Improving grassland quality in communal arable lands in the Eastern Cape Province, South Africa

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Abstract. Overgrazing and shifting cultivation practise have severely degraded communal lands in the Eastern Cape of South Africa. Methods need to be developed to improve forage quality of grazing land, especially previously cultivated lands. The aim of the study was to investigate legume species to rehabilitate arable lands abandoned from cropping, to enhance their forage quality, productivity and ecological integrity. The study was conducted in seven communities within the Eastern Cape Province. This study showed that within the communal lands studied extensive areas have been cultivated and the majority of this land is now poorly utilised. Natural grasslands ploughed for cropping did not recover its original composition and therefore lost its primary ecological condition. New improved legume cultivars can significantly enhance forage quality on cultivated lands but individual species may not have the resilience to survive nutrient poor lands and variable winter rainfall. This study shows that using a mixture of annual and perennial legume species with different life traits contributed to enhanced forage quality, especially during winter when the nutritional value of grasses was low. Because of management constraints, pasture legumes cannot be seen as stand-alone pastures, but provide a mechanism to extend the forage potential of communal grazing lands.

Keywords: Degraded grasslands, land cover, rehabilitation, ordination, legumes.

Introduction

Communal land harbours some of the most degraded grasslands in South Africa (Hoffman and Todd 1999), a consequence of state enforced land use planning and the disintegration of the tribal authorities in the 1990's (Bennet *et al*. 2009). The major contemporary drivers of the degraded state of some communal lands in South Africa are over-grazing and the indiscriminate cropping (then abandonment) of marginal soils through shifting cultivation (Hoare 2003; Vetter *et al*. 2006). The issue of degraded grasslands further accentuates the challenges of communal land tenure in the former homeland areas of South Africa, as described in the "tragedy of the commons" scenario by Hardin (1968).

Although cattle are seen as a wealth symbol in African culture, many communal farmers in the Eastern Cape rely on wool from sheep as a form of income. Large areas of communal lands in the Eastern Cape contain "sour" grassland where overwintering of animals requires nutrient supplementation. Sour grassland in South Africa is defined as grasslands in cool moist climates at higher altitudes that lose palatability and forage value from late summer till winter (Tainton 1999). Intervention strategies are urgently needed to reduce land degradation in these areas, to alleviate poverty and to improve food security.

The aim of the study was to investigate using legume species to rehabilitate degraded, arable lands, which had been abandoned from cropping, to enhance their forage quality, productivity and ecological integrity. The investigation aimed to:

- Map and quantify the extent of the cropped and degraded lands at the community level.
- Determine the impact of land cover change on the ecological condition of the rangelands.
- Evaluate the success and impact of establishing legume species on these degraded arable lands.

Method

Study area

The initial (pilot) evaluation studies of annual and perennial legumes were conducted in six rural communities in the Eastern Cape Provence of South Africa (Fig. 1). Roxeni, Lushington and Allanwaters are located in the Ciskei region (32°S; 26°E). Detailed descriptions of these three communities are given by Bennet *et al*. (2009). Rockcliff is located in the Sterkspruit area in the foothills of the Maluti/Drakensberg Mountains (30°S 27°E). Dudumashe and Nyandeni are located in the Transkei region (31°S

