Ekológia (Bratislava) Vol. 29, No. 2, p. 219–226, 2010
doi:10.4149/ekol_2010_02_219

# EFFECTS OF GRAZING AND TRAMPLING ON PRIMARY PRODUCTION AND SOIL SURFACE IN NORTH AFRICAN RANGELANDS

MOULDI GAMOUN[1]*, MOHAMED TARHOUNI[1], AZAIEZ OULED BELGACEM[1], BELGACEM HANCHI[2], MOHAMED NEFFATI[1]

[1] Laboratoire d'Ecologie Pastorale, Institut des Régions Arides (IRA), 4119 Médenine, Tunisia; e-mail: gamoun.mouldi@yahoo.fr
[2] Faculté des Sciences, Campus Universitaire, 2092 Tunis, Tunisie

Abstract

Gamoun M., Tarhouni M., Ouled Belgacem A., Hanchi B., Neffati M.: Effects of grazing and trampling on primary production and soil surface in North African rangelands. Ekológia (Bratislava), Vol. 29, No. 2, p. 219–226, 2010.

Grazing damages primary production and trampling compacts the soil, thereby reducing organic matter and increase sandy dune. The primary production and soil surface were studied simultaneously in both grazed and protected range sites with two different soil types; sandy and limestone. Vegetation characteristics, in particular productivity cover, differed significantly between the protected and grazed sites and increased significantly in the non-grazed range site. We also observed a significant increase in wind veil rates in the grazed range site compared to the protected range site that is more marked on the sandy soil. Litter content was higher inside and exposed bare soil greater outside the protected area. A comparison of production and soil surface within the ungrazed showed that vegetation condition and soil surface were good and that removal of grazing animals on the sandy soil that on the limestone soil, as in the protected, causes an improvement in rangelands condition in this region. On the other hand the limestone soil supports better overgrazing.

*Key words*: livestock grazing, disturbance, primary production, soil surface, management

## Introduction

The recent studies, based on the space observation, show that the border of the desert advances or moves back according to the quantity of precipitations in a year given (Tucker et al., 1991). On the other hand, according to Le Floc'h (1996), more the ecological serious

*Corresponding author

problems come from the behavior of the populations and the actions led during the climatically favorable periods, whereas the consequences appear only after, when degradation led to the loss of impact strength and the capacities of recovery of the mediums towards the disturbances. However the impact of the drought is weak or negligible where the human and animal impact is low or null (Le Houérou, 1993).

The influence of grazing on soil is closely linked to the effects of animal. Depending on the texture of the soil, trampling may favor or impede (sandy soil) surface crusting (Valentin, 1985). The livestock, can have an enormous impact on the rangelands, sometimes positive, generally negative, even disastrous (Le Houérou, 1986, 1992). Grazing is a complex process that involves a large number of individual processes: selection of a forage item at the species and individual plant level, herbivory in itself, trampling, etc. (Parsons, Dumont, 2003). The plant species of the desert steppe are resistant to heavy grazing pressure but litter ground cover is readily removed, which exposes the soil to wind erosion (Li et al., 2008).

From a soil point of view, desertification appears as linked to physical degradation (Valentin, Casenave, 1990) including sealing, crusting, hardsetting, and eventually wind and water erosion, since vegetation can recover, trapping airborne sand and gradually burying the erosion crusts (Valentin, 1985). The differences in the land use can cause changes in soil properties. Overgrazing and its attendant effects reduce plant cover and trampling of soil contributes to degradation of soils (Branson et al., 1981). Livestock trampling compacts soil and significantly reduces water infiltration rate (Abdel-Magid et al., 1987; Fleischner, 1994; Gamougoun et al., 1984; Evans, R., 1998; Schlesinger et al., 1990; Perevo1otsky, 1994; Evans, N.V., 2000; Amiri, 2008). However, the hoof action reduced the size of naturally occurring soil aggregates and increased density of the surface soil layer. Wind-drilled sands are entrapped by surrounding vegetation and can evolve in turn into sieving structural crusts if vegetation decays due to drought and/or overgrazing (Valentin, 1985). Generally, hard-hoofed animals have had a major impact on the generally thin soil of the rangelands, particularly when vegetation cover has been cleared, or where vegetation has been subject to overgrazing (Earl, Jones, 1996), once grass is removed and loose, sandy soil is exposed, it is easily eroded by strong winds (Fredrickson et al., 1998).

