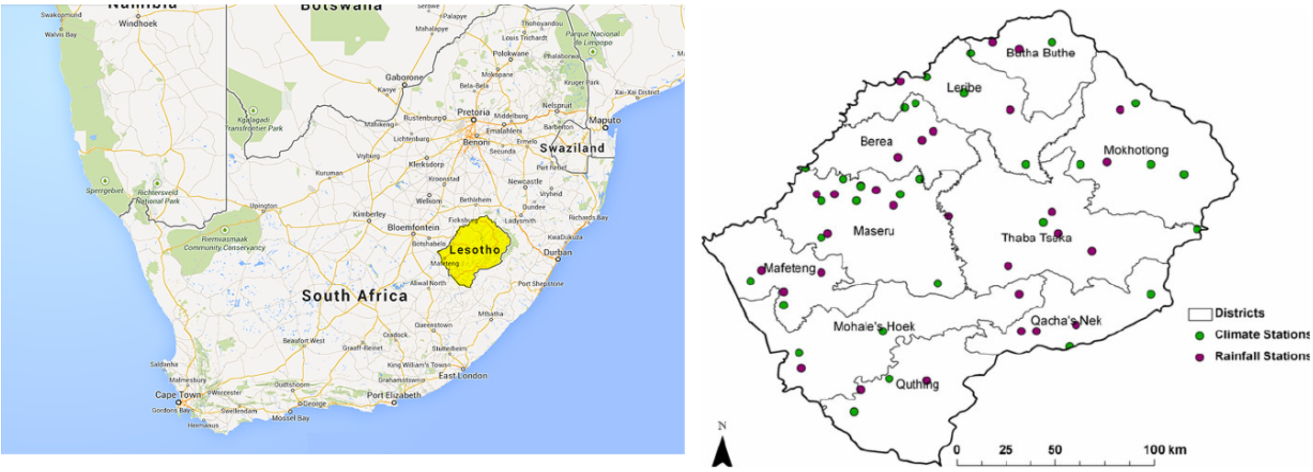

Figure 1: Lesotho in South Africa and ten administrative districts.

