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Indigenous Knowledge and Approaches of Soil Fertility Management among Small Scale Farmers in Semi-Arid Areas of South Africa

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ABSTRACT

As is the case with many other countries in sub-Saharan Africa, crop production among small scale farmers, especially those in semi-arid regions of South Africa, is hampered by predominance of extreme climate (low, irregular & erratic rainfall), low inherent soil fertility and low use of mineral fertilizers. However, the small scale farmers have developed a range of indigenous knowledge and practices which have played a pivotal role in the management of soil fertility for sustaining crop productivity. This study sought to establish and document these strategies in four farming districts located in semi-arid areas of the country. It was found that farmers use locally adaptable and cost effective strategies including animal manure, ash from veld fire, agroforestry, fallow, *termitaria*, and earthworm castings to manage soil fertility. Some of these strategies were applied in specific niche locations and soils, times and crops. Furthermore, the farmers have developed local knowledge and criteria of classifying manure quality based on characteristics such as colour, wetness, presence of moulds and sand content that are used to make soil fertility management decisions. Analyses of samples of some of the organic resources used for soil fertility management confirmed their superior plant nutrient contents. The study concluded that research endeavors should recognize and build upon this wealth of indigenous knowledge and practices of soil fertility management by small scale farmers in these marginal environments of the country.

Keywords: Indigenous knowledge; nutrient management; semi-arid areas; small scale farmers; soil fertility, soil nutrients

INTRODUCTION

The sub-Saharan Africa is the only region of the world where per capita food production has remained stagnant for a long time (Sanchez, 2002). The majority of the resource poor people in this region reside in rural areas and agriculture is the principal economic sector upon which they depend for their livelihoods. Africa's food security is directly related to insufficient total food production. Low agricultural production results in low income, poor nutrition, low consumption, poor education, poor health and lack of empowerment (CIAT, TSBF & ICRAF, 2002). Although the low crop productivity is due to many factors, however, decline in soil fertility is considered to be one of the major factors for this situation (Smaling and Braun, 1996; Sanchez, et al., 1997). Soil fertility status is the foundation of cropping system productivity in the smallholder agriculture sector of Southern Africa (Snapp, 1998). Depletion of soil fertility often results in low yields which threatens household food security.

Consequently, household food security and nutrition issues are at the top of the planning agenda in many countries in sub-Saharan Africa (Babu, 2000).

Intensification of agricultural production is required to meet the food and income needs of the poor, and this cannot occur without investment in soil fertility (Laker, 1976). Although the use of mineral fertilizers is commonly applied to overcome nutrient depletion in soils, its use by the majority of small scale farmers in South Africa is still limited due various constraints (FSSA, 1997; Gerner and Harris, 1993). These farmers have some of the lowest rates of fertilizer use in the world (Smaling et al., 1997). Neither the majority of African farmers, nor African economies, can afford the financial resources needed to adequately fertilize their cropland with commercial fertilizers. In semi-arid areas that occupy about 23% of South Africa (Maraka, 1987) a combination of inadequate soil moisture and poor soil fertility presents one of the most challenging agricultural environments for crop production. Yet, soil fertility management has long been part of farming practice of local communities throughout the country. Small scale farmers have long recognized the need to enhance soil properties, including its structure, nutritional and water retention capabilities, by using soil amendments (Campbell et al., 1998). According to Edje, Semoka and Haule (1988), farmers in the region were generally organic in nature and used neither chemical fertilizers nor pesticides to support crop production. Using indigenous knowledge and experiences, farmers in the semi-arid environments have developed various practices of improving or maintaining soil fertility and systems (Mascarenhas, 2004).