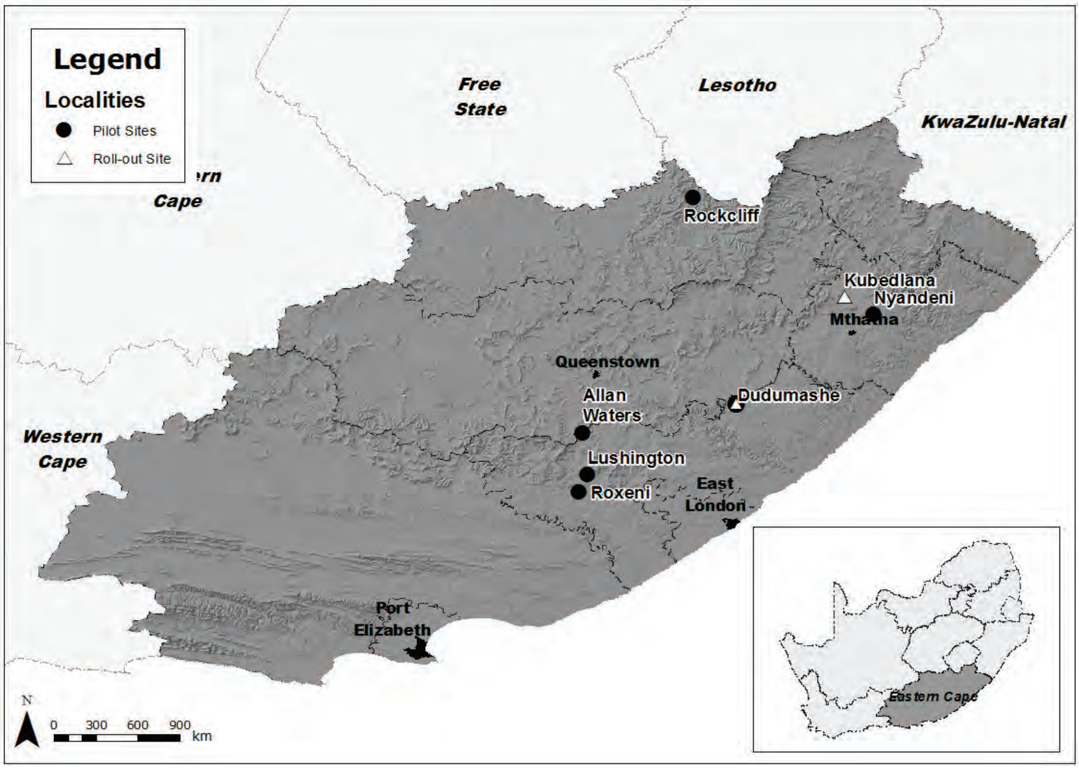

Figure 1. Locality map indicating the location of original pilot communities (●) and the roll-out communities (∆) in the Eastern Cape Province, South Africa.

28°E). All communities fall in the summer rainfall region but receive occasional winter rainfall or, in the case of Rockcliff, snow. Roxeni and Allanwaters are the driest sites with annual rainfall below 600 mm. No accurate climate data are available for the communities since no weather stations are located in the vicinity of the study areas. The pilot trial areas were fenced and grazing controlled by the Chief of each community.

The roll-out study was conducted in two communities in the Transkei region in the Eastern Cape (Fig. 1). The Dudumashe community is situated in the Amathole District on the escarpment of the Kei River Valley. The Kubedlana community is situated in the OR Tambo District on the escarpment of the Umzimvubu River. The vegetation is described by Mucina *et al.* (2005) as Drakensberg Foothill Moist Grassland. Rainfall for both these communities exceeds 650 mm and predominantly falls during summer (November – April). The site at Dudumashe is located in a fenced area whereas the site at Kubedlana is not properly fenced and grazing control is less than at Dudumashe.

Extent of degraded arable lands

The extent of the degraded arable lands was mapped using recent (2005 - 2011) SPOT-5 imagery provided through a governmental contract with SPOT-Image. Broad land cover classes were digitized from 2.5 m panchromatically sharpened imagery and aerial photographs using ArcGIS software (ESRI 2011).

Ecological condition of communal grazing lands

A vegetation survey of natural, fallow arable lands (those cultivated within the last five years) and abandoned arable lands (those cultivated more than five years ago) was conducted in 2012 in the community of Dudumashe. The surveys were done by recording the nearest plant at 1 m intervals along three 50 m transects spaced 10 m apart. The relationship between species and surveys conducted in the three land cover types were analysed using a Detrendend Correspondence Analysis (DCA) ordination with CANOCO 4.5 (Gauch 1982; Ter Braak & Šmilauer, 2002).

Legumes as a catalyst to rehabilitate cultivated arable lands

The ecological study was preceded by legume evaluation trials at six pilot communities in the Eastern Cape (Fig. 1) set up in 2007-2008 as the first phase of ECCAL (Eastern Cape Communal Arable Lands) Research Project (Howieson 2006; Davis *et al*. 2008). Access to cultivated, then abandoned, arable lands was negotiated with the communities. The soil phosphate levels were corrected to 20 mg P/kg. All legume seeds were inoculated with the appropriate inoculant and seeded using a no-tillage Aitchison Mini Seeder after grass residues were heavily grazed. At each site twelve different pasture legume species were planted and replicated twice in a randomized block design in plots measuring 30 m X 2.5 m. Since season could be a major factor in establishment, plots were planted in both spring and autumn of 2007-2008. The autumn plantings relied for success upon water stored in the soil from late summer rains, followed by winter rains that historically provided 100-120 mm during April – September. Preliminary data on these trials were reported by Jordaan *et al.* (2010)

Based on the experience gained from these legume evaluation trials, a legume seed mixture with inoculants was prepared and sown using the no till planter within two roll-out sites each of 10 ha at Dudumashe in March 2010 and Kubedlana in April 2011. Three 50 m transects were set out in each of the mixed planting sites. Along each transect the nearest plants were recorded at a 1 m interval using the descending point method. At each point the nearest legume and the distance between the descending point and the legume were recorded (Cottam and Curtis 1956). The survey determined the total composition as well as the composition of the legume stand. The distance between the descending point and nearest legume was used as surrogate for plant density.