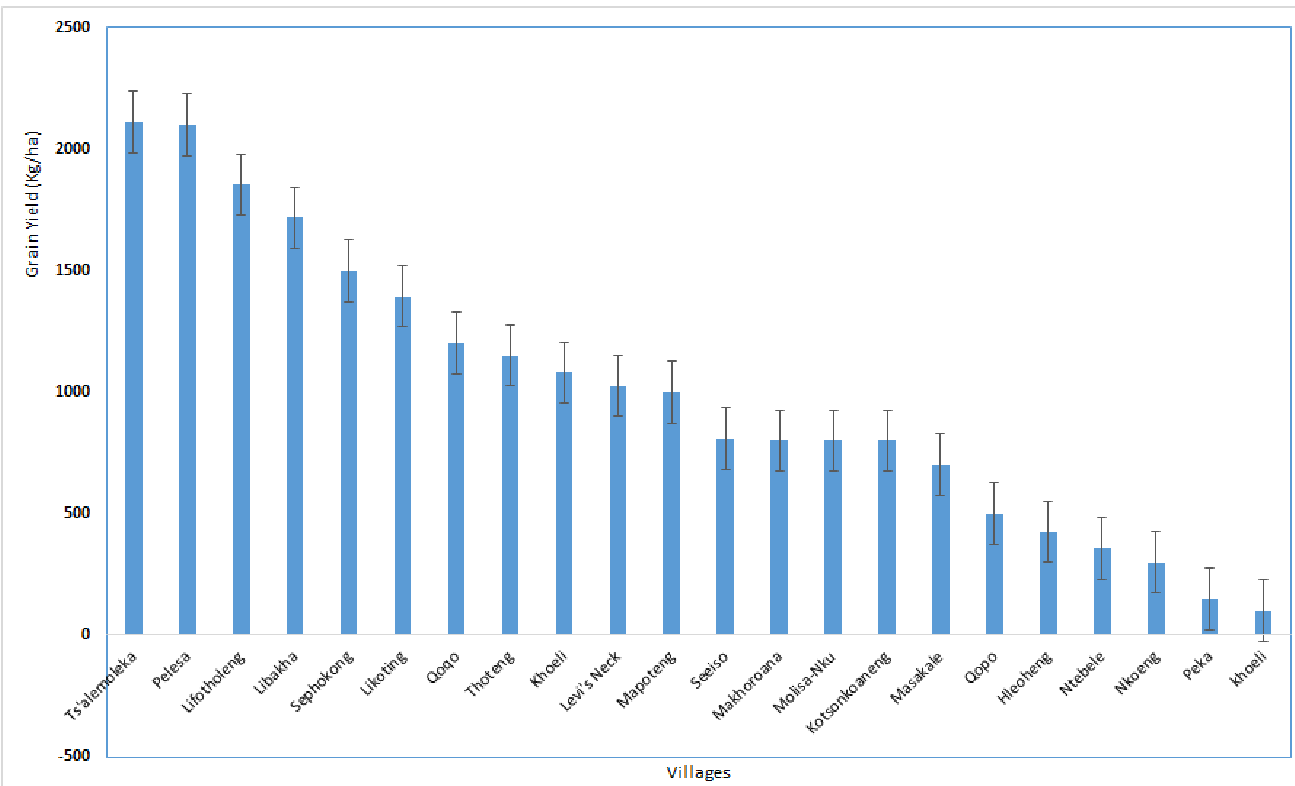

Figure 2: Grain yields of maize across 22 villages located in four districts of Lesotho.

Agro-ecological zones	Altitude (m) above sea level	Topography	Mean annual rainfall (mm)	Mean annual Temperature (°C)
Lowland	< 1800	Flat to gentle	600 - 900	-11 to 38
Senqu river valley	1000 - 2000	Steep sloping	450 - 600	-5 to 36
Foot-hills	1800 - 2000	Steep rolling	900 - 1000	-8 to 30
Mountains	2000 - 3,484	Very steep bare rock and gentle rolling valleys	1000 - 1300	-8 to 30

Table 1: Agro-ecological zone characteristics of Lesotho.

nonnegative vector of output vector $y = (y_1, \ldots\ldots\ldots y_N) \varepsilon \Re^{M+})$. The technical efficiency of the k-th DMU, which is a measure by which the k-th DMU is evaluated for its performance relative to the performance of other DMUs in consideration is given by Khshroo et al. [18]:

$$TE_k = \frac{\lambda_1 y_{1k} + \lambda_2 y_{2k} + \ldots\ldots\ldots, \lambda_M y_{Mk} = \sum_{m=1}^{M} \lambda_m y_{mk}}{v_1 x_{1k} + v_{2k} +, \ldots\ldots\ldots + v_N x_{Mk} = \sum_{n=1}^{N} v_n x_{nk}} \qquad (2)$$

Where TE_k is the technical efficiency score given to the k-th DMU; v and λ denote input and output weights. The efficiency study analyzed using basic Data Envelopment Analysis (DEA) [11] which is based

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on the linear programming tools as shown in equation 1 above. The software used was the DEA-Solver (DEA-Solver-PRO version 12.0 – SAITECH, Inc.) [12,28].

Thus, the second stage DEA employed the use of Tobit Regression using efficiency scores derived from the basic DEA model as the independent variable [29,30] and the inputs as dependent variables using STATA [31]. The aim of the second stage DEA is to elucidate factors that affected the efficiency score θ (i.e., set of environmental influences or causal factors) which are beyond the control of farmers. The grain yields of maize across villages were analyzed using the general linear model procedure (PROC GLM) and the Means was separated using the Proc Means [32].

Results and Discussion

The physico-chemical properties of the soils collected across the villages are presented in Table 2. Comparing Table 2 with the critical levels for maize (Table 3), the results showed that the soils in the four districts (i.e., across all the villages) are acidic (i.e., ≤ 5.0) [33]. The soil organic matter contents, total N, available P as well as the base cations (i.e., K, Ca, and Mg) were well below the critical levels as reported by Ayodele and Agbool [33] for maize cultivation (Table 3). As a result, there is need for application of adequate fertilizer which should be based on soil test/critical values (Table 3) in order to prevent environmental pollution and avoid a waste of resources (i.e., fertilizer). An observation of the grain yield presented by villages is presented in Figure 2. The yield of maize among the farmers practising LFS is a function of soil properties, adequate rainfall, absence of pest and diseases, availability of fertilizer in the right amount, and at the right time as well as availability of labour to make the "*likoti*" holes. Therefore, very low grain yields of maize recorded in Lesotho compared to other countries within the Southern African Development Community (SADC) might be associated with sub-optimal contents of N, P and K coupled with acidic soil pH and declining rainfall (Figure 3). The annual rainfall pattern is bi-modal in Lesotho, but it has been observed that the rainfall season has been shortened, which has negative implications for most short-season crops (Figure 3) and has been declining over the years (i.e., 1900 - 2007). As such, the cropping calendar has shifted in most of the Agro-Ecological Zones (AEZ) in Lesotho. In order to cope with the shorter cropping seasons and declining rainfall, most farmers have resorted to mitigating these effects by adopting *likoti* farming. The low grain yields of maize are further exacerbated by high HIV/AIDS scourge in the country as majority of households are headed by women and youths.

