Chapter

Agroforestry Trees for Fodder Production in Limpopo Province, South Africa

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Abstract

Climate change and land degradation, resulting from human-induced pressures on ecosystems are threatening crop productivity, food and feed supply, and food security in the Limpopo Province of South Africa, especially within the socio-economically marginalised communities. A combination of survey and field experimentations were conducted from 2016 to 2018 to assess potential climate-smart farming practices that can assist farmers to adapt to local climate change and variability in the province. Results from the survey revealed that agroforestry system with woody perennial speices which encourages minimum soil disturbance, increase soil cover and increase agrobiodiversity is being promoted in the province as one of the effective avenues to achieve sustainability in farming systems in the midst of global climate change. *Moringa oleifera* and *Acacia karroo* (now *Vachellia karroo*) were identified as potential agroforestry tree species to address feed gaps during dry winter months, based on their good nutritional value, drought hardiness and effective carbon capture for climate change mitigation.

Keywords: *Moringa oleifera*, *Vachellia karroo*, climate change, feed, smallholder farmers, food security

1. Introduction

Climate change and soil degradation are real challenges which are currently stressing the already threatened habitats and ecosystem functioning in Africa, with consequent impacts on agricultural productivity and food security [1, 2]. The fast pace of climate change is frightening as this will have a far-reaching impact on agro-ecosystems and their productivity. Human-induced pressures on ecosystems are placing many inhabitants on the African continent at risk, especially within the marginalised communities who rely heavily on the natural environment for sustenance and livelihood [2]. Climate predictions for South Africa indicate that the country has been getting hotter at least 1.5 times more than the global average of 0.65 °C over the past five decades with an increasing number of warmer days and decreasing cooler days [3, 4]. Furthermore, the average annual rainfall of South Africa is 450 mm which is far below the world's average of 860 mm per annum. The country is also characterised by a comparatively higher evaporation rate [3, 5] placing severe stress on soil moisture retention. A yield improvement of more than

20 percent over current investments in agricultural research and development is required, if South Africa is to adapt to the adverse consequences of global climate change [6]. Incidences of water stress and soil fertility degradation during growth results in reduced crop growth, yield losses, low quality products and high level of yield variability.

Agriculture and food security are expected to be highly impacted from the increasing heat and water stresses, land degradation and resource depletion [1] which will likely overburden rural economies in South Africa [7]. In a semi-arid environment such as the Limpopo Province of South Africa, where smallholder agriculture is usually rainfed, the reported impacts of these climatic stresses are already evident on rangeland degradation and livestock production [8]. Livestock production is an important agricultural activity in the rural areas of the province, with the natural pastures (rangelands) and crop residues serving as the main sources of feed, especially during winter dry months. However, the supply of good quality and quantity feed from the rangelands and crop residue cannot be sustainably maintained during the winter and early spring months mainly because of low and erratic rainfall in preceding summer season [9]. The adoption of feed supply systems that are more productive, efficient in resource use, resilient to climate risks and have less variability and greater stability in their outputs in the Limpopo Provinceis required if productivity in crop and livestock farming system is to be maintained.

The national Department of Agriculture, Land Reforms and Rural Development has embarked on LandCare Programmes as an effective avenue to achieve sustainability in the smallholder farming system in South Africa. LandCare is a community based and government-supported approach to the sustainable management and use of agricultural natural resources with the overall goal of sustainable productivity, food security, job creation and better quality of life for all. The programme is implemented through five focus areas, namely: VeldCare (Rangeland), SoilCare, WaterCare, JuniorCare and Conservation agriculture (CA). Conservation agriculture, which promotes permanent or semi-permanent organic soil cover, zero or minimum tillage, and agro-biodiversity in association (intercropping or agroforestry) or sequentially (crop rotation) [10] is one of the practical and affordable location-specific adaptation strategies to address global climate change.

Regarding cropland diversification, agroforestry is being promoted as a feasible strategy that can be adopted by resource-poor farmers to cope with climate change [11]. To optimise the benefits of agroforestry interventions, an approach where CA practices are combined with the establishment of woody perennial species in agroforestry system could significantly improve the productivity of farmers amid climate change in the Limpopo Province. A key aim of the agroforestry system is to enhance positive interactions between its component species leading to the achievement of a more ecologically diverse and socially productive output from the land than is possible through conventional agriculture.

Reported advantages of agroforestry system in conservation agriculture include the restoration of soil health which is pivotal for increasing agricultural productivity, improved supply of fodder for livestock and enhance economic benefits [12, 13]. The recent understanding of global climate change and its consequent impacts on food security and humanity has given credence to Agroforestry as an important climate-smart practice for farmers. The system has a strong ability to sequester carbon and mitigate climate change while increasing the socio-economic and environmental sustainability of smallholder farming system. Furthermore, agroforestry can contribute to the achievement of several listed Sustainable Development Goals (SDGs) and achieve national developmental imperatives.