Standing biomass was randomly sampled during winter 2011 and summer 2012 with a 1 m^2 square quadrat. Material were clipped, separated in to grasses, legumes and forb fractions, dried, milled and chemically analysed for crude protein and phosphorus at the Envirotek Labs, Brits, Gauteng.

Results and Discussion

Extent of cultivated lands

In both communities more than forty percent of the communal land had been cultivated, and only about half of that showed signs of active cultivation at the time of the study. Based on the available satellite data it is estimated that less than 30% of the natural grassland is left at Dudumashe and less than 37% at Kubedlana. Interrogation of the SPOT time series data from 2005 until 2011 also revealed areas of historical disturbance *e.g.* kraals and small cultivated lands.

Ecological condition of communal grazing lands

The Sample ordination diagram revealed a strong cultivation gradient along the first ordination axis (Fig. 2). As part of the ordination a benchmark site for sour grassland (Danckwerts and Teague 1989) was included in the analysis. The DCA ordination clustered the natural grassland site surveys at Dudumashe with the benchmark suggesting that the condition of the natural grassland sites were still comparable with climax grassland for sour grassland. The fallow lands were located at the opposite end of the DCA scatter diagram. Abandoned cultivated lands were associated more closely with the natural grassland sites, but still formed a separate cluster (Fig. 2).

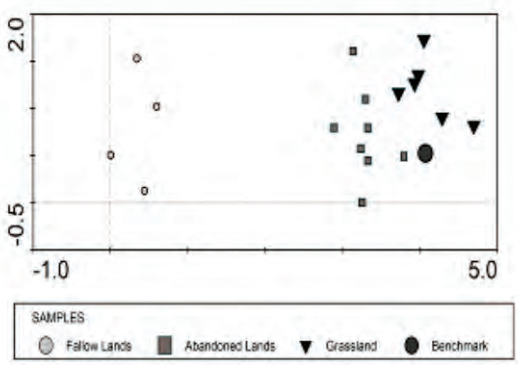

Figure 2. DCA ordination diagram of vegetation sampled in Fallow lands (lands cultivated during the past five years), Abandoned land (lands cultivated more than five years previously) and Grassland (natural grassland with no signs of cultivation) at Dudumashe community.

Legumes as a catalyst to rehabilitate cultivated arable lands

Legume establishment was more successful in the autumn sowings conducted in March 2007 and 2008 than in the parallel spring sowings (Jordaan *et al.* 2010). A survey to determine the persistence of the legumes was conducted four years after establishment, following intensive grazing in the previous years. More of the legume species grew and survived at Lushington and Nyandeni, however there was significant legume x site interactions (Fig. 3). For example, *Lespedeza cuneata* proved exceptionally resilient