Indigenous knowledge is unique to a particular culture and society and is the basis for local decision-making in agriculture and other activities (DST, 2005). Indigenous knowledge provides the basis for problem-solving strategies for local communities, especially the poor. Indigenous agricultural and environmental knowledge gained global recognition through the United Nations Conference on Environment and Development (UNCED) in 1992. Indigenous knowledge is an immensely valuable resource that provides insights on how to manage soils for sustainable crop production, and can contribute significantly to increased food availability household food security (Mascarenhas, 2004). Indigenous knowledge systems are being examined by academicians, development planners, and researchers as alternative approaches to development (World Bank, 1989). Given that the Green revolution aspects of agriculture have largely failed in many semi-arid areas of sub Saharan Africa, strengthening and building on the existing indigenous knowledge base through interfacing with modern technology may help reverse the declining trends in soil fertility.

The objective of this study was to document and quantify some of the indigenous knowledge and soil fertility management strategies used by small scale farmers in semi-arid areas of South Africa.

MATERIALS and METHODS

Location of Study Sites within the Semi-Arid Areas of South Africa

The study was conducted in four farming districts of the North West province in South Africa *viz* Mafikeng, Ditsobotla, Ganyesa and Taung all located in semi-arid regions. Semi-arid areas make about 23% of the country and it is estimated that approximately 14% of the population live in such areas. The areas are characterized by poor and erratic rainfall that ranges from 450-650 mm $annum^{-1}$. The probability of a 'normal' season occurring in these regions is 34-40% (Maraka, 1987). Although livestock production and cultivation of drought-resistant grain and fodder crops are emphasized, less-tolerant crops like maize are also dominant.

The soils in the study areas can broadly be categorized into two clusters consisting low infiltration rate, relatively high fertility clays and high infiltration rate, relatively low fertility sandy loams. The clays are either alluvial or derived from dolerite outcrops, while the sandy loams are derived primarily from granite. There are numerous intergradations within and between these broad types. The predominant soil profiles consist of an orthic topsoil with red apedal B-horizon which according to the local classification system belong to the Hutton form (Soil Classification Working Group, 1991).

Sampling Procedure and Data Collection

The study was collected during the summer (October 2006 to March 2007). A list of farmers involved in crop production in each of the study districts was obtained from the respective district offices of agriculture. A sample of 50 farmers in each area was randomly selected from the list. Visits were made to each farmer and a questionnaire was administered using a Participatory Rapid Appraisal (PRA) approach. The interview consisted of a combination of structured and open-ended questions. Information sought was related to the nature of indigenous knowledge, approaches used and their reasons, the source of knowledge and time of use. Physical observations were sued to verify the information.

Collection and Analysis of Soil Fertility Management Resources

In order to quantify the nutrient content and supplying capacity, samples of some resources used for soil fertility management (manure, ash, earthworm casts and termitaria) were collected from randomly selected farms visited during the study. The samples were analyzed for ash and organic matter content by igniting 5 g sample at $500^{o}C$ for 2 h (Okalebo et al., 1993). Ashed materials were extracted three times with 50% HCl and the dissolved material was analyzed for potassium and sodium by flame photometry; calcium, magnesium, iron, zinc and manganese by atomic absorption spectrometry. Nitrogen and phosphorous content of the materials were determined colorimetrically after digesting in sulphuric acid and hydrogen peroxide (IITA, 1979).

Data Analysis

Descriptive statistics for the socio-economic variables collected by questionnaires were analyzed using frequency counts, percentages, means and standard deviations using the SPSS software. A t-test and Least Significant Differences were used to compare means of the analytical values of the organic resources.

RESULTS AND DISCUSSION

Indicators of Soil Fertility Problems

Soil fertility problems were widely recognized by farmers in the study areas using various indicators (Table 1). Progressive decline in crop yields was associated more with soil fertility than rainfall. Most of the farmers could remember trends of yield declining in the monocropped cereals. Yellowing and other coloration of leaves during crop growth was also related to poor soil fertility although no specific nutrients would be indicated. Framers also clearly indicated that as a result of poor soil fertility, crop growth was stunted in most fields. Other notable indicators of low soil fertility included: lot of sand in the field, soil compaction and poor seedling emergence.