Additional benefits of agroforestry are improved livelihoods through enhanced crop and livestock health and nutrition, increased economic growth and strengthened environmental resilience and ecosystem sustainability. The diversification of farm enterprise through agroforestry minimises the risk of complete loss of income, in extreme weathers especially from annual crops which are more vulnerable to such harsh conditions relative to the woody perennial component species. Through long-term carbon sequestration, soil enrichment and biodiversity conservation can be enhanced. The prolific root growth of tree species in agroforestry systems builds spongier soils to increase soil's capacity to soak up heavy rainfall and hold the water for dry periods.

Despite the reported benefits of agroforestry systems, the adoption of the techniques among farmers in the Limpopo Province has been suboptimal. Factors that influence the adoption of agroforestry is reported to vary between studies, and as such, further enquiry into adoption process under local scenario is critical to understanding the effectiveness of the system within a community [14]. Currently, locally generated information on agroforestry practices under conservation agriculture in the Limpopo Province is limiting. A survey study conducted by Ayisi, Belete [15] however, indicated that most farmers in the province have a keen interest in adopting agroforestry as a landuse option. The incorporation of fruit trees and fodder species were identified as some of the preferred species by farmers for agroforestry.

To scale out the adoption of agroforestry in the farming system in the Limpopo Province and to address fodder flow constraints among farmers, detailed information on growth, yield, quality of potential fodder species and their overall impacts in conservation agricultural systems in the province is required. *Moringa oleifera* and *Acacia karoo* (*now Vachellia karroo)* are identified as potential tree species that can be cultivated for fodder in the province, with moringa being the most preferred. Moringa is a fast-growing tree species which can reach up to 6–7 m within a year under low rainfall of at least 400 mm per annum [16]. It is also known forits resistance to drought and diseases and also establishing well under harsh growing conditions where most trees cannot withstand [17]. *Moringa oleifera* can be cultivated in all five districts of the Limpopo Province under diverse climatic conditions [18]. In comparison with two dominant indigenous tree species, Mopane (*Colophospermum mopane*) and Marula (*Sclerocarya birrea*), moringa was reported to be superior in photosynthetic rate and stomatal conductance under drought conditions, indicating its potential for climate change mitigation [18].

Vachellia karroo (*formerly Acacia karroo*) is a leguminous indigenous species that easily grow under a wide range of habitats. As a result, it can become an aggressive invader on farmlands and grazing areas. Several areas of the Limpopo Province have already been severely invaded by the species. The carrying capacity of grazing areas and grassland productivity can also be reduced significantly from invasion mainly due to tree-grass competition for soil moisture [19].

Despite its invading characteristics and thorniness, *Vachellia karroo* leaves, pods and seeds are valuable feed supplements during the dry season [20] as they are at times collected by farmers to feed their livestock. Livestock farmers in the Limpopo Province are thus, already knowledgeable about the value of *Vachellia karroo* as a livestock feed supplement but detailed information about its impact on their livestock productivity and quality, particularly goats is limiting. Identifying effective ways of using *Vachellia karroo* will greatly improve smallholder livestock productivity in the province whilst addressing the environmental impact caused by its invading characteristics.

The current approach to controlling the invasion of *Acacia species* in the province is by mechanical and chemical means, controlled fires and the use of goats to browse on the species. Clearing of *Vachellia karroo* on rangelands has been reported to increase of grass productivity [21]. Any additional approach which can utilise the pruned biomass from the *Vachellia karroo*after mechanical control for livestock feeding will be beneficial. Furthermore, if a reduced amount of *Vachellia karroo* is left on defined areas of the rangelands, the increased quantity and quality of the grass in combination with the invader *Vachellia karroo* legume will constitute a workable tree-livestock pasture system to address feed gap for the livestock farming communities in the Limpopo Province.

This study was initiated to promote agroforestry systems among smallholder farmers in the Limpopo Province of South Africa, following two key objectives: First, to understand the reason behind the lack of adoption of agroforestry by farmers as a landuse option to adapt to climate challenges despite the numerous government's interventions. Secondly, to report on results from local on-station and on-farm experiments about the potential of *Moringa oleifera* and *Vachellia karroo (formerly Acacia karroo)* as agroforestry fodder tree species in combination with conservation agriculture practices to address feed gaps in the province.

2. Materials and methods

2.1 Study location

The study was conducted in the Limpopo Province of South Africa. The Limpopo Province is currently divided into five administrative districts, namely Vhembe, Capricorn, Waterberg, Sekhukhune and Mopani with 29 Local Municipalities across the districts (**Figure 1**). Though, the province has a wide range of annual rainfall, ranging from <300 mm to >1000 mm, most parts are relatively dry receiving an annual rainfall of around 400 to 500 mm. Part of the study with field experimentations was conducted at the University of Limpopo experimental farm (Known as Syferkuil) and Itemeleng Bamakhutjwa Farmers' Cooperative (Ofcolaco) during 2014–2015.

