Range Mgmt. & Agroforestry 38 (2) : 176-180, 2017
ISSN 0971-2070

Effect of unguided cattle husbandry on selected soil physical properties in common property regimes in Alice, Eastern Cape Province, South Africa

Anye Chungag[1], Johan J. Van Tol[2,3]* and Bheki Magagula[1]

[1]Department of Geography and Environmental Sciences, University of Fort Hare, Alice, 5700, South Africa
[2]Department of Agronomy, University of Fort Hare, Alice, 5700, South Africa
[3]Department of Soil, Crop and Climate Sciences, University of the Free State, Bloemfontein, 9300, South Africa
*Corresponding author e-mail: vantoljj@ufs.ac.za

Received: 2nd August, 2016 Accepted: 18th August, 2017

Abstract

Unguided cattle husbandry (UCH) is a form of resource exploitation in South Africa where common property is treated as rangeland, and cattle herds of varying sizes without herdsmen make their way into these properties whenever they can. The environmental consequences of this widespread husbandry method have not been studied in the Eastern Cape Province. We conducted a study on the impact of UCH on soil physical properties including bulk density, infiltration, macroporosity and penetration resistance. Results obtained showed that there was a significant increase in bulk density and penetration resistance on the tracks when compared with the control whereas hydraulic conductivity and macroporosity were significantly decreased by cattle grazing activities. It was concluded that exposure of community lands to UCH caused substantial damage to the soil physical properties.

Keywords: Bulk density, Common property regime, Infiltration, Macroporosity, Penetration resistance

Introduction

Half of the world's land area is rangeland (Havstad, 2008), and grazing by domestic livestock is a substantial and pervasive land use form throughout the world (Milchunas and Lauenroth, 1993; Diaz *et al*., 2007). Recent investigations in cattle husbandry practiced on rangelands showed how rangeland ecosystems have adjusted to alterations induced by human exploitation. Many studies have shown that grazing might have a positive impact on landscape elements such as soil, water and vegetation and enhance biodiversity, especially on riparian pastures (Kauffman and Krueger 1984; Smith and Maltby, 2003; Humphrey and Patterson 2000). Vegetation density and diversity increased as cattle dung and urine revitalized soil and vegetation when compared to ungrazed sites. Van Uytvanck *et al.* (2009) showed that free ranging cattle can be used to restore nitrogen depleted soils and thus serve as a potential management tool.

The greater proportion of literature have however, shown that these environmental elements suffer from more negative effects from grazing than positive ones (Mekuria *et al*., 2007; Zhao *et al*., 2007). Faecal and urine deposits may be potential sources of air and water pollution despite their restorative capacities on land, there is also significant correlations between overgrazing and soil infertility as livestock reduce biomass, trample vegetation, disturb and compact soils through disruption of the soil structure (Abril and Butcher, 1999). Soil degradation further limits production of forage (Singh *et al*., 2011). One of the major impacts of livestock on soil resources is compaction. Soil compaction leads to the increase in bulk density of soils as a result of applied pressure or load (Kasisra, 2005). Compaction allows the soil particles to move closer to each other, reducing the pore spaces between them and increasing the bulk density of the soil. The pressure exerted by cattle results in the compression of soil particles which greatly reduces water and air storage in the soil profile. The reduced water storage increases the risk of moisture stress and reduces infiltration which enhances the soil erosions.

Unguided cattle husbandry can, therefore, have a negative impact on soil resources and reduce the ecosystem services rendered. In this study it was aimed to quantify the impact of this land use system on selected soil physical properties in the common property regimes of Alice, Eastern Cape, South Africa.

Materials and Methods

***Study area*:** The study was conducted in Alice (34 000 inhabitants), the Eastern Cape Province of South Africa (Fig 1). The climate is semi-arid with an annual rainfall of approximately 530 mm; the majority of the precipitation falling during warm summer months (Fig 2).