Animal Manure

Animal manure is of vital importance in maintaining soil fertility among small scale farmers in semi-arid areas of South Africa due to the low levels of use of inorganic fertilizer. The use of animal manure as a source of plant nutrients is a well-established practice especially among the small scale-farming sector in the study areas (Table 2). This is because keeping of livestock is an integral part of the households in semi-arid areas. It was clear from the responding farmers that they used manure because of its ability to improve soil fertility and crop yields (Table 3). Manure is used mainly as a source of N and P, which are nutrients that limit crop production in the majority of agricultural soils in South Africa. The main reason given by the respondent farmers for not using animal manure in managing soil fertility was that it encouraged weeds and pests. As a result, some of the farmers preferred to compost the manure before using it in order to kill the wed seed bank. Some of the farmers indicated that they did not have sufficient management knowledge to effectively use manure and feared that it could ‘burn’ their crops. In many of the areas, farmers were constrained from using manure because it was used as source of energy and decoration on the walls of their mud houses.

Another strategy of manure utilization involved the use of old cattle kraal sites for growing crops. Many farmers indicated that higher crop yields were obtained from those grown on previous kraal site compared with that grown away from the kraal site. Because of this, previous kraal sites are widely protected and used for crop production long after the kraal has been moved and/or abandoned. The better growth and yield of maize grown on previous kraal site was ascribed to improved soil structure which benefits the soil's water storage and nutrient availability.

Manure Quality

The quality of manure for soil fertility is determined by the chemical composition of the manure. High quality manure has low C:N ratio and releases nutrients rapidly during decomposition whereas low quality manure has a high C:N ratio and causes immobilization of nutrients during the early stages of decomposition. The study recognized that farmers in the study areas have different perceptions and indicators of manure quality (Table 4). Colour of manure, moisture content, texture and presence of moulds and un decomposed crop residues stood out as the most important indicators of manure quality. The farmer quality criteria were consistent across the study areas. A good quality manure was considered to be dark, moist, fine, with no sand, few moulds and has no crop residues. They also recognized that manure of high quality has a long residual effect and that it results in good soil moisture retention, crop germination and increased yields. Although it was established that the majority of farmers were aware that manure quality was affected by management and housing, there was very little being done to improve the quality. Consequently, the quality of most of the manure was lower compared to that from commercial farmers in the same areas (Table 5).

Generally, there was a large variation in the nutrient and sand contents of manure from the different households and villages. This was associated with differences in the management of the manure especially the housing, supplemental feeding and provision of bedding materials. The relatively high sand content of the manure samples was a concern as it reduced the quality of the manure.

Ash from Veld Fires

Fire has for a long time been considered a valuable tool in the management of savanna areas used for livestock and wildlife production in many parts of the semi-arid areas of South Africa (Tainton, 1988). The four main objectives for using fire in veld management include: to burn off unpalatable growth left over from the previous season; to stimulate growth during seasons when there is little young forage available on the veld; to destroy parasites, particularly ticks; and to control the encroachment of undesirable plants in the veld. Burning of the veld by farmers in the dry areas of South Africa is done in such a way that it coincides with the first spring rains because experience has shown that good spring rains accelerate regrowth of burnt veld (Teague et al., 1981; Trollope, 1978). Grass from regrowth of burnt veld has been shown to be more nutritious and acceptable to grazing animals than that which has been defoliated by grazing or mowing (Tainton et al., 1978). Small scale farmers in the study areas indicated the knowledge that veld which is burned early (June or July) recovers to an acceptable grazing stage no earlier (and indeed no later) than veld that is deliberately burned in August or early September just before or after the first spring rains.