2.2 Climate

The Limpopo Province is characterised by hot summer temperatures and cooler winter months with annual rainfall around 500 mm. The spring season starts in September whereas winter commences in June. The monthly temperature and rainfall recorded during the period of experimentation at the two locations are presented in **Figure 2**.

The project objectives were achieved through on a combination of several activities including meetings with relevant stakeholders and farmers, workshop deliberations, review of pertinent government documents and field experimentation. With the assistance of the provincial department of agriculture, farmers engaged in conservation agriculture across the different districts and local municipalities of the province were selected for the study. Farmers from all the five districts participated in the study, thus presenting diversity in the agroecological conditions (rainfall, temperature and soil) under which they are farming.

The approach used to achieve the two project objectives are presented as follows:

a. Resistance to the adoption of agroforestry

Information about the study sites is presented in **Table 1**. The survey was conducted from November 2016 to May 2017 using a quantitative structured

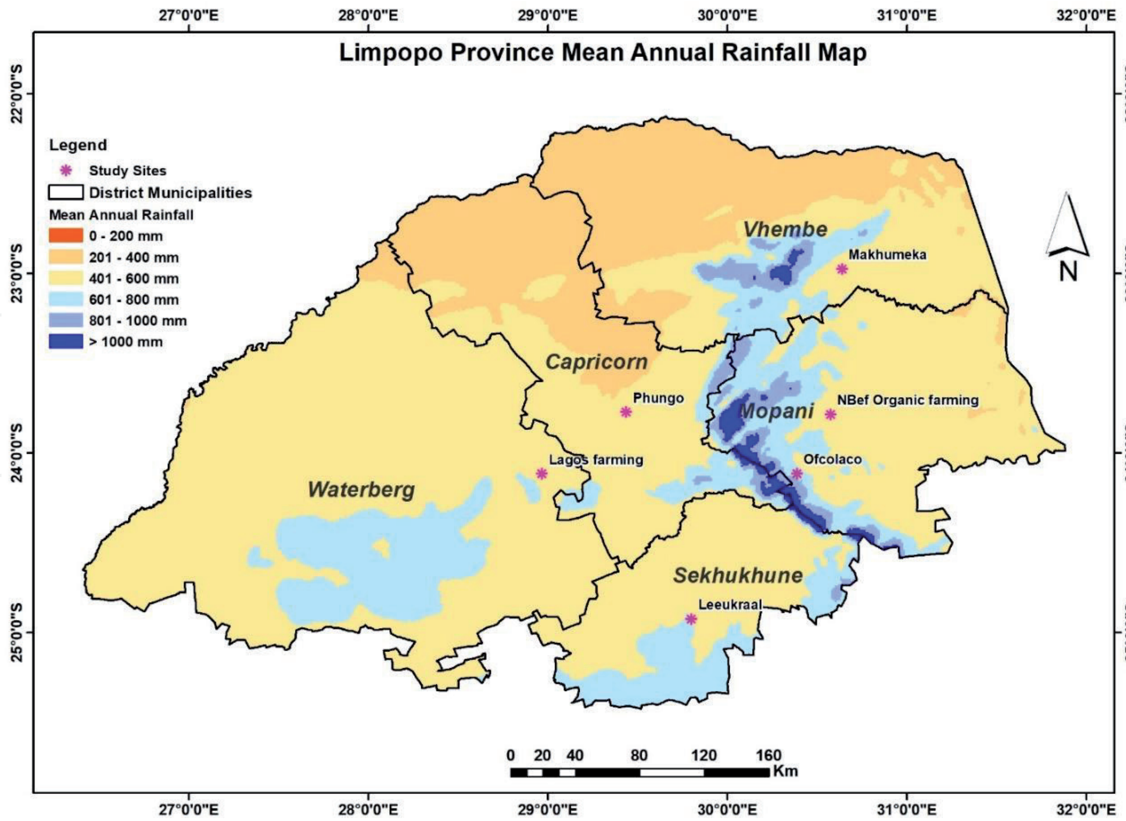
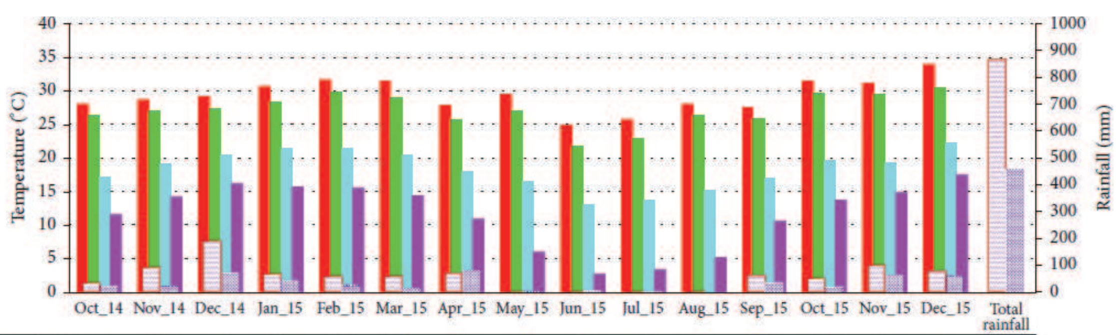


Figure 1.
The administrative districts of Limpopo Province showing annual rainfall and study sites.



