Soil physical and biological properties as influenced by growth of vetiver grass (*Vetiveria zizanioides* L.) in a semi-arid environment of South Africa

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Abstract

The influence of 15-years of vetiver grass growth on soil quality was assessed by measuring physical and biological properties which were compared with adjacent lands that had been under natural fallow and continuous grazing. Soil properties were better under grass than non-grassed control. Soil in plots under vetiver grass was consistently of better quality than that under natural fallow grass. Increased soil organic matter and microbial biomass contents were considered to be responsible for the improved quality on soils under grass than control plots. The improvement in soil properties was more pronounced under vetiver than natural grass. It is concluded that higher organic matter input from vetiver grass residues and roots, exudation of organic compounds from roots and a large microbial biomass in the rhizosphere of vetiver grass contributed to the improvement in soil properties. The use of vetiver grass is recommended as an affordable and sustainable soil management practice to improve soil quality.

Key Words

Soil quality, soil erosion, land degradation, sustainable soil management, semi-arid areas

Introduction

Soil erosion is a serious land degradation problem threatening the productivity and sustainability of many South Africans' arable lands especially in semi-arid areas (Hoffman and Ashwell, 2001). The use of vetiver grass is one strategy that is actively being promoted as a means to rehabilitate eroded soils worldwide (Pang *et al*., 2003). In 1993, the provincial Department of Water Affairs and Forestry (DWARF) established plots (about 1.5 ha) of vetiver grass on an agricultural land that had been exposed to severe erosion overtime. A land adjacent to the vetiver plot was left under natural fallow grass (*Cynodon dactylon* and *Eragrostic species*) for the same period of time. Both plots were fenced to prevent any disturbance and protected from fire. The objective of this study was to evaluate the ability of vetiver grass to restore soil quality when compared with natural grass. A plot without any grass (non-grassed) was used as a control.

Methods

The study was conducted in July 2008 at Danville, a site located about 2 km outside the city of Mafikeng (longitude 25^{o}48' S, latitude 25^{o}38' E; 1218 m asl) in the North West Province of South Africa. Mafikeng has a typical semi-arid tropical savanna climate and receives summer rainfall with an annual mean of 571 mm. The surface (0-20 cm) soil at the site is a brown to dark reddish brown sandy loam classified as Hutton form according to the South African soil classification system (Soil Classification Working Group, 1991) and has characteristics similar to a Chromic Luvisol.

For purposes of statistical analysis, each of the three one hectare plots (vetiver grass, VG; natural grass, NG; non grassed control, CC) was divided into three equal sub-plots which were used as replicates. Soil samples were collected from five randomly selected positions within each replicate using a spade to a depth of 0-15 cm. The sub-samples from each replicate were mixed thoroughly to make one composite sample on which the analyses of the physical and biological properties of the soils were conducted to determine quality. For the fractionation of particulate organic matter and determination of microbial biomass, fresh subsamples were kept in airtight plastic bags and stored in a refrigerator. The rest of the samples were air dried. Samples for the determination of soil water retention were collected in cylindrical metal rings.

Physical properties

The distribution of aggregate sizes was determined by the method of Kemper and Rosenau (1986). Aggregate stability was determined using the wet-sieving technique. Bulk density was determined using the clod method. Soil water retention was determined at two soil water potentials (-33 and -1200 kPa) using the standard pressure plate apparatus. Soil penetration resistance was measured using a hand held cone type proving ring penetrometer model 29-3739 with a cone diameter of 6.2 mm. Gravimetric soil moisture content was determined by drying sub-samples of the soil in the oven at 105^{o}C for 24h.

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Biological properties
Soil organic carbon was determined using the wet oxidation method. Physical fractionation of soil to collect the particulate organic matter (POM) fraction was conducted using a modification of the method described by Okalebo *et al*. (1993). Microbial biomass was determined on fresh samples by the chloroform extraction method (Vance *et al.*, 1987).

Analysis of data
Since the treatments in the original set up were not properly replicated or randomized, the results are presented using means and standard deviations. Significant differences among treatment means were tested using by the least significant difference at p=0.05(Steel and Torrie, 1980).