The summary statistics of the variables used for the DEA analysis across the four districts sampled is shown in Table 4. The farm size ranged between 0.80 ha (*Leribe* District) and 3.69 ha (Berea District) and the cost of acquiring these plots of land also ranged between 3000 (*Leribe* District) and 18,000 (*Maseru* District) Loti. Maseru is the capital city and is located within Maseru District. Thus, plots of land are very expensive (Table 4). Other socio-economic variables collected showed high variation across districts (Table 4). It was also observed on the field that most of the soils cropped by farmers in Lesotho are characterised by low amounts of soil organic matter (< 1%), plant available Nitrogen (N), and Phosphorous (P) (Table 3). From this study, it was observed that during the survey, the mean quantity of fertilizer applied, though different, varied across districts and from farmer to farmer ranging between 20 kg/ha (*Leribe* District) to about 320 kg/ha (*Butha Buthe*) (Table 4). The only drawback may be the high cost of purchasing these inputs as well as availability at the right time coupled with prevailing government policies on fertilizer usage. In practice, sustainable agriculture uses fewer external inputs (e.g., purchased fertilizer) and more locally available natural resources [34,35]. Low soil N and P availability may be two of the major constraints to crop production in Lesotho as most soils are acidic in pH (i.e., ≤ 5.0). This

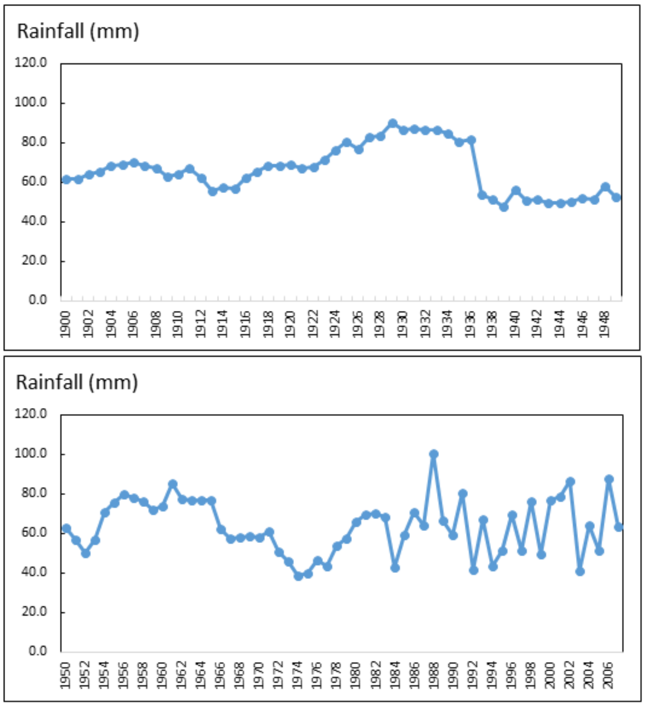

Figure 3: Long term mean rainfall data (1886-2007) in Lesotho (Source: Lesotho Meteorological Stations).

Variables	Berea	Butha Buthe	Leribe	Maseru
pH (water)	4.00	4.75	4.75	5.00
Org. C (%)	0.58 ± 0.3	0.37 ± 0.3	0.48 ± 0.22	0.44 ± 0.3
Org matter (%)	1.01 ± 0.53	0.68 ± 0.42	0.71 ± 0.38	0.77 ± 0.50
C-pool (kg C m^{-2})	15.27 ± 10	11.10 ± 7.3	nd	10.75 ± 8.1
Exch. Cations (C mol/kg)				
Ca	1.90 ± 0.86	1.70 ± 1.10	2.44 ± 0.35	4.80 ± 0.30
Mg	1.0 ± 0.4	1.71 ± 1.1	1.80 ± 0.56	2.91 ± 1.90
K	0.12 ± 0.10	0.46 ± 0.18	0.21 ± 0.02	0.26 ± 0.15
Na	0.10 ± 0.01	0.10 ± 0.03	0.04 ± 0.01	0.41 ± 0.40
Available P (mg/kg)	0.25 ± 0.15	0.59 ± 0.42	0.50 ± 0.12	0.60 ± 0.45
Total N (%)	0.10 ± 0.10	0.15 ± 0.03	0.16 ± 0.10	0.11 ± 0.01
Number of Samples	n = 19	n = 5	n = 5	n = 16

Table 2: Physical and chemical properties of the selected districts.