In southern Tunisia, in front of the big number of the livestock, which of him higher than that is allowed by the production of the ecosystem, more share rangelands are overgrazed (Le Houérou, 1971), thus their use exceeds 35% of phytomass available (Le Houérou, 1962, 1969, 1989). This ill-considered exploitation of the rangelands leads to a disturbance of the natural environment leading to serious long-term consequences, until the turning into a desert of the medium (Floret, Pontanier, 1982; Khatelli, 1996).

The objective of work presented here is to evaluate the effect of trampling on the soil surface the short-term ground. The principal assumption is that the effect of trampling on the soil surface results from type of soil and the effects of the disturbances of soil surface.

## Methods

### *Study area*

The study was conducted in 2008 at the El'Ouara rangelands. The study area is located in the Governorate of Tataouine (Southern Tunisia; 32°30' N, 10°40' W), and is characterized by an arid Mediterranean bioclimate with a moderate winter. Rainfall is low and sporadic; the mean annual is estimated to be around 100 mm. Temperatures are generally cold in winter and hot in summer with a mean annual of about 20.1°C. The water balance is greatly affected by the low dense soil cover and exposition to winds. Potential evapo-transpiration is estimated around 1600 mm year$^{-1}$ in average (Tataouine meteorological station, 1954–2000 period).

The experiment was conducted in spring (month of March) 2008, inside the protected area, and in its surrounding area which is subjected to continuous heavy grazing. Soil surface as well as rangelands production were the main assessed indicators. The rainfall quantity was very low during 2007 (37 mm) and reached 78 mm in 2008 (Fig. 1).

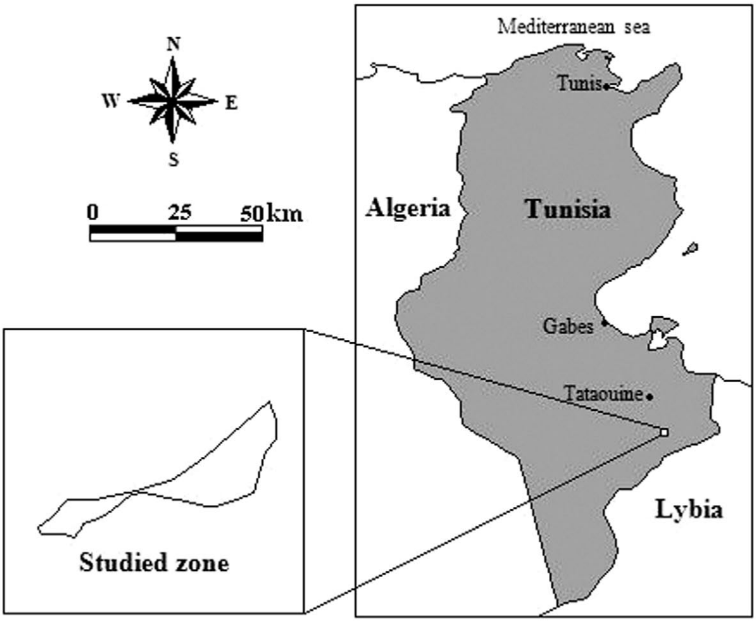


Fig. 1. Geographic localization of the studied rangelands.

### *Data collection*

Data were collected from protected and heavy grazed sites. In each vegetation type (sandy soil and limestone soil) we established three sampling sites at least 100 m apart. At each site, six 100 m transects were set: three at the reserve and the other in the grazed field. Within each sampling quadrat (Jauffret, Visser, 2003) we recorded at the soil surface.

Both in protected and in heavy grazed area, biomass production was estimated by clipping all vegetation (annual and perennial) within 32 quadrats of 4 m$^2$ in each area.

*Statistics*

Differences in mean soil surface, and rate of biomass production between land uses categories were tested, on untransformed data, with the ANOVA. The data collected were summarised in Statistical Package for the Social Sciences (SPSS) and analysed using the same programme (SPSS Inc., 2002).

## Results

Regarding productivity, we found significant effects of treatment ($F = 871.758$; $P < 0.0001$; df = 1) with a higher abundance in protected area (mean = 180 kg DM. $ha^{-1}.year^{-1}$) respect to overgrazed (mean = 91 kg DM. $ha^{-1}.year^{-1}$). There were also significant effects of soil type ($F = 82.793$; $P < 0.0001$; df = 1) with the highest abundance in sandy soil (mean = 149 kg DM. $ha^{-1}.year^{-1}$) followed by limestone soil (mean = 122 kg DM. $ha^{-1}.year^{-1}$). All interactions between effects were significant: treatment and soil ($F = 380.172$; $P < 0.0001$; df = 1). These interactions reflect that the effect of considered factors on biomass became more intense in the protected area, as well as tendencies among soil types were opposite (Fig. 2).