In order to quantify the effect of veld fire on changes in nutrient concentration of a surface (0-5 cm) layer of a veld soil, we sampled soil from selected farms where the veld was subjected to burning before the rain. Table 6 shows that burning significantly increased the concentration of exchangeable Ca, Mg, K, Na, pH and extractable P but reduced the organic carbon and total N contents of the soil in both burnt plots. The amount of nutrients in the ash depended on the quantity of biomass available on the plot at the time of burning. Organic C and N were however significantly ($P < 0.05$) higher in unburnt than burnt plots. These results show that burning resulted in substantial increases of extractable P and exchangeable Ca, Mg, K and Na in the surface soil. The nutrients were bound in plant tissues before the fire and were therefore temporally unavailable for plant growth. The fire was considered to have provided a quick mechanism of releasing the nutrients locked up in the above ground biomass back to the soil surface (Stock and Lewis, 1986). Because of the increased concentration of nutrients and the raised pH in the surface layers of the soil, it may be possible that growth and productivity of grass in the veld will respond to burning through improved nutrient uptake.

Agroforestry

Agro forestry is a land-use system that integrates the production of woody perennials (trees and/or shrubs) with agricultural crops (food, fodder, fibre crops) with or without livestock simultaneously, sequentially, zonally or in relay on the same unit of land (Young, 1988). In parts of the semi-arid areas of South Africa, farmers have since time in memorial known, utilised the agroforestry potential of indigenous *Acacia* spp. trees in their landscape for crop production.

Acacia erioloba also known as Mpatsaka (Sotho), Mokala (Tswana), Kameeldoring (Afrikaans), Umwhohlo (Ndebele), Moghlo (Sepedi) and Camel Thorn (English) is an indigenous leguminous tree of the dry savanna environments of Southern Africa including Namibia, Angola, Zimbabwe, Botswana, South-western Zambia and South Africa (Smit, 1999). *A. erioloba* is found mostly on deep sandy soils of the semi-arid areas where it occurs in open savanna or on alluvial soils along dry river beds. The tree is evergreen to semi-deciduous and can grow up to 20 m tall with a wide spreading crown. Although not normally used for human food, *A. erioloba* trees provide many valuable products including fuel wood, wood for building, thorny branches for fencing, proteinaceous forage from its pods and shade for domestic livestock and people. Farmers generally recognize that crops grow better in the soil under *A. erioloba* than in areas outside the trees' influence. Consequently, the farmers protect the trees and cultivate crops under their canopies.

To further investigate the nutrient cycling by *A. erioloba* trees, we measured the concentration of nutrients in soils collected from under and beyond canopies of *A. erioloba* trees in two common local agroforestry practices in the study areas. Paired soil samples taken under and beyond *A. erioloba* tree canopies showed that there was a significantly higher ($P<0.05$) concentration of N, P, Ca, Mg, Zn and Mn in soils collected from under *A. erioloba* canopies compared with those collected beyond the canopies (Table 7). The nutrient concentrations were consistently higher in soil from trees that were located in grazing land than croplands. Except for Ca, the concentrations of all other nutrients were significantly higher ($P<0.05$) in soil from under *A. erioloba* canopies than in that from beyond. Soil pH was significantly lower ($P<0.05$) under than beyond tree canopies. The study concluded that the presence of *A. erioloba* trees improved the fertility of soils under the tree canopies in the agroforestry practices studied. The source of increased nutrients under *A. erioloba* trees was attributed to leaf fall, the organic matter added to the soil from grass and cattle dung, and urine from domestic livestock. This was consistent with reports of the ability of similar tree species (e.g. *Acacia albida*) to influence soil nutrient concentration, growth and yields of crops documented elsewhere on the continent (Gerakis and Tsangarakis, 1970; Weil and Mughogho, 1993; Buresh and Tian, 1998).