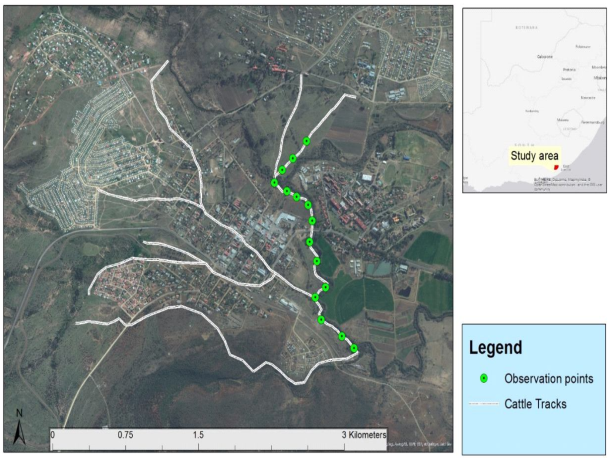

Fig 1. Study area (Alice), dominant cattle tracks and location of observation points

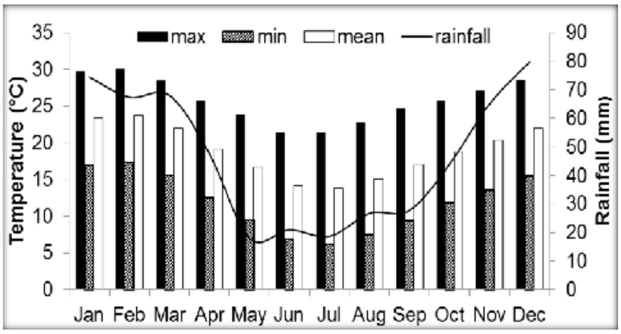

Fig 2. Selected climatic parameters for the study area

The vegetation forms part of the Savannah biome, characterized by herbaceous vegetation and short structured graminoids which grow and flourish in the same cyclical pattern as the rainfall (Mucina and Rutherford, 2011). The flood plain of the Tyume river (where observations were made) has deep alluvial soils generally referred to as the Orthic luvisols which belongs to the Oakleaf-Jozini series (Van Averberke and Marais, 1991).

Methodology: Soil samples were collected from 15 positions established on the animal tracks (Fig 1). Samples were collected at a depth of 0 - 15 cm and 15 - 30 cm. Control plots were set adjacent to tracks but at distances eliminating cattle interaction (approximately 5 m). Disturbed samples were collected to determine the particle size distribution (using the Bouyoucos hydrometer method). Undisturbed samples were collected from the sites using a core sampler with core having diameter of 11 cm and height of 7.7 cm. These 60 undisturbed samples were used to determine the dry bulk density (Db) of the different sites as well as hydraulic characteristics. Saturated hydraulic conductivity (Ks) was determined using the falling head double ring method. After the core was saturated, a smaller core (diameter 6 cm) was installed on top of the undisturbed core. Saturated hydraulic conductivity was calculated following Bouwer and Rice (1976):

$$K_s = \frac{L}{t} \times \frac{(h_o + L)}{(h_1 + L)} \quad \text{.................(Eq 1)}$$

Where: L was the thickness of the core; t was time till constant infiltration rate was obtained and h_0 and h_1 were the head of water above surface before and at the start of test and after respectively.

Hydraulic conductivity was also measured on the undisturbed cores at different suctions using tension infiltrometers. Infiltration rates were calculated using the approach followed by Ankeny *et al*. (1990). This method had the advantage that only steady state infiltration measurements were required, pore structure was not disturbed, the same soil surface was used and the calculations of the hydraulic conductivity were straightforward. Infiltration rates at different tensions were used to calculate the water conducting macroporosity (WCM).

In this study macropores were the pores which were emptied at a suction head of 3 cm with an equivalent pore radius (*r*) larger than 0.05 cm, following Luxmoore (1981). Macroporosity was calculated using the Watson and Luxmoore (1986) approach from the difference between pounded (double ring) infiltration rate and the infiltration rate at a tension of 3 cm. The theory behind this approach was that the capillary rise equation could be used to calculate the maximum pore size [(*r*) in cm)] which was filled with water at a certain suction head [(*h*) in cm]:

$$r = \frac{2\gamma\cos(\vartheta)}{\rho g h} \approx \frac{0.015}{h} \quad \text{.................(Eq 2)}$$

Where: γ = surface tension of water (M T^{-2}); ϑ = contact angle between water and pore wall (assumed to be 0); ρ = density of water (M L^{-3}) and g = gravitational force (L T^{-2}). Using the assumption of Watson and Luxmoore (1986) equation 2 predicted that all pores with a radius larger than 0.05 cm were macropores.