	Oct_14	Nov_14	Dec_14	Jan_15	Feb_15	Mar_15	Apr_15	May_15	Jun_15	Jul_15	Aug_15	Sep_15	Oct_15	Nov_15	Dec_15	Total rainfall
Max temp: Ofcolaco	28.05	28.72	29.22	30.58	31.7	31.54	27.78	29.57	24.93	25.7	28.02	27.56	31.44	31.11	34.01	
Max temp: Syferkuil	26.35	27.04	27.44	28.37	29.88	29	25.68	26.97	21.75	22.85	26.38	25.93	29.6	29.55	30.57	
Min temp: Ofcolaco	17.12	19.16	20.43	21.37	21.49	20.44	17.97	16.5	13.07	13.67	15.2	17.06	19.67	19.3	22.26	
Min temp: Syferkuil	11.5	14.23	16.22	15.65	15.56	14.32	10.86	5.91	2.75	3.38	5.16	10.53	13.65	14.82	17.51	
Rain: Ofcolaco	34.04	93.47	191.77	66.02	60.19	60.45	69.59	0.25	0.51	0.25	1.27	62.21	50.54	100.59	79.76	870.91
Rain: Syferkuil	21.08	23.37	70.12	43.68	24.13	14.98	81.28	0.25	4.57	1.52	0	32.26	17.28	64.26	60.19	458.97

Figure 2.
Weather data recorded during the 2014 and 2015 field trials at Syferkuil and Ofcolaco.

questionnaire to gather all relevant information from the categories of farmers listed in **Table 1**. Focus group discussions and field observations were also conducted to validate the data obtained from the farmers. The questionnaire included open-ended questions which were valuable in allowing farmers to freely express their opinions about the adoption of agroforestry in their conservation agricultural practices. The farmers selected had previously been trained in climate-smart and conservation agricultural technologies.

b. Field trials for tree fodder assessment

Following the analysis of farmers' perception on the adoption of agroforestry as a valuable landuse option for climate change mitigation, the reliable supply of

Farm	District Municipality	Local Municipality	Current Farming Activity	Farming system	No. of farmers	Coordinates
Trichardsdaal: Ofcolaco	Mopane	Maruleng	Maize, Vegetables, Drybean, Mangoes and litchis Pigeon pea, Cattle and goats	Irrigated and dryland	38	S 24 06 45.68 E 30 23 15.85
NBef Organic farming	Mopane	Ba-Phalaborwa	Moringa, and Vegetables, tree lucerne	Irrigated Organic farming	12	S 23 47 00.2 E 30 34 28.7
Phungo Livestock Farm, Palmietfontein	*Capricorn*	Polokwane	Sheep and goats raised on rangeland with grass and Acacia shrub.	Dryland	4	S 23 46 14.24 E 29 26 05.13
Lagos farming cooperative	Waterberg	Mogalakwena	Goat production raised on rangelands and moringa.	Irrigated and dryland	2	S 24 06 50.68 E 28 57 56.82
Leeukraal farm in Nebo	Sekhukhune	Makhudumathaga	Dryland maize and sorghum production, cattle and goats raised on rangeland	Dryland	48	S 24 55 22.15 E 29 48 00.05
Makhumeka Irrigation scheme	Vhembe	Thulamela	Conventional vegetable, maize and mango production.	Irrigated	25	S 22 58 23.2 E 30 38 20.3

Table 1.
Information on survey study conducted in Limpopo Province.

livestock feed from agroforestry tree species to address feed shortages emerged as one of the key focus areas that farmers are determined to pursue. To facilitate the incorporation of agroforestry fodder in the farming activities in the Limpopo Province, a review of the limited field studies on *Moringa oleifera* and *Vachellia karroo* that have been conducted in the province and their potential as a feed source for livestock farmers is reported here.

2.3 *Moringa oleifera* trial

2.3.1 Study site

The moringa trial was established as a randomised complete block design (RCBD) at two locations in the Limpopo Province, namely the University of Limpopo experimental farm at Syferkuil and farmers' field at Ofcolaco, Trichardsdaal Mopani District 2014 to 2016 to assess the effect of planting density and cutting interval on aboveground biomass production and nutritional quality of *Moringa oleifera* under different climatic conditions. The densities examined were four levels, namely, 435,000, 300,000, 200,000, and 100,000 plants ha^{-1} under four replications. Planting was carried out on 07 to 15 December 2014 at the two locations.