Fallow

Fallow is a cropland that is left without crops for periods ranging from one season to several years. There can be several reasons for fallowing. In the study, the number of farmers' fields which laid fallow were identified and visited. The proportion of small scale cropping land that had fallow is shown in Table 8. The farmers were asked the reasons for leaving the land fallow and the significance of the fallow (Table 9). The average land under fallow in the study areas was 31%. The main reason given as to why farmers had stopped cultivating was: Land tenure system; Lack of finance; Soil fertility management; Low & erratic rainfall; Lack of tractors & implements and High input costs. Some of the grass species that dominated the fallow fields included *Tagetes minuta, Sporobolus africanus, Eragrostis lehmanniana, Cynodon dactylon, Hyparrhenia hirts, Chenopodium carinatum,* and *Richardia brasiliensis*. There were Acacia bushes in most of the fields which the farmers said were kept to fasten the regeneration of soil fertility. The fallow periods ranged from 0-3 years (57%) and >3 years (43%). Overtime, it was suggested that the fallow period would increase the organic matter content of the soil; improve the soil structure including water holding capacity; recycle and trap nutrients from sub-soil; protect the soil from erosion and eliminate weeds, pests and diseases specific to the cropping system.

Termite Mound Soil-Termitaria

Many landscapes of South Africa, especially grazing lands (*veldt*), are dotted with small to large soil mounds constructed by termites. These are more often termed as "white ants", "termite mounds" or "anti hills". The termites are closely associated with soil since they: ingest soil as source of food, construct nests and mounds, and break down organic materials/forage which they utilize as food sources. Consequently, the termite mound soil has superior properties for plant growth and yields. This unique attribute of mound soils has been recognized by many farmers in South Africa's semi-arid areas as an agronomic resource for replenishing soil nutrients, as well as other parts of the Southern African Region (Mapfumo and Giller, 2001; Scoones et al., 1996).

In these areas, some of the mounds are broken down and the mound soil is spread over the other parts of the field as a soil amendment and fertilizer. The rate of application was quite variable and could be estimated at between 0.25 and 7 t ha^{-1} by individual farmers with a wide variation between farms. Crops such as water melon, butternut, green pepper, spinach and sweet sorghum cane which require good water supply and high nutrient levels are almost exclusively grown on termite mounds.

Farmers indicated that they used termitaria as an insurance against crop failure in the case when there is drought at critical stage in the development of the crop. Some farmers indicated that they applied the termitaria in small dollop holes close to the maize plant as is done with inorganic fertilizer. The rates of application were quite variable and could be from 0.25 to 10 t ha^{-1} on individual farms. In many instances, farmers traveled into the grazing area and bring back termite mound soil in a cart and mix it with the poor sandy soils to improve their fertility. It was claimed that this significantly increases the fertility and strength of the soil, and made it hold water better and longer. Availability of labour was the major constraint for using termitaria for soil fertility management.

Earthworm Casts,

Earthworms constitute a large proportion of soil mesofauna and are extremely important because they are involved in many key processes in the soil. Earthworms play a vital role in nutrient cycling through organic matter decomposition (Lee, 1985), and have the potential to significantly improve soil physical, chemical & biological properties (Lavelle et al., 1998). Through their feeding and burrowing, earthworms can improve soil aggregate stability, incorporate surface organic matter, lime and fertilizers, create macro porosity, increase soil microbial activity and enhance nutrient availability in the soil (Lee, 1985). Because of these key roles in soil ecosystem functioning, earthworm numbers and biomass have been used as indicators of soil quality and sustainable land management practices (Karlen et al., 1997). Apart from the population and size of earthworms, the species composition is also important as it influences the efficient functioning of earthworms in an ecosystem to which they are well adapted.

In respect of the chemical fertility, farmers in the study area were aware that worm-cast soil is superior to the surrounding non-casted soil and so claimed that this was responsible for the improved growth, in both field crops and veld grass, in areas where substantial amounts of casts were deposited by worms. Our analysis of the nutrient content of dry earthworm casts and corresponding non-casted soil confirmed the farmers claim (Table 10). It was therefore not surprising to note that some farmers in the study area used the casts like dressings of fertilizer by placing them in dollop holes close to the plant roots. The farmers also indicated that they preferred to use fresh casts as opposed to old casts since the former were easy to break and produced better results.