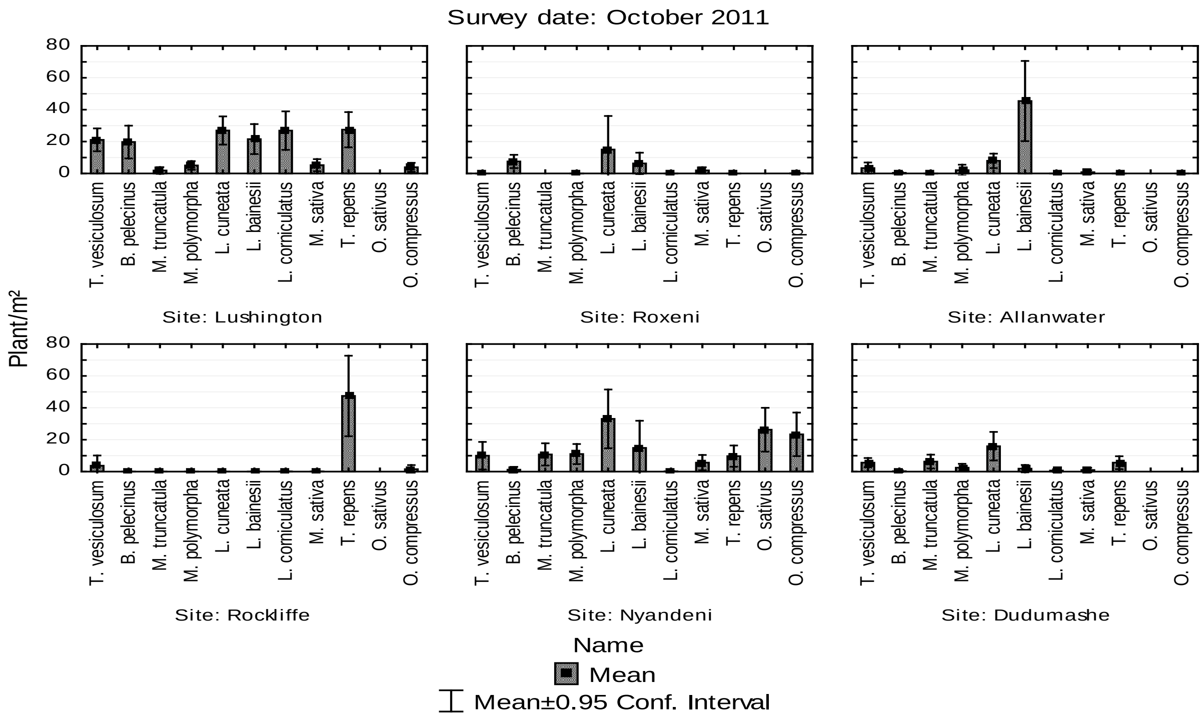

Figure 3. Plant counts (plants/m^2) for species evaluation trials planted during 2007 - 2008 at the six pilot sites.

Table 1. Legume composition (%) in mixed plantings at Dudumashe and Kubedlana.

Legumes	Dudumashe				Kubedlana			
	Aug 2011	Mar 2012	Aug 2012	Jan 2013	Jul 2011	Mar 2012	Aug 2012	Jan 2013
Legumes absent	19.3	25.0	28.4	17.4	0.7	3.3	4.1	2.0
Annual Legumes								
Biserrula pelecinus	5.6	1.3	0.0	0.0	14.0	0.0	0.0	0.0
Lotus subbiflorus	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0
Medicago species	10.7	1.3	0.0	0.0	22.7	0.0	1.3	0.0
Ornithopus species	37.2	4.7	25.4	4.7	16.0	2.0	1.3	2.0
Trifolium hirtum	2.8	0.0	0.7	0.0	6.0	0.0	0.7	0.0
Trifolium vesiculosum	0.7	0.0	0.7	1.3	14.0	0.0	7.4	0.0
Vicia benghalensis	2.0	3.4	4.6	1.3	0.0	0.0	0.0	0.0
Perennial Legumes								
Lespedeza cuneata	0.0	0.7	0.0	5.4	0.0	2.6	0.0	6.0
Lotus corniculatus	1.4	7.3	8.7	24.3	4.0	9.8	14.1	14.0
Medicago sativa	2.0	8.7	9.3	8.7	0.0	1.3	0.0	0.0
Securigera varia	0.0	4.0	1.4	3.3	0.0	0.0	0.0	0.0
Trifolium repens	18.1	43.6	20.9	30.2	22.7	80.9	71.2	76.0
Legume Distance (cm)	14.0	15.2	15.3	16.7	7.4	7.9	7.6	6.8

Table 2. Forage quality (% protein and % phosphorus (P)) of grasses and legumes in mixed plantings and control sites at Dudumashe and Kubedlana.

Treatment	Material	Protein	P	Protein	P	Protein	P	Protein	P
		Dudumashe				Kubedlana			
		Aug 2011		Mar 2012		Jul 2011		Mar 2012	
Control	Grass	4.43	0.03	5.72	0.21	4.2	0.06	4.04	0.11
MixedPlanting	Grass	4.1	0.08	6.05	0.18	4.76	0.12	5.53	0.16
	Legume	16.41	0.17	15.58	0.18	12.69	0.3	12.1	0.17

under intensive grazing at several sites, whilst the annual legumes *Biserrula pelecinus* and *Trifolium vesiculosum* persisted better at the drier sites in the Ciskei. The data indicated that overall *Trifolium vesiculosum*, *Biserrula pelecinus*, *Lespedeza cuneata*, *Lotononis bainesii*, *Lotus corniculatus*, *Ornithopus sativus*, *Ornithopus compressus* and *Trifolium repens* persisted the best of the legumes evaluated. *Medicago polymorpha* persisted in most of the pilot sites, but was nowhere abundant, whereas *Lotononis bainesii* was very successful at the Allenwater community.

By August 2011, four months after the final establishment of the roll-out sites, annual legumes had established first and were more abundant (Table 1) at both sites than perennials, following a wet winter. The composition between the two sites was very similar with the exception of *Trifolium vesiculosum* and *Biserrula pelecinus* which established in higher numbers at Kubedlana. A further difference was the better legume stand density at Kubedlana in comparison to Dudumashe. The species establishment corresponded to the outcomes from the pilot evaluation trials which showed that this group of hard seeded annual species together with the perennial species *Trifolium repens* and *Lespedeza cuneata* established reliably within the permanent grassland setting.