Crust rate was significantly between treatments ($F = 210.007$; $P < 0.0001$; df = 1) with high rate in the reserve (mean = 58%) respect to the grazed area (mean = 0%), and among all soil types ($F = 163.242$; $P < 0.0001$; df = 1) with the highest rate at sandy soil (mean = 53%) followed by limestone soil (mean = 3%). As regards interactions, there were significant interactions between crust and treatment ($F = 163.242$; $P < 0.0001$; df = 1).

Too, the wind veil was significantly between treatments ($F = 1588.512$; $P < 0.0001$; df = 1) with high rate in the ungrazed area (mean = 8%) respect to the grazed area (mean = 66%),

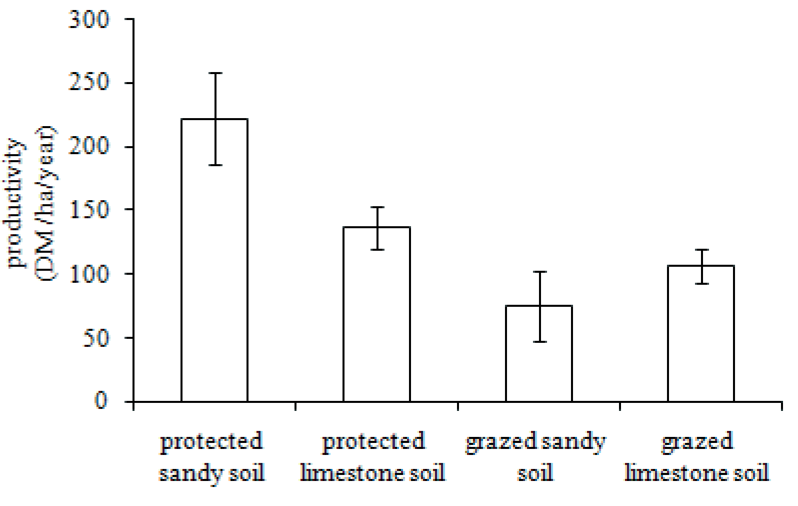


Fig. 2. Primary production in protected and grazed areas in sandy and limestone soil.

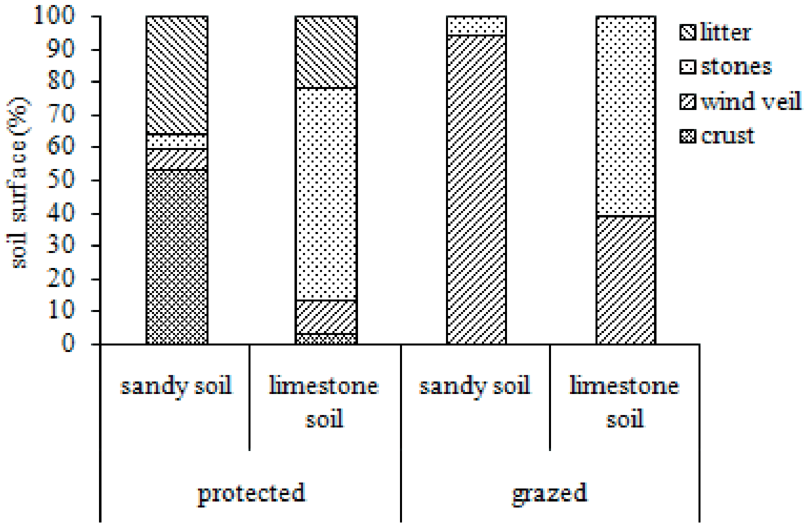


Fig. 3. Soil surface in protected and grazed areas in sandy and limestone soil.

and among all soil types (F = 304.051; P < 0.0001; df = 1) with the highest rate at sandy soil (mean = 50%) followed by limestone soil (mean = 24%). As regards interactions, there were significant interactions between wind veil and treatment (F = 397.128; P < 0.0001; df = 1).

The stones did not differ between grazed (33%) and ungrazed (35%) treatments (F = 1.779; P = 0.218; df = 1), and regarding soil types, it was higher in limestone soil (62%) and lower in sandy soil (5%) (F = 1750.367; P < 0, 0001; df = 1).