CONCLUSIONS

This study has shown small scale farmers in the study areas effectively utilize indigenous knowledge and available resources for soil fertility management in the semi-arid areas of South Africa. Indications are that, as the intensification of small-scale farming becomes higher due to the large numbers of emerging farmers in South Africa, these strategies and knowledge base will continue to play an important role as a way of maintaining soil fertility for sustainable crop productivity. Evidence from this study suggests that there are scientific basis for these approaches. It is therefore concluded that indigenous knowledge is vital in the technology adoption process and needs to be strengthened in the study areas.

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Table 1

Farmers' indicators of soil fertility problems

Rank	Indicator	Mafikeng	Ditsobotla	Ganyesa	Taung	Mean±SD
1	Low crop yields	73±5	81±4	78±2	75±5	77.8±6
2	Yellowing of leaves	68±4	61±3	65±2	67±5	62.3±3
3	Stunted growth of crops	61±3	60±6	59±4	64±8	61.0±2
4	Uneven growth of plants in field	56±2	57±6	60±4	53±2	56.5±3
5	Soil compaction	51±6	50±4	57±5	55±6	53.3±5
6	Poor soil structure	43±4	46±8	45±2	48±3	45.5±6
7	Lot of sand in the field	39±5	42±2	39±4	41±5	39.8±3
8	Poor emergence & stand	26±2	31±7	28±8	33±4	29.5±1
9	Disease and pest proliferation	11±6	19±3	22±7	15±6	16.5±4

Values are means ± SD, n=50

Table 2

Proportion of farmers using animal manure for soil fertility management in the study districts

District	Used manure	Did not use manure
Mafikeng	69	31
Ditsobotla	84	16
Ganyesa	77	23
Taung	81	19
Mean±SD	77.8±6.5	22.3±3.4

Table 3

Reasons given by farmers for using and not using manure for soil fertility management (in order of decreasing importance)

Rank	Using manure	Not using manure
1	Improves soil conditions	Encourages weed infest station in fields
2	Improves soil nutrients	Lack of labour
3	Increases soil moisture holding	Not enough manure (too few animals)
4	Better crop yields	Encourages worms and insects
5	No money to buy fertilizer	Bad smell
6	Health crops	Can not afford to purchase
7		Prefer fertilizers
8		Burns crops
9		Lack of knowledge in manure management
10		Alternative use as energy and decoration

Table 4

Manure quality indicators recognized by farmers in the study areas (in order of importance)

District	Quality indicators and criteria
Mafikeng	Presence of moulds; Moisture content; Presence of cow dung clods; Presence of crop residues; Compactness of manure; Manure odour.
Ditsobotla	Colour; Sand content; Compactness; Moisture; Presence of moulds; Cow dung clods; Presence of crop residues; Weight;.
Ganyesa	Colour; Texture of manure; Sand content; Odour; Cow dung clods
Taung	Moisture content; Colour; Presence of sand; Presence of moulds; Presence of cow dung clods; Compactness.

Table 5

Quality characteristics of cattle manure samples collected from selected farmers' fields in the study districts

District	Nutrient content (%)				Moisture content (%)	Organic carbon (%)	Sand content (%)	C:N ratio
	N	P	K	S				
Mafikeng	1.15±0.92 (0.62-2.3)	0.19±.07 (0.05-0.31	0.63±.55 (0.27-2.01)	0.08±.02 (0.02-0.16)	9.7±4.6 (6.3-15.4)	17.6±3.2 (12.1-23.3)	52.6±6.1 (34.2-58.3)	15:1
Ditsobotla	0.98±1.01 (0.86-2.7)	0.25±.12 (0.03-0.34)	0.91±.83 (0.42-1.89)	0.23±.06 (0.16-0.45)	11.3±3.5 (7.1-14.8)	19.3±2.1 (14.2-24.1)	56.1±4.4 (39.2-61.5)	19:1
Ganyesa	1.22±2.01 (0.77-3.2)	0.13±.03 (0.06-0.27)	1.02±.37 (0.36-1.25)	0.14±.04 (0.08-0.29)	12.5±1.1 (8.4-14.6)	14.2±2.8 (11.4-18.6)	49.5±5.2 (42.4-54.7)	11:1
Taung	0.83±1.87 (0.56-2.5)	0.07±.15 (0.05-0.16)	1.17±..21 (0.60-1.63)	0.32±.07 (0.11-0.38)	15.7±2.7 (9.5-17.5)	16.5±3.3 (10.3-21.4)	39.4±10.3 (28.6-52.8)	19:1
Mean±SD	*1.02±.22*	*0.16±08*	*0.93±23*	*0.19±11*	*12.3±2.5*	*17.4±2.9*	*49.4±7.2*	
T-test	*	*	**	*	*	* *	**	**