Soil Properties	Fertility Classes			
	Critical Level	Low	Medium	High
Organic matter (%)	2.00	0 - 2.0	2.0 - 3.0	> 5.0
Acidity (p^H)	-	6 - 6.9	5.0 - 5.9	< 5.0
Total N (%)	0.15	0 - 0.15	0.15 - 0.20	> 0.20
Available P (mg/kg)	8.50	0 - 8.50	8.5 - 12.50	> 12.50
Exchangeable Cations (Cmol/kg)				
K	0.16	0 - 0.16	0.16 - 0.31	> 0.31
Ca	1.50	0 - 1.50	1.60 - 4.0	> 4.0
Mg	0.28	-	-	-

Source: Ayodele and Agboola [33]

Table 3: Fertility classes for evaluting maize nutrient levels.

Variables	Category	Observation (N)	Mean	Std. Dev	Min	Max
	----------------------------------- Berea District---					
Grain yield (kg/ka)	Output (O)	30	1218.19	1053.24	150	4500
Farm size (Ha)	Input (I)	30	3.69	5.34	0	24.03
Payment for land (Loti)	Input (I)	30	1550.89	1778.01	0	5000
Fertilizer used (kg/ha)	Input (I)	30	137.19	115.27	0	400
Fertilizer cost (Loti)/season	Input (I)	30	88.25	83.24	0	290
Quantity of seeds used (kg/ha)	Input (I)	30	15.27	14.39	0	50
Man-days (hrs)	Input (I)	30	37.42	32.02	0	100
Wage rate/day	Input (I)	30	18.27	24.22	0	100
Quantity of herbicide used (Litres/ha)	Input (I)	30	0.26	0.44	0	2
Price of herbicides (Loti)/season	Input (I)	30	24.91	32.03	0	113.33
Labour cost (Loti/season)	Input (I)	30	973.27	1599.71	0	6300
Efficiency score	---	30	0.365	0.37	0.0001	1.0
	----------------------------------- Butha Buthe District ---					
Grain yield (kg/ka)	Output (O)	45	1850	1559.65	450	4000
Farm size (Ha)	Input (I)	45	3.5	1.93	2	6.8
Payment for land (Loti)	Input (I)	45	4420	3997.75	500	10000
Fertilizer used (kg/ha)	Input (I)	45	320	130.38	200	500
Fertilizer cost (Loti)/season	Input (I)	45	112.40	66.02	2	160
Quantity of seeds used (kg/ha)	Input (I)	45	26	11.40	10	40
Man-days (hrs)	Input (I)	45	85	154.54	0	360
Wage rate/day	Input (I)	45	14	19.49	0	40
Quantity of herbicide used (Litres/ha)	Input (I)	45	0.35	0.49	0	1
Price of herbicides (Loti)/season	Input (I)	45	28	4702.34	0	100
Labour cost (Loti/season)	Input (I)	45	2480	0.284	0	10800
Efficiency score	--	45	0.281		0.0002	0.625
	--- Leribe District --					
Grain yield (kg/ka)	Output (O)	15	610	569.43	150	1600
Farm size (Ha)	Input (I)	15	0.80	0.83	0	2
Payment for land (Loti)	Input (I)	15	860	1244.19	0	3000
Fertilizer used (kg/ha)	Input (I)	15	20	20.91	0	50
Fertilizer cost (Loti)/season	Input (I)	15	28.60	37.81	0	70
Quantity of seeds used (kg/ha)	Input (I)	15	8	8.37	0	20
Man-days (hrs)	Input (I)	15	15	15.65	0	35
Wage rate/day	Input (I)	15	17	0	0	30
Quantity of herbicide used (Litres/ha)	Input (I)	15	0	0	0	0
Price of herbicides (Loti)/season	Input (I)	15	0	463.54	0	0
Labour cost (Loti/season)	Input (I)	15	435	0.361	0	1050
Efficiency score	---	15	0.369		0.09	0
	-- Maseru District ------------------------------					
Grain yield (kg/ka)	Output (O)	15	896.88	800.51	100	3000
Farm size (Ha)	Input (I)	15	2.5	1.89	0.20	7
Payment for land (Loti)	Input (I)	15	3368.75	5034.91	100	18000
Fertilizer used (kg/ha)	Input (I)	15	117.19	109.82	0	400
Fertilizer cost (Loti)/season	Input (I)	15	113.13	48.95	0	180
Quantity of seeds used (kg/ha)	Input (I)	15	18.59	11.79	10	50
Man-days (hrs)	Input (I)	15	40.25	25.96	0	96
Wage rate/day	Input (I)	15	19.06	14.17	0	50
Quantity of herbicide used (Litres/ha)	Input (I)	15	0.38	0.306	0	1.26
Price of herbicides (Loti)/season	Input (I)	15	103.28	202.08	0	800
Labour cost (Loti/season)/season	Input (I)	15	813.44	819.00	0	2880
Efficiency score	--	15	0.144	0.23	0	0.69