Irrigation was applied for four hours twice a week using a sprinkler irrigation system until the sixth week to encourage good tree establishment, afterwhich the study was allowed to run under rainfed conditions. Weather data were collected throughout the trial from Syferkuil and at a weather station located less than 10 km from the experimental area at Ofcolaco. During the course of the study, the experimental units were well maintained by removing weeds manually with hand hoes. Insect pest and plant disease incidences were not observed during the study. To reflect the financial constraints experienced by the local smallholder farmers, no fertiliser was applied in this study. The initial physical and chemical properties of the soils under test were determined at a depth of 0–30 and 30–60 cm using an auger to identify their nutrient status.

Aboveground biomass was harvested manually with pruning shears from a 2.5 m^2 area when 90% of the plants within an experimental unit reached a height of at least 50 cm, measured from ground height of 10 cm above the ground surface. The height of plants was measured from five plants selected randomly from an experimental unit prior to harvesting the biomass. The measurements were made between ground level and the tip of the uppermost leaf of the plant. Biomass harvesting from main plant and regrowth occurred in all four seasons, Summer, Autumn, Winter and Spring designated as H1, H2, H3 and H4.

Moringa leaf samples, dried at room temperature (24∘C) for 72 hours, and then further oven-dried for 48 hours at 65∘C until the samples had reached constant dry weight were ground to pass through a 2 mm sieve. Ten grams of a fine fraction was used to determine their chemical composition. Crude protein was determined using the Kjeldahl method [22]. Other minerals such as P, K, Ca, Mg, Mn, and Zn were determined using atomic absorption [23].

Data were analysed using the standard analysis of variance procedure with the Statistix version 10.0 to determine the effect of planting density and harvest frequency on measured variables. Where significant F-values from the treatment effect were found, means were separated by the least significant difference (LSD) at a probability level of 0.05. Linear correlation and regression analyses were performed using Microsoft Excel to determine the relationship between cutting frequency and biomass yield.

2.4 *Vachellia karroo* trial

2.4.1 Study site

The study was conducted at the University of Limpopo experimental farm at Syferkuil in 2015 to access the impact inclusion of *Vachellia karroo* in the diet of indigenous Pedi goats on palatability indices, feed intake, digestibility, body weight change, carcass characteristics and histological parameters. Fresh leaves of *Vachellia karroo* were hand-harvested at the University of Limpopo Experimental farm using pruning shears in summer (November 2014 to January 2015). The leaves were air-dried under the shade to minimise nutrient loses to ultraviolet rays [24]. The leaves were separated from the branches by shaking them off gently after drying, leaving the thorns behind. The leaf meal was stored until feeding time. *Setaria verticillata* (a bristle grass) hay was obtained from a local farmer and included in the study. The dried leaves of both *Vachellia* and *Setaria* were milled using a hammer mill (13 mm screen) to reduce diet selection by the animals when fed.

2.5 Results, discussion and analysis of fodder agroforestry practices

2.5.1 Farmers perception on agroforestry adoption

Following the analysis of responses from 129 farmers engaged in conservation agricultural programmes in the Limpopo Province of South Africa, the following could be deduced about the cultural practices and attitudes that contribute to resistance to the adoption of agroforestry development alternatives:

Limited land area per household which cannot accommodate trees. Majority of smallholder dryland farmers in the Limpopo Province operate on parcels of land ranging from 1 to 3 hectares. Despite their willingness to grow trees, there is a general feeling among the farmers that trees occupy large space which could limit the production of the main crops of interest. Land constraint to adoption of agroforestry practices has been reported by Kabwe, Bigsby [14].

Lack of land ownership for long term investment in the woody perennial species. Control of land in rural communities in South Africa is by the Traditional Leaders. Farmers are usually given a temporary permit to produce crops on allocated parcels of land which are valid for 1 to 3 years. The lack of long-term security of land ownership is a major constraint to farmers that are engaged in conservation agriculture. This constraint has been reported by other authors [11]. The authors recommended that long-term, secure tenure and access to significant land is a key prerequisite if smallholder farmers in rural communities are to adopt and reap the benefits from agroforestry.

Extension service for CAwT is sub-optimal in most rural communities of the Limpopo Province. This is partly attributable to the fact that conservation agriculture is a relatively new concept in the province and hence the agricultural extension personnel are not well equipped in this area to effectively render the desired service to farmers. Capacitating the extension service in CAwT will invariably increase awareness and contribute to the uptake of agroforestry systems by farmers. In a study in other parts of Africa, it was observed that a group of female farmers and youth showed significant uptake in agroforestry and an increased in agroforestry planting across fields in villages receiving extension services was evident.

Inadequate water in drier areas for successful cultivation and management of beneficial woody perennial species was mentioned as a constraint. Water is the major resource limiting crop production in the Limpopo Province. To address this, a good understanding of the sources and patterns of tree water uptake is crucial to better understand how trees influence the local water balance and the productivity of an agroforestry system. This knowledge will also be a useful guide in the selection of component plant species for agroforestry systems.