Values are means ±SD; Numbers in parenthesis are ranges; *p<0.05; **p<0.001

Table 6

Effect of burning frequency on soil nutrient pools in the 0-5 cm layer of a veld soil measured before (BB) and after (AB) burning of biomass at a site in Ganyesa district. The control treatment was not burnt

Soil Nutrient	Sampling time			Burning frequency								
				No burning		Every year		Every 3 years		Mean	SE	
Ca (mg kg^{-1})	BB			453±26	426±17	487±43	455	25				
	AB			-		528±24	559±31	544	16			
		Mean				477		523		500		
Mg (mg kg^{-1})	BB			81±5		93±3		99±10		91	7.0	
	AB			-		107±5		111±7		109	2.0	
		Mean				100		105				
K (mg kg^{-1})	BB			308±62	212±38	215±45	245	45				
	AB			-		285±49	301±51	294				
		Mean				249		259				
Na (mg kg^{-1})	BB			53±6		38±2		38±6		44	8.0	
	AB			-		88±3		60±3		74	14	
		Mean				63		49				
P (mg kg^{-1})	BB			9.9±2		6.5±.7		10.2±3		8.9	1.6	
	AB			-		11.9±3		13.0±1.912.5		12.5		
		Mean				9.2		11.6				
Org. C	BB			1.36±.2	0.9±.13	1.14±.111.15		0.16				
(g kg^{-1}) AB			-		0.68±.080.93±.060.9			0.13				
		Mean				0.88		1.04				
Total N	BB			2.5±.3		1.67±.1	2.17±.2	2.11	0.3	(mg		kg^{-1})
AB			-		1.04±.091.73±.331.39			0.21				
		Mean				1.34		1.95				
pH	BB			5.48±.065.52±.045.76±.025.57								
	AB			-		6.08±.236.28±.296.23						
		Mean				5.9		5.89				

Values are means of four determinations ! standard deviation
SE, standard error of the mean

Table 7

Soil nutrients and pH at different canopy locations of the *Acacia erioloba* tress in the selected study dry areas

Canopy Location	Total N (%)	Available P (mg kg^{-1})	Exchangeable cations (mg kg^{-1})					
			K	Ca	Mg	Zn	Mn	pH
Mafikeng (n=13)								
Beneath canopy	0.14±.01	15.1±.4.3	191.1±32	805.7±97	351±.102	3.9±.24	44.8±.17	6.2±.08
Beyond canopy	0.08±..02	11.5±.6.4	115.6±77	768.8±105	359±.84	2.2±.43	30.3±.9	6.5±.03
t-test	ns	*	**	ns	ns	*	*	*
Ditsobotla (n=27)								
Beneath canopy	0.24±.01	19.6±.2.3	213.1±21	904±47	332±67	2.9±.04	31.8±.83	6.6±.4
Beyond canopy	0.11±..01	11.5±.4.1	175.6±47	834.8±105	299±74	1.6±.33	29.6±.92	6.8±.3
t-test	*	*	*	ns	ns	**	ns	ns
Ganyesa (n=11)								
Beneath canopy	0.74±.05	26.4±.1.3	186±32	756±27	322±67	4.1±.34	56.7±.13	6.8±.3
Beyond canopy	0.38±.03	19.3±.3.4	132±77	742±76	289±84	3.6±.41	48.9±.66	6.2±.1
t-test	*	*	*	ns	*	*	*	*
Taung (n=21)								
Beneath canopy	0.51±.03	17.4±.2.3	224±32	645±47	210±42	2.7±.24	29±3.7	6.0±.8
Beyond canopy	0.23±.02	13.6±.1.4	193±27	578±12	184±.17	2.4±.43	21±1.8	6.3±..3
t-test	*	*	*	*	*	ns	*	*