During the second year the abundance of the annual Mediterranean legumes decreased and the occurrence of perennial legume species, particularly *Trifolium repens*, increased during summer 2012. This was as expected, as the Mediterranean species were present and grew through the winter months, whereas the perennial species tended to grow through the wet summer months. During the two growing seasons the legume density and occurrence fluctuated slightly. The legume density decreased at Dudumashe (legume distance increased) but remained constant at Kubedlana. Results from January 2013 indicate that *Trifolium repens* and *Lotus corniculatus* were the two most successful perennial species to establish. The study also showed that the success of *Trifolium repens* is dependent on good winter and spring rainfall, since the 2011/2012 season was a particularly good season. In contrast, *Lespedeza cuneata* was able to establish at sites with variable winter rains

The difference in stand density and occurrence between the two sites can be partly ascribed to different managerial regimes. The site at Dudumashe is well fenced and is the property of the communal Chief, whereas the site at Kubedlana is also fenced but animal movement is controled to a lesser degree. The Kubedlana site is therefore grazed more intensively and for longer periods than at Dudumashe, which has assisted legume persistence.

The quality of legume material harvested from the mixed plantings significantly enhanced the overall forage quality of the abandoned arable land the legumes were planted into (Table 2). The protein in material collected from legume pasture species were significantly higher ($P<$ 0.05) than grass material collected in the same plots and also in control plots not planted with legumes. The legumes had no significant effect on the quality of the grass material in which they were planted into. No significant differences were found in the quality of the grass material between the seeded plot and the control plot.

Conclusion

The survey data has revealed widespread cultivation within the two study areas of Dudumashe and Kubedlana. This cultivation has altered the vegetation cover, and illustrates the role that disturbance has played in degradation of the natural grasslands. The data indicate that legume introduction could play a role in its recovery, particularly by providing alternative feed through the winter months, and fixed nitrogen to increase the protein levels in the grasses.

The problem of altered vegetation cover in the disturbed arable lands is not necessarily the lack of forage quantity, but quality, since the successional climax of old lands are towards large tufted grasses. The need to find sustainable rehabilitation technologies to improve the forage value of abandoned cultivated lands is therefore well illustrated. In this context rehabilitation does not necessarily refer to restoring the vegetation to its natural composition, but to enhancing forage quality.

On the original legume evaluation trial sites established in 2006 and 2007 a number of legume species have persisted as a significant component of the pasture, without any additional fertiliser application, for five years (Jordaan *et al.* 2010). This persistence has been the result of the establishment of hard seed "banks" in the soil with germination through the cooler winter months, as seeds become permeable to moisture (Loi *et al.* 2005). The study also illustrated that it is possible to establish legume species with minimum inputs and maintenance, and with minimal control of grazing. Although the legume-enhanced pastures established on the abandoned arable lands did not have the same productivity as a well maintained natural pasture, the overall quality of the pasture increased markedly, and the temporal aspects of pasture supply cannot be overestimated. The annual legumes often provided green feed in the winter months when sour grasslands typically fell into a severe feed deficit. Availability of the legumes for grazing during this period allowed animals to gain, rather than lose, weight (Howieson *et al.* 2011). Perennial stoloniferous leguminous species, such as *Trifolium repens*, also provided a good mechanism to stabilize soil.

The use of cultivated pastures is not part of the pastoral culture for Xhosa communities. The concept of introducing legumes is therefore foreign and requires nurturing. The roll-out sites at Dudumashe and Kubedlana have been highly successful through intervention at the sociological and scientific levels. The partnership with Australian scientists who developed the new legume species such as *Biserrula* and *Ornithopus* (Howieson *et al.* 2000), and who understand the subtleties of hard seed breakdown and seed dynamics, are needed to implement the technology further and to provide support to the communities where these demonstrations are on-going. Lastly, in the "tragedy of the commons" (Hardin 1968) has alerted many to the difficulties of managing commonly grazed lands. This present study has illustrated that the introduction of exotic legume pasture species, which have been selected on the basis of their resilience to infertility and acidity (Howieson *et al.* 2000), and with mechanisms that protect them from over-grazing (Loi *et al.* 2005), to commonly grazed lands, can be successful. These are uncommon species in agricultural settings outside Western Australia, and hence the "tragedy of the commons" may more aptly be termed the "tragedy of the common species".

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