Over-aged women in farming who though have deep knowledge about tress but are constrained by the physical strength required for farming. This problem is being addressed by the government through specific programmes targeting the youth.

Lack of improved germplasm to support agroforestry. Good cultivars of herbaceous crops such as grain crops as well as breeds of livestock exist for farmers to use in agroforestry systems. However, the availability of improved varieties and seedlings for the woody perennials in the system is largely lacking and this needs to be addressed. Farmers engaged in conservation agriculture receive good support from the provincial department of agriculture and land reforms in terms of seeds and other production inputs such as fertilisers and agrochemicals.

Farmers do not have access to credit facilities to satisfy the financial requirements of intensive agriculture including agroforestry. Farmers requested assistance from the provincial government in this regard.

The *interference of tree species with land preparation equipment* and *excessive shading* by large trees on herbaceous annual component crops which may reduce yields of the latter were mentioned by the farmers. This specific situation could be improved by the choice of the tree component, careful pruning and using the harvested biomass for livestock feed or mulch to improve soil organic matter, fertility and moisture-holding capacity.

Farmers indicated that there is a *lack of control over movements of livestock, mainly cattle* in their communities and the roaming animals will likely damage tree seedlings before they are well established. Furthermore, if palatable tree species are planted on their farmland, this will attract both domestic and wild animals leading to the destruction of their fragile fences. Protecting tree species against roaming livestock and wildlife during the juvenile stages until they are well established is an important consideration in the implementation of agroforestry by conservation agriculture farmers. However, the high demand for fencing to protect young tree and shrub seedlings from roaming ruminants is costly for farmers and hence the assistance the government is required.

Few of the farmers mentioned that dense stand of trees on their farmlands could attract snakes and pose a threat to the farmers and their children who occasionally assist them in the farm operations.

Despite the challenges outlined above, over 70% of the farmers interviewed expressed their desire to incorporating agroforestry in their conservation agricultural farming operations. The inclusion of fruit trees for income and fodder species to address feed shortages in dry winter and early spring months were the preferred technologies mentioned by the majority of the farmers.

2.6 Results from field experimentation

2.6.1 Moringa oleifera *trial*

A summary result from moringa planting density and fodder field trials conducted at the two locations in the province, Syferkuil and Ofcolaco revealed that dry matter production of moringa varied with location, planting density and biomass sampling stage. On average, more biomass was produced at Ofcolaco relative to Syferkuil (**Figure 3**). Biomass production generally increased with increasing density across the two locations at all sampling stages, with higher rates of increase occurring at the 481 sampling date at Syferkuil and the 56 and 366 DAP at Ofcolaco.

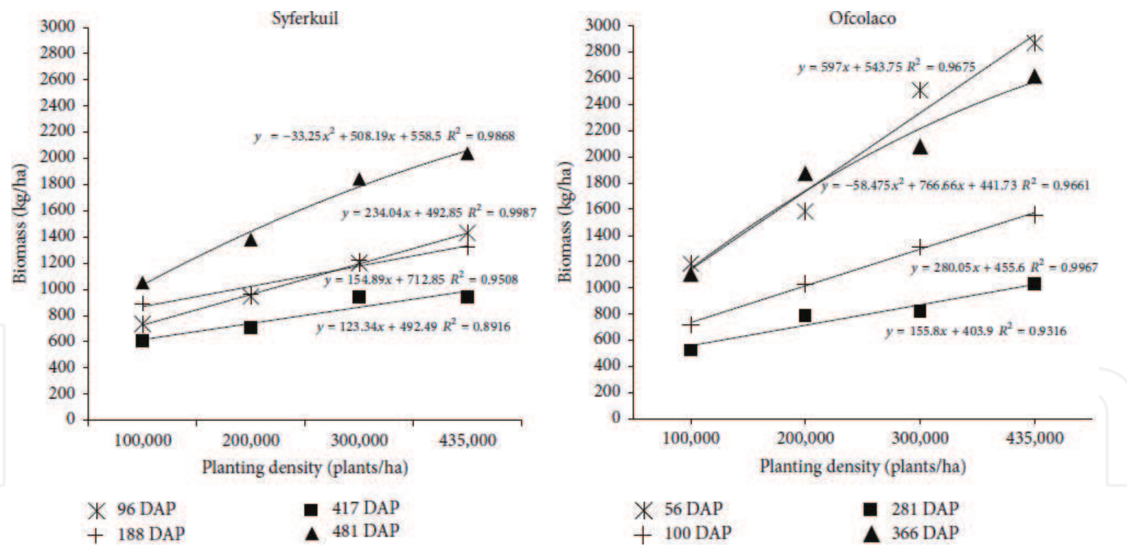


Figure 3.
Moringa biomass production as influenced by planting density and sampling stage at Syferkuil and Ofcolaco. (Extracted from Mabapa et al., 2018). H1 (Autumn), H2 (Winter), H3 (Summer), H4 (Spring).