Table 4: Summary statistics of input and output variables used across districts for DEA analysis.

is exacerbated by soil fertility depletion through nutrient removal as most of the harvested crop residues are not returned back on to the soil, but are either used as forage to feed animals or to build houses. Therefore, majority of farmers may not be able to compensate for these losses that result in negative nutrient balances on their farms [36]. In addition, the use of organic nutrient sources is also constrained by labor availability for collecting and applying these materials as there is competing demand for these crop residues for fuel, fodder and thatch for building houses.

The results of the agronomic yield across the 22 villages where *likoti* is practised are presented in Figure 2. There were significant differences in the grain yields of maize across these villages. Results showed that grain yield ranged from 150 – 4500 kg/ha with a mean of 1218.19 kg/ha (Berea District) to between 150-1600 kg/ha with a mean of 610 kg/ha (*Leribe* District) (Table 4). Examination of grain yields across these villages showed that a village called *Ha-Ts'alemoleka* (*Butha Buthe* District) had the highest grain yield of 2113.0 kg/ha and the least was about 100 kg/ha in *Ha-Khoeli* village (*Maseru* District). When the DEA method was used to examine the productivity of the LFS across these villages using not only the output (i.e., grain yield), but other inputs (i.e., amount paid for renting land (Loti), quantity of fertilizer used (kg/ha), amount spent on purchasing fertilizer (Loti), quantity of seeds used (kg/ha), man-day spent on the field (hrs), quantity of herbicides used (litres/ha), and cost of purchasing herbicides (Loti), the result was interesting [37]. It showed that about 18.20% (4 DMUs/villages) were technically efficient (i.e., efficiency score was 1.0). The technically efficient "*likoti*" farmers are located in Berea (i.e., *Ha-Qoqo, Ha-Lifotholeng*, and *Ha-Pelesa* villages) and *Leribe* (*Ha-Levi's Nek* village) districts. These villages actually used the minimum amount of input to produce the outputs (i.e., grain yield). The eighteen other farmers (i.e., 81.80%) can be classified as inefficient (Figure 4) as they were using more inputs to produce the same amount of grain yields (i.e., output). Other results of LFS published by other authors considered only agronomic yields; such studies though very informative [1,4,5], did not examine in detail how much inputs were used by the farmers considred. For example, a closer observation of the results presented in Figure 2

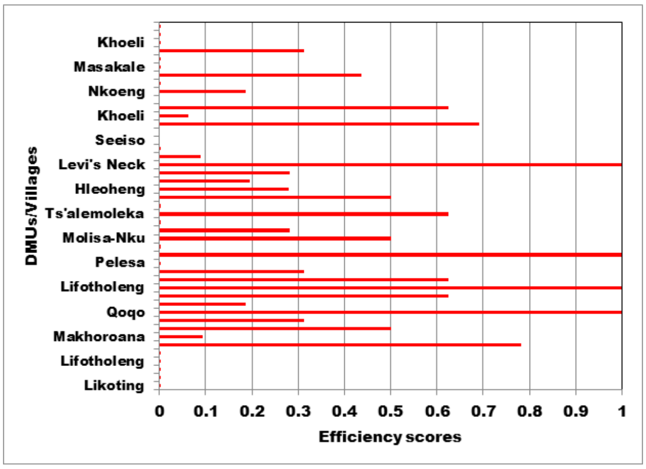

Figure 4: Technical efficiency scores of *Likoti* Farming System across all villages.

showed that in terms of agronomic yield of maize, the best performing *Likoti* farmers were those in *Ha-Ts'alemoleka* village (*Butha Buthe* District) and the least performing was in a village called was *Ha-Khoeli* (*Maseru* District). However, an observation of the technical efficiency scores of these *likoti* farmers in the afore-mentioned villages were 0.625 and 0.312 respectively [38].