By making use the minimum pore radius at a certain tension in conjunction with *Poiseuille's law* the maximum number of water conducting macropores were determined by Watson and Luxmoore (1986):

$$N = \frac{8\mu K_m}{\pi \rho g r^4} \quad \text{.................(Eq 3)}$$

The total effective water conducting macroporosity (WCM, Θ_m) in $m^3\ m^{-3}$ was then obtained by equation 3; and was expressed as a percentage of the total soil volume in this study.

$$\Theta_m = N\pi r^2 \qquad \text{.................(Eq 4)}$$

An American Society of Agricultural Engineers standard dynamic cone penetrometer (DCP) was used to measure penetration resistance and hence the effects of hoofing on soil compaction (Herrick and Jones, 2002). This DCP consists of a 30º hardened cone with a 2.03 cm diameter base. The energy source was obtained from a 2 kg slide hammer with a drop height of 40 cm. The soil resistance was measured by:

$$R_s = \frac{W_s}{P_d} \qquad \text{.................(Eq 5)}$$

Where R_s was the soil resistance (N), W_s was the work done by the soil in (J) and P_d was the distance travelled by the penetrometer through the soil. Herrick and Jones (2002) calculated the work done by a single blow was 7.84 J. The distance (P_d) was determined after 5 blows and therefore the average resistance over P_d.

Statistical analysis: The statistical package SPSS version 19 was used to assess the differences between infiltration, bulk density, moisture content and penetration resistance of track and control points as well as between treatments at different depths. Fisher's Least Significant Difference (LSD) was used to evaluate differences between different parameters.

Results and Discussion

Particle size distribution: The results presented in Table 1 indicated that there were no significant differences in the textural classes of the 15 sample points and their controls ($P > 0.05$). The soils had sandy clay loam texture. Indeed, texture is constant soil property, not influenced by external treatments. The homogeneous texture between the track and control sites implied that any differences in the more dynamic soil properties, such as bulk density, hydraulic conductivity and water conducting macroporosity were due to animal impacts and not due to inherent differences between the soils.

Bulk density and penetration resistance: The bulk densities were significantly higher on tracks when compared to the control plots ($P < 0.001$). There were no differences within the groups i.e. at different depths (Table 1). Similar to the bulk density, significantly higher penetration resistance (R_s) values were measured on the tracks when compared to the control points ($P < 0.005$). R_s was only measured on the surface (0 - 15 cm). This clearly indicated that the soils were more compacted in the tracks than in the control plots. The capability of cattle to impact the mechanical elements of the soil was related to the fact that soil bulks contain voids. Voids facilitate the development of healthy root system, and they also easily respond to trampling pressure exerted by grazing cattle on rangelands. Where pressure exerted by animal hooves is high, more particulate materials are forced to move closer to each other. Consequently, more voids are impaired leading to greater compaction. This implied the tracks invariably were more compacted with higher bulk densities at both 0 - 15 cm and 15 - 30 cm levels given the incessant animal passes. It was noted from the results that there was a slight decrease in the bulk density with increasing depth in the track treatment (Table 1). Although not significantly different it was worth mentioning that the impact of cattle appears to be greater in the surface layers. These findings were agreed with those obtained by Chaichi *et al*. (2005) who investigated the impact of grazing intensities on rangeland in the Lal

Table 1. Soil particle size distribution, bulk density, saturated and unsaturated hydraulic conductivity, water conducting macroporosity and penetration resistance of different depths of tracks and their controls

Treatment	Track	Track	Control	Control	Significance (p value)
Depth (cm)	0-15	15-30	0-15	15-30	
Sand (%)	63.50[a]	59.80[a]	60.09[a]	59.10[a]	$p > 0.05$
Silt (%)	15.60[a]	18.60[a]	16.81[a]	18.70[a]	$p > 0.05$
Clay (%)	20.90[a]	21.60[a]	23.10[a]	22.20[a]	$p > 0.05$
Texture class	SaClLm	SaClLm	SaClLm	SaClLm	
Db[1] ($g\ cm^{-3}$)	1.54[b]	1.51[b]	1.37[a]	1.38[a]	$p < 0.001$
Ks[2] ($cm\ h^{-1}$)	2.236[b]	2.172[b]	5.337[a]	6.244[a]	$p < 0.001$
K_3[3] ($cm\ h^{-1}$)	0.317[a]	0.243[a]	0.406[a]	0.523[a]	$p > 0.05$
WCM[4] [$\Theta_{m(\%)}$]	0.104352[a]	0.104909[a]	0.268073[b]	0.311059[b]	$p < 0.05$
R_s[5] (N)	414.62[b]		205.29[a]		$p < 0.005$