Regarding litter, we found significant effects of treatments (F = 143.611; P < 0.0001; df = 1) with a higher abundance in protected area (mean = 28%) than the grazed area (mean = 0%). There were also significant effects of soil type (F = 8.563; P = 0.019; df = 1) with a higher mean for the sandy soil (mean = 18%) than the limestone soil (mean = 11%). All interactions between effects were significant: soil and treatment (F = 8.563; P = 0.019; df = 1) (Fig. 3).

## Discussion and conclusion

Several studies have dealt with the relationship between livestock grazing and traits of the ecosystems, finding significant interactions (Floret, Pontanier, 1982; Floret et al., 1981; Noy-Meir et al., 1989; Hadar et al., 1999; Sternberg et al., 2000).

We found that grazing effects on productivity varied among soil types. Productivity was higher in the sandy soil in protected area while under heavy grazed area the opposite occurred. Moreover, a balanced stocking rate and herbage production is particularly difficult due to the high variability of biomass growth during the grazing seasons (Pavlů et al., 2006).

In the arid regions where it is directly in contact with the atmosphere, the soil surface plays an important part especially in the development of the spontaneous or cultivated plants, in the water cycle and in the erosion processes (Escadafal, 1981; Valentin, 1985a).

Beyond the degradation of the vegetation, we can note also the sanding of the grazed rangelands accelerated by desertification at the beginning, wind erosion and animal trampling. The observations of the soil surface, show us that the wind veil colonizes almost the majority of surface of the land, and reached 100% sometimes on the sandy soils.

Between soil types, the sandy soil is higher affected by animal trampling then limestone's soil, since this last is more compact, therefore able to retain the plant species, whereas sandy soil surface disturbances resulted in greatly decreased soil resistance to wind erosion (Zhang et al., 2006).

Livestock may ingest plant in a selective way when consuming litter, thus trampling had a significant effect on the total productivity of rangelands, in addition trampling had a significant on total litter cover and crust.

Since most of the aerial part of the grass is generally eaten by grazing animals, it is mainly the overgrazing which exposes the land to erosion. The action of trampling may be important in rupturing the soil surface and breaking litter which aid their transport by the wind. In other hand, trampling also reduces niches for water capture and seed germination, and compromises the ability of the surface to capture and store soil water (Eldridge, 1998).

This effect of trampling activates the wind effect which is a major erosive force in deserts where there is little organic matter or vegetation cover to protect the soil surface. This erosive force contributes to the sanding land whatever the soil type; in particular, wind erosion promotes accumulation of sands on the soil surface (Li et al., 2006).

Our study indicated that greater litter was removed by trampling or consumption under heavy grazing. As grazing animals trample and remove live vegetation and litter mass, production is reduced, especially in arid ecosystems.

Summarizing, the heterogeneous vegetation matrix of the arid rangelands represents different substrates for livestock effects, leading to diverse responses in some parameters which could be due to different grazing intensities among other factors. Further-more, there is an variation in the productivity of plants, and as a consequence, a differently sensitive substrate to grazing.

The sandy soil is more productive than the limestone soil, whereas the latter are more resistant to animals trampling. Trampling effects on dry soil decreases soil surface roughness and increases erosion and reduces plant production, production reductions may decrease interception and transpiration damage or kill the plants and stimulate plant growth.

We conclude that productivity and soil surface promoted by different environmental factors, is determinant for the response to disturbance of arid communities. Our data on vegetation support that idea and confirm that these organisms are good models for this kind of assessment. We suggest, however, that long-term studies are necessary to fulfill the picture in our ecosystems, accomplish the building of predictive models for the management of our resources, and finally the number of livestock in an area is important in studies of grazing gradients in terms of assumptions about the degree of grazing intensity (Hoshino et al., 2009).

*Translated by the authors*

**References**


Abdel-Magid, A.H., Schuman, G.E., Hart, R.R., 1987: Soil bulk density and water infiltration as affected by grazing systems. J. Range Manag., 40: 307–309. doi:10.2307/3898725

Amiri, I.F., Ariapour, A., Fadai, S., 2008 : Effects of Livestock Grazing on Vegetation Composition and Soil Moisture Properties in Grazed and Non-Grazed Range Site. J. Biol. Sci., 8: 1289–1297.

Branson, F.A., Gifford, G.F., Renard, K.G., Hadley, R.F., 1981: Rangeland hydrology. Reid, E.H. (ed.), Soc. Range Manage. Kendull/Hund Publ. Com. Iowa.