Results and discussion
Table 1 show that the soil in plots of both vetiver (VG) and natural fallow (NG) grass had more improved structural conditions compared to that without grass (CC). The former had significantly lower (P<0.05) bulk density, penetrometer resistances and smaller aggregate sizes but had significantly higher (P<0.05) soil water content and retention properties. Within the grass species however, the soil with vetiver grass had better properties than that under natural grass. Similar observations were made with respect to soil biological properties (Table 2). The organic C, POM, microbial biomass C and microbial quotient were highest in VG and lowest in CC while that for NG was in the middle. The microbial quotient ranged from 1% to 4% which is in the range commonly found in soils. Table 3 shows that organic matter and particulate organic matter were the most conspicuous soil properties that were influenced by the presence of grass in the plots and these were also strongly correlated with a wide range of other soil properties.

The higher organic carbon content in the plots with grass suggests higher organic matter inputs from litter originating from above and below ground parts of the grass. The humus which is produced after decomposition, binds to soil minerals to form soil aggregates that are stable thereby improving soil porosity, aeration and the water-retention capacities of the soil (Haynes, 1999). It has been well established from many parts of the world that organic matter has a profound influence on many soil properties and is therefore a key attribute of soil quality (Gregorich *et al*., 1994). The higher aggregation and stability of aggregates in vetiver plots is likely due to the influence of extensive mat of fine roots and microbially produced polysaccharides associated with the rhizophere of the vetiver grass (Pang *et al*., 2003). This implies that the aggregates and pores in this soil will remain undamaged on exposure to stress arising from raindrop impact thereby improving the movement and storage of water, air and biological activity, and growth of crops.

It was interesting to note the significant relationship between POM, microbial biomass C and the other soil properties. Both POM and microbial biomass are the labile non-humic fraction of organic matter and therefore constitute important pools of nutrients in the soil (Stevenson, 1994). The POM fraction hosts a large concentration of microorganisms because it provides a substrate for their activities (Janzen et al., 1992). The soil microbial biomass is thus important in maintaining soil structure in that the microorganisms associated with it exude mucilaginous carbohydrate material which acts as a glue and helps cement soil aggregates together (Dalal, 1998).

Conclusion
It is evident that vetiver grass had an ameliorative effect on soil quality under the semi-arid conditions of South Africa. It not only increased the soil organic matter in the surface soil, but also improved the physical and biological properties which are important for crop production and the environment in general. Its use for soil conservation is therefore recommended.

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Table 1. Physical properties of the surface (0-15 cm) soil after 15-years under different grass species. Values are means (± SD).

Grass	Bulk Density (Mg m^{-3})	Soil Water Retention (%) -33 kPa	Soil Water Retention (%) -1200 kPa	Soil Water Content (%)	Penetrometer Resistance (kPa)	Aggregate Stability (%>2.0mm)	Aggregate Mean Weight Diameter, dry (mm)
VG	1.23±0.11	17.32±1.02	13.44±0.97	15.78±2.43	386±43	65.4±5.1	3.2±0.10
NG	1.44±0.06	12.64±0.76	10.08±1.04	11.67±0.74	517±24	54.2±2.3	4.7±0.33
CC	1.68±0.75	8.13±0.48	5.06±0.12	9.15±1.26	829±55	21.6±8.1	7.8±0.45
LSD (p=0.05)	*0.19*	*3.77*	*3.26*	*2.33*	*125*	*9.6*	*1.44*

Table 2. Influence of vetiver grass on biological properties of a surface (0-15 cm) at Danville. Values are means (± SD).

Grass	Organic C (%)	POM (%)	Microbial Biomass C (mg/kg)	Microbial Quotient	Proportion of POM in whole soil (%)
VG	2.53±0.35	3.29±0.08	306±63	0.04	5.27±0.03
NG	1.64±0.56	2.67±0.15	218±24	0.02	3.32±0.44
CC	0.67±0.12	1.37±0.10	96±8	0.01	1.16±0.28
LSD (p=0.05)	*0.75*	*0.54*	*9.85*	*0.007*	*1.74*

Table 3 Some of the significant correlation coefficients estimated between the measured soil properties

	BD	POM	SWC	SWR	PR	AS	MBc
Organic carbon (OC)	-0.78**	0.85***	0.68*	0.53*	-0.61**	0.71**	0.89***
Particulate organic matter (POM)	-0.55*	-	0.51*	0.59*	-0.73	0.64*	0.87**

BD= bulk density; POM=particulate organic matter; SWC=soil water content, SWR=soil water retention; PR=penetrometer resistance; AS=aggregate stability; MBc= microbial biomass carbon;*,**,*** significant at the *P*<0.05, *p*<0.01, *P*<0.001 respectively