Values are means ±SD; *$p<0.05$; ns, not significant

Table 8

Proportion of farmers in the study districts with fallow on their cropping land

District	Average Farm size (ha)	Fallow (%)
Mafikeng	3.2	20
	(2-8)	
Ditsobotla	4.1	37
	(4-9)	
Ganyesa	3.5	41
	(1-5)	
Taung	7.6	26
	(3-15)	
Mean±SD	4.6±2.3	31±9.7

Numbers in brackets are ranges

Table 9

Reasons for leaving land fallow

Reason	Mafikeng	Ditsobotla	Ganyesa	Taung	Mean±SD
Lack of finance	73	77	69	75	73.5±3
Lack of tractors & implements	61	67	57	71	63.0±6
Low & erratic rainfall	68	64	55	65	63.0±4
Soil fertility management	63	56	50	46	53.8±7
Land tenure system	58	54	53	55	55.3±2
High input costs	50	48	45	53	49.3±4
Lack of farming knowledge	34	30	28	31	30.8±5
Lack of training & ext service	22	24	16	11	18.3±6

Table 10

Nutrient content of dry earthworm casts and corresponding non-casted surface soil from selected farmers' fields in the study areas

Material	pH-H_2O	Organic C (g 100 g^{-1})	Bray 1-P (mg kg^{-1})	Total N (g 100 g^{-1})	Exchangeable cations (mg kg^{-1}) Ca	Mg	K	Zn	Mn
Mafikeng (n=17)									
Worm-cast	6.4±0.2	1.47±0.32	17.4±5.2	1.25±0.12	890±65	185±31	537±78	8.3±0.3	19.4±2.3
Non-casted soil	5.7±0.4	0.89±0.03	4.1±1.5	0.22±0.03	603±37	97±18	288±56	1.7±0.1	8.6±0.8
T-test	*	*	**	*	*	*	*	**	**
Ditsobotla (n=11)									
Worm-cast	7.3±0.1	1.66±0.24	26.4±3.2	1.66±0.28	786±69	145±09	613±84	7.1±0.8	23.4±1.3
Non-casted soil	6.5±0.3	0.93±0.11	11.1±0.4	0.42±0.13	503±27	107±26	248±50	2.2±0.2	6.6±0.5
T-test	*	*	**	*	*	*	*	**	**
Ganyesa (n=9)									
Worm-cast	6.8±0.2	1.58±0.13	32.7±6.2	1.06±0.48	943±71	223±24	638±97	9.5±0.7	18.7±3.3
Non-casted soil	6.1±0.3	0.67±0.03	13.6±0.5	0.32±0.22	669±27	100±08	433±26	5.8±0.1	7.7±0.2
T-test	*	*	**	*	*	*	*	**	**
Taung (n=21)									
Worm-cast	6.7±0.5	1.92±0.22	21.4±4.2	1.27±0.31	708±49	143±23	501±88	6.1±0.4	21.4±1.3
Non-casted soil	5.9±0.2	0.77±0.13	9.9±1.1	0.66±0.16	567±58	121±12	312±46	3.9±0.1	12.6±0.5
T-test	*	*	**	*	*	*	*	**	**

Values are means ±SD, n=15; *$p<0.05$; **$p<0.001$