[1]D_b= Bulk density; [2]K_s = Saturated hydraulic conductivity; [3]K_{30} = Hydraulic conductivity at -30 mm tension; [4]WCM = Water conducting macroporosity; [5]R_s = Penetration resistance, Parameter values with different letters are significantly different (P <0.05) according to Fischers' LSD

rangeland in Iraq. The reason advanced to explain this tendency by Chaichi *et al*. (2005) was that the stocking density of cattle exceeded the numbers that the enclosure could hold. In this current study it was not a question stocking densities, but that of uncontrolled number of routine passes throughout the day. Equal farming rights with the system of exploitation leads to this. High bulk densities easily translate into poor soil health; the soil then fails to function as a vital living system within the ecosystem and living land boundaries. Since there were no differences in the bulk densities within groups it indicates that unguided cattle grazing/movements do affect soil mechanical properties to a depth of 30 cm and even more (Naeth *et al*., 1991; Chaichi *et al*., 2005). Compaction of surface layers are further supported by the increase of penetration resistance of surface layers (Table 1).

***Hydraulic conductivity and water conducting macroporosity*:** The saturated hydraulic conductivity (K_s) was significantly higher in the control plots when compared to the tracks. Interestingly K_s was lower in the surface (0 - 15 cm) of the control plots than the 15 - 30 cm depth, although this difference was not significant. There was no significant difference in the hydraulic conductivity at a suction of 3 cm ($P > 0.05$). The water conducting macroporosity (WCM) was, however, significantly higher in the control plots when compared to the animal trodden tracks. But there were no differences in WCM at different depths (Table 1).

The differences in saturated hydraulic conductivities in this study rather strongly suggested that the pore spaces in various shapes or sizes had been damaged by compaction. The reduced pore sizes and distorted pore shapes, the broken inter-connective links and walls, were found to be more plausible explanations than differences in structure and texture. Discontinuous pores were very common in soils that were subjected to external burdens such as trampling pressures exerted by ruminant grazers (Van Tol *et al*., 2012). Pores were defined by Hendrickx and Flurry (2001) as 'all phenomena where water and solutes move along certain pathways, while bypassing a fraction of the porous matrix'. Taboada and Lavado (1993) showed that compaction could reduce WCM into a series of disconnected micro-pores inhibiting soil aeration and infiltration. This change in pore distribution shifts the function of the surface soil from aeration to water clogging. This action may then block the exchange of gases between the soil and the atmosphere and degrade the soils capacity to support plant life. The lower hydraulic conductivity of animal tracks will further inhibit water infiltration and can result in the generation of overland flow which may cause significant soil water erosion.

Conclusion

The numerous passes from countless herds created denuded tracks with increased bulk densities and thereby reduced the storage capacities of the soil for water. The greater penetration resistance, smaller infiltration capabilities and fewer macropores of the soils subjected on animal trodden paths implied that the soil physical health were substantially damaged leaving the soils very vulnerable to erosive forces. Conclusively, unguided cattle husbandry had comparatively greater negative impacts to the soil physical properties namely bulk density, hydraulic conductivity, penetration resistance and water conducting porosity.

References

Abril, A. and E. H. Bucher. 1999. The effects of overgrazing on soil microbial community and fertility in the Chaco dry savannas of Argentina. *Applied Soil Ecology* 12: 159-167.

Ankeny, M. D., T. C. Kaspar and R. Horton. 1990. Characterization of tillage and traffic effects on unconfined infiltration measurements. *Soil Science Society of America Journal* 54: 837-840.

Bouwer, H. and W. C. Rice. 1976. A slug test for determining hydraulic conductivity of unconfined acquifers with completely or partially penetrating wells. *Water Resources Research* 12: 423-428.

Chaichi, M.R., M.M. Saravi and A. Malekian. 2005. Effects of livestock trampling on soil physical properties and vegetation cover (case study: Lar rangeland, Iran). *International Journal of Agricultural Biology* 7: 904-908.