Lower biomass was harvested at 481 and 281 DAP at Syferkuil and Ofcolaco compared to the other sampling dates. These periods coincided with the winter months where moringa dropped significant amounts of leaves, (*Extracted from Mabapa, Ayisi* [18]).

2.6.2 Seasonal influence on moringa biomass

Low temperature and drought such as experienced in winter and early spring periods of the Limpopo Province reduced moringa biomass production (**Table 2**) and nutritional composition (**Figure 4**). The mineral ion that was severely impacted was iron. To optimise the use of moringa as a nutrient source during winter and early spring when feed supply is severely constrained, the biomass can be harvested more intensely in summer and autumn months and stored for the winter period. Moringa should also be mixed with grass as feed inclusion to increase the volume of feed available to the livestock.

2.6.3 Nutritional value of moringa

The crude protein content of moringa leaves ranged from 27.96 to 33.74% at Syferkuil and from 16.32 to 30.3% at Ofcolaco. (**Table 2**). At Syferkuil, plant density and cutting interval did not influence crude protein (%), Ca, Mg, K, P, and Zn content. However, a decrease in iron content and an increase in manganese content were observed during the third harvest across all planting densities (**Table 2**). At Ofcolaco, cutting interval had a negative influence on the nutritional quality of moringa leaves mainly at harvests 3 and 4. The chemical properties affected by sampling interval were crude protein, K, P, Fe, Mn, and Zn content. At harvests 1 and 2, the chemical compositions were generally higher than later, although at harvests 3 and 4 these fell markedly (**Table 2**).

2.7 Vachellia karroo trial

The nutritional composition of *Vachellia karroo* leaves and *Setaria verticillata* grass hay is presented in **Table 3**.

Syferkuil	96 DAP	177 DAP	417 DAP	481 DAP	$LSD_{(0.05)}$
CP (%)	32.92	27.96	32.93	33.74	*ns*
Ca (%)	1.60	1.76	1.48	1.76	*ns*
Mg (%)	0.67	0.63	0.65	0.82	*ns*
K (%)	1.60	1.73	2.04	1.64	*ns*
P (%)	0.29	0.32	0.34	0.39	*ns*
Fe (mg/kg)	207.0	166.0	152.0	323.0	*74.45*
Mn (mg/kg)	65.00	61.00	86.00	61.70	*13.29*
Zn (mg/kg)	26.00	24.50	28.70	21.80	*ns*
Ofcolaco	56 DAP	100 DAP	281 DAP	366 DAP	$LSD_{(0.05)}$
CP (%)	24.20	30.3	17.02	16.32	3.49
Ca (%)	1.82	1.92	2.22	2.00	ns
Mg (%)	0.66	0.66	0.88	0.76	ns
K (%)	2.35	2.55	0.63	0.70	0.19
P (%)	0.47	0.58	0.18	0.17	0.02
Fe (mg/kg)	138.0	182.0	176.0	75.0	35.12
Mn (mg/kg)	95.70	82.60	100.1	98.10	2.89
Zn (mg/kg)	28.10	28.00	19.9	11.10	1.96

Table 2.
Nutritional value of Moringa oleifera leaves at 435000 plants ha^{-1} *as influenced by sampling date at Syferkuil and Ofcolaco.*

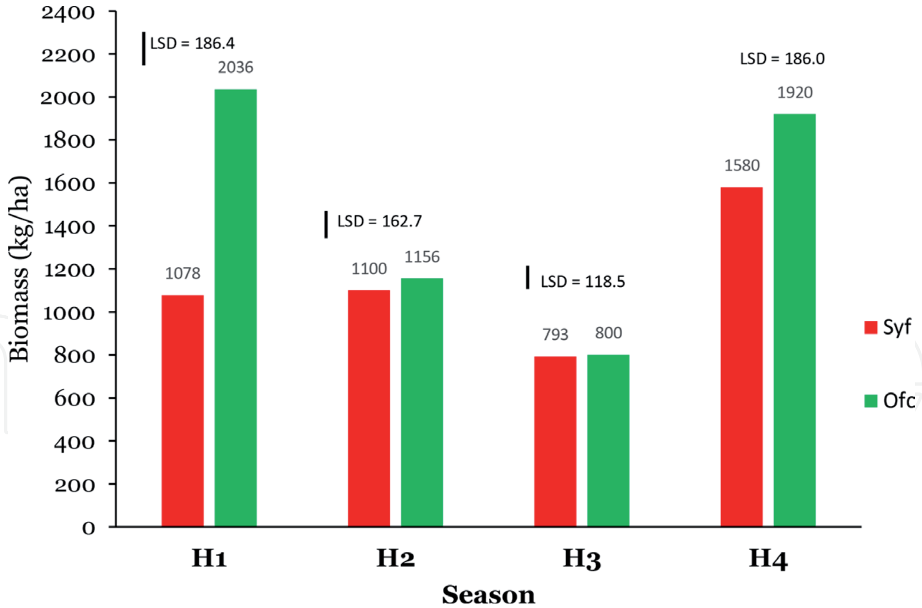


Figure 4.
Seasonal biomass production of moringa at Syferkuil and Ofcolaco across densities. H1 (Autumn), H2 (Winter), H3 (Summer), H4 (Spring).