The results of the second stage DEA showed that the following inputs (i.e., amount paid for land (i.e., land rent), man days, wage rate and cost of labour were significantly related to the efficiency score across all the villages/districts (Table 5). This suggests that in order for these farmers to be technically efficient and for *likoti* farming practices to be adopted, the Government Of Lesotho (GOL) should formulate a policy where farmers adopting these farming practices would pay less for land being purchased and the wage rate would be increased from minimum of 100 loti/day as in the case of Berea district (Table 4). It would be observed that majority of the technically efficient smallholder farmers are located in this district [39]. Thus, it is recommended that in order for smallholder farmers in Lesotho to properly adopt the LFS, the government should reduce the amount of money paid by farmers to rent/own landed property, increase the wage rate of labourers on such farms to encourage LFS among the rural poor.

Conclusions

Climate change (CC) and soils with sub-optimal nutrient contents is negatively impacting the yield of maize in Lesotho. One of the ways smallholders in Lesotho try to mitigate the impact of CC and sub-optimal nutrient contents are through the practise of conservation agriculture (CA) called *likoti* farming. From this investigation, results have shown that it may be erroneous for researchers evaluating the impact any form of conservation agriculture (CA) (i.e., *likoti farming*) to base their results only on agronomic yield of crops being planted. It would be worthwhile for researchers to try and factor in other household level covariates (e.g. age, sex, farm size, quantity of fertilizer, and herbicides, and amount of labor used etc.) in evaluating the yield of crops [10] before making decisions on whether such technologies are technically efficient or not. Results has shown that higher agronomic yield of crops (e.g. maize) in this investigation did not translate into higher efficiency or productivity of such farmer(s).

Acknowledgement

Part of the funding to conduct this investigation was due to support from The Forum for Agricultural Research in Africa (FARA)/ Norwegian Agency for Development Cooperation (NORAD) in support of "Sustaining the Comprehensive African Agriculture Development Programme (CAADP) momentum".

	Coefficients	Std. Error	t	P > |t|	-95% Confidence Interval-	
Farm size (Ha)	-0.004040	0.010183	-0.40	0.694	-0.024712	0.0166332
Payment for land (Loti)	-0.000023	0.000011	-2.14	0.039*	-0.000044	0.0000019
Fertilizer used (kg/ha)	-0.000169	0.000413	-0.41	0.684	-0.001007	0.0006681
Fertilizer cost (Loti)/season	0.0002641	0.000638	0.41	0.681	-0.001031	0.0015594
Quantity of seeds used (kg/ha)	0.0056878	0.004435	1.28	0.208	-0.003316	0.0146916
Man-days (hrs)	-0.006378	0.002228	-2.86	0.007**	-0.010902	-0.0018552
Wage rate/day	-0.015214	0.003450	-4.41	0.000**	-0.022218	-0.0082091
Quantity of herbicide used (Litres/ha)	-0.008751	0.108157	-0.08	0.936	-0.228320	-0.0082091
Price of herbicides (Loti)/ season	-0.005234	0.000301	-1.74	0.093	-0.001135	0.2108189
Labour cost (Loti/season)	0.0002016	0.000077	2.63	0.013**	0.0000459	0.0000879
Constant	0.5977546	0.086232	6.93	0.000	0.422694	0.0003573
Sigma	0.2319654	0.025655				0.2840486
Number of observations = 105; LR Chi^2 (10) = 32.63; Prob > Chi^2 = 0.0003; Pesudo R^2 = 0.9262 Log Likelihood = -1.300; *= significant at 5%; **=significant at 1%						

Table 5: Results of Tobit regression analysis using efficiency scores as independent variable.

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This article was originally published in a special issue, **Global Climate Change** handled by Editor. Dr. Fatih Evrendilek, Abant Izzet Baysal University, USA