Earl, J., Jones, C., 1996: The need for a new approach to grazing management—is cell grazing the answer? Rangelands Journal, 18: 327–350. doi:10.1071/RJ9960327

Eldridge, D.J, 1998: Trampling of microphytic crusts on calcareous soils, and its impact on erosion under rain-impacted flow. Catena, 33 : 221–239. doi:10.1016/S0341-8162(98)00075-7

Escadafal, R., 1981 : L'étude de la surface du sol dans les régions arides (sud-tunisien), recherches méthodologiques. ORSTOM, 67 pp.

Evans, N.V., 2000 : The vegetation potential of natural rangelands in the mid-fish river valley, Eastern Cape, South Africa: towards a sustainable and acceptable management system. Thesis doctor of philosophy of Rhodes University Grahamstown, 149 pp.

Evans, R., 1998: The erosional impact of grazing animals. Prog. Phys. Geog., 22: 251–268.

Fleischner, T.L., 1994: Ecological costs of livestock grazing in western North America. Conserv. Biol., 8: 629–644.

Floret, C., Le Floc'h, E., Romane, F., Pontanier, R., 1981 : Dynamique des systèmes écologiques de la zone aride. Application à l'aménagement sur les bases écologiques d'une zone de la Tunisie présaharienne. Acta Oecologica, Oecol. Applic., 2 (3) : 195-214.

Floret, C., Pontanier, R., 1982: L'aridité en Tunisie présaharienne: Climat – sol – végétation et aménagement. Trav. et Doc. ORSTOM, n° 150, Paris, 544 pp.

Fredrickson, E., Havstad, K.M., Estell, R., Hyder, P., 1998: Perspectives on desertification: southwestern United States. J. Arid Environ., 39, 2: 179–190. doi:10.1006/jare.1998.0390

Gamougoun, N.D., Smith, R.P., Wood, K., Pieper, R.D., 1984: Soil vegetation and hydrologic responses to grazing management at Fort Stanton, New Mexico. J. Range Manag., 37: 538–541.

Hadar, L., Noy-Meir, I., Perevolotsky, A., 1999: The effect of shrub clearing and grazing on the composition of a Mediterranean plant community: functional group versus species. J. Veg. Sci., 10: 673–682. doi:10.2307/3237082

Hoshino, A., Yoshihara, Y., Sasaki, T., Okayasu, T., Jamsran, U., Okuro, T., Takeuchi, K., 2009: Comparison of vegetation changes along grazing gradients with different numbers of livestock. J. Arid Environ., 73: 687–690. doi:10.1016/j.jaridenv.2009.01.005

Jauffret, S., Visser, M., 2003 : Assigning life-history traits to plant species to better qualify arid land degradation in Presaharian Tunisia. J. Arid Environ., 55 : 1–28. doi:10.1016/S0140-1963(02)00258-6

Khatelli, H., 1996 : Erosion éolienne en Tunisie aride et désertique: Analyse des processus et recherches des moyens de luttes. Th. Doct. Univ. De Gent, Belgique, 180 pp.

Le Floc'h, E., 1996 : Desertification in the Near East region, perspectives, strategies and plan of action. IATF Meeting on desertification, 27 pp.

Le Houérou, H.N., 1962 : Les pâturages naturels de la Tunisie aride et désertique. 12pl.h.t. 4 cartes ½.000.000ème. Inst. Sc. Econ. Appl, Ministère du plan, Tunis, 106 pp.

Le Houérou, H.N., 1969 : La végétation de la Tunisie steppique (avec références aux végétations analogues de l'Algérie, de la Lybie et du Maroc). Annales de L'INRAT, vol. 42 Fasc. 5, Tunis; 617 p; annexes + carte couleurs h.t.

Le Houérou, H.N., 1971: An assessment of the primary and secondary production of the arid grazing lands: ecosystems of North Africa, 25 p. FAO–Rome et Proc. Intern. Symp. On Ecophysiol. Foundation of ecosystems productivity in Arid zones, p. 168–172. Nauka, Leningrad.

Le Houérou, H.N., 1986 : La régénération des steppes algériennes. Paris: Institut national de la recherche agronomique, 45 pp.

Le Houérou, H.N., 1989: The grazing Land of ecosystems of the Sahel. Ecological Studies No. 75. Springer Verlag, Heidelberg, 282 pp.

Le Houérou, H.N., 1992: The grazing Land of Mediterranean Basin. In Coupland, R.T. (ed.), Natural grassland. Ecosystem of the word. Vol. 8. Elsevier, Amsterdam, p. 171–196.

Le Houérou, H.N., 1993: Evolution climatique et désertisation. In André, J.C., Fellous, J.L., Podaire, A. (eds), Les climats subtropicaux et leur évolution. CNES, Toulouse, 704