V. karroo leaves have crude high protein contents, ranging from 10.65 to 14.65% (mean of 12.7%). The crude protein contents of *V. karroo* could support maintenance requirements and some production levels in ruminants, particularly, goats. Thus, *V. karroo* leaves have the potential of being a protein feed for ruminants, especially during the long dry season. The results of the palatability indices indicated

Nutrient (% DM)	*Acacia karroo* leaves	*Setaria verticillata* hay
Dry matter	97.1 ± 2.01	96.2 ± 0.40
Organic matter	92.1 ± 0.21	91.4 ± 0.12
Crude protein	12.7 ± 2.02	7.9 ± 1.12
Fat	2.4 ± 0.10	0.8 ± 0.01
Ash	7.9 ± 0.40	8.6 ± 0.31
Acid detergent fibre	32.5 ± 3.02	50.7 ± 4.01
Neutral detergent fibre	38.0 ± 4.01	77.9 ± 3.02
Condensed tannins[#]	2.0 ± 0.01	ND
Total Phenolics[##]	1.95 ± 0.001	ND

[#]: Condensed tannins as percentage DM leucocyanidin equivalent [##]: Expressed as tannic acid equivalent (%); ND: Not detected

Table 3.
The nutritional composition of Vachellia karroo *leaves and* Setaria verticillate *grass hay.*

that diets with higher *V. karroo* inclusion levels had higher intakes and relative palatability rankings by goats, regardless of the higher condensed tannin and phenolic levels. Inclusion of *V. karroo* leaf meals improved nutrient digestibility and growth rate of goats. *V. karroo* leaf meal inclusion did not adversely affect goat meat tenderness, juiciness, flavour, taste, aroma and overall acceptability. Reduction in internal parasites and methane gas emission were also recorded in goats fed with tanniniferous *V. karroo.*

3. Concluding remarks

Climate change has become a threat to smallholder crop and livestock productivity in many rural areas of South Africa. To address this challenge, coordinated efforts in the implementation of workable technologies needs to be pursued. However, agricultural practices and technologies communicated to farmers in previous years by diverse stakeholders have not produced the desired results. In some situation, the information received has reduced farmers' awareness about the fact that their physical well-being depends, to a large degree on the way the natural resources are managed.

From the information gathered from the farmers, it is deduced that the general lack of knowledge about the benefits of woody perennial species in an agro-ecosystems does not encourage the adoption of agroforestry. Several farmers view the presence of trees on farmlands as an interfering, rather than a beneficial component. Additionally, in some rural communities, where members are aware of the benefit of certain tree foliage in livestock feed, farmers could not comprehend how the management operations should extend to the tree species.

For successful scaling out of this farming practice in the Limpopo Province, thorough training of participating farmers and all the relevant stakeholders will be required. Relevant research into management practices required for successful agroforestry interventions is also critical to the successful adoption of agroforestry in the province.

Planting *Moringa oleifera* at a relatively high density increased biomass production. A planting density of 435,000 plants ha^{-1} resulted in higher biomass accumulation at all sampling intervals. Moringa can thus, be planted by farmers at higher densities on their fields in an agroforestry system. Moringa can be harvested at a height of 50 cm above ground level, which facilitates mechanical harvesting, and while the stem is still pliable. The relatively high protein content of moringa leaves makes it an attractive fodder crop for farmers who are eagerly seeking a solution to address winter and early spring feed gaps. The crude protein content of moringa far exceeded that of *V. karroo* and that of *Setaria verticillata* up to 20 and 25 percentage respectively. *V. karroo* will thus be able to supply livestock farmers with satisfactory amounts of crude protein, to sustain productivity. The moringa tree is also rich in other nutrients, making it a potentially valuable source of feed supplement for livestock in the Limpopo Province. Furthermore, both *M. oleifera* and *V. karroo* have proven to be valuable species that can survive harsh growing conditions where most of the dominant natural quality natural quality grasses such as *Panicum maximum*, *Themada triandra* and *Urochloa mosambicensis* fail in winter months.

V. karroo leaves have the potential of being a protein feed for ruminants and its inclusion in the diet increased intake by goats regardless of the higher condensed tannin and phenolic levels. Leaf meals with *Vachellia karroo* improved nutrient digestibility and growth rate of goats and did not adversely affect goat meat tenderness, juiciness, flavour, taste, aroma and overall acceptability. Additional benefit recorded was a reduction in internal parasites and methane gas emission when goats were fed tanniniferous *V. karroo.*

With careful planning, research and education, specific agroforestry systems could be established in the different agro-ecological zones of the Limpopo Province to satisfy local livelihood and adaptation needs.

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