Diaz, S., S. Lavorel, S. McIntyre, V. Falczuk, F. Casanoves, D. G. Milchunas, C. Skarpe, G. Rusch, M. Sternberg, I. Noy-Meir, J. Landsberg, W. Zhang, H. Clark and B. D. Campbell. 2007. Plant trait responses to grazing-a global synthesis. *Global Change Biology* 13: 313–341.

Havstad, K. M. 2008. Mongolia's rangelands: Is livestock production the key to the future? *Frontiers in Ecology and the Environment* 7: 386-387.

Hendrickx, J. M. H. and M. Flury. 2001. Uniform and preferential flow, mechanisms in the vadose zone. Conceptual Models of Flow and Transport in the Fractured Vadose Zone, National Research Council, National Academy Press, Washington, DC. pp. 149-187.

Herrick, J. E. and T. L. Jones. 2002. A dynamic cone penetrometer for measuring penetration resistance. Soil Science Society of American Journal 66: 1320-1324.

Humphrey, J. W. and G. S. Patterson. 2000. Effects of late summer cattle grazing on the diversity of riparian pasture vegetation in an upland conifer forest. Journal of Applied Ecology 37: 986–996.

Kassisra, L. L. 2005. Force modelling and energy optimization for sub-soilers in Tandem. Unpublished PhD Thesis, University of Pretoria, South Africa.

Kauffman, J. B. and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications, a review. Journal of Range Management 37: 430–438

Luxmoore, R.J. 1981. Micro-, meso- and macroporosity of soil. Soil Science Society of America Journal 45: 671–672.

Mekuria W., E.Veldkamp, H. Mitiku, J. Nyssem, B. Muys and G. Kindeya. 2007. Effectiveness of exclosures to restore degraded soils as a result of overgrazing in Tigray, Ethiopia. Journal of Arid Environments 69: 270-284.

Milchunas, D.G. and W. K. Lauenroth. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. Ecological Monographs 63: 327–366.

Mucina, L. and M. C. Rutherford. 2011. The vegetation of South Africa, Lesotho and Swaziland. South Africa National Biodiversity Institute, Pretoria.

Naeth, M. A., A. W. Bailey, D. S. Chanasyk and D. J. Pluth. 1991. Water holding capacity of litter and soil organic matter in mixed prairie and fescue grassland ecosystems of Alberta. Journal of Range Management 44: 13-17.

Singh, J.P., V., Paul, S., Maiti, S., Ahmad, D., Deb, R.S., Chaurasia and R. Soni. 2011. Sustainability of temperate/alpine pastures vs landform and soil status: A case study of Sikkim using GIS and RS techniques. *Range Management and Agroforestry* 32: 19-24.

Smith, R. D. and E. Maltby. 2003. *Using the ecosystem approach to implement the convention on biological diversity: Key issues and case studies*. ICUN, Gland, Switzerland and Cambridge, UK.

Taboada, M. A. and R. S. Lavado. 1993. Influence of trampling on soil porosity under alternate dry and ponded conditions. *Soil Use and Management* 9: 139-143.

Van Averberke, W. and J. N. Marais. 1991. *An evaluation of Ciskeian ecotopes for rain fed cropping*. ADRI, University of Fort Hare, South Africa.

Van Tol, J. J., P. A. L. Le Roux and M. Hensley. 2012. Pedotransfer functions to determine water conducting macro porosity in South African soils. *Water Science and Technology* 65: 550-557.

Van Uytvanck, J., T. Milotic and M. Hoffmann. 2009. Nitrogen depletion and redistribution by free-ranging cattle in the restoration process of mosaic landscapes: the role foraging strategy and habitat proportion. *Restoration Ecology* 18: 205–216.

Watson, K. W. and R.J. Luxmoore. 1986. Estimating macroporosity in a forested watershed by use of a tension infiltrometer. *Soil Science Society of America Journal* 50: 578-582.

Zhao, Y., S. Peth, J. Krummelbein, R. Horn, Z. Wang, Z. Steff, C. Hoffmann and X. Peng. 2007. Spatial variability of soil properties affected by grazing intensity in Inner Mongolia grassland. *Ecological Modelling* 205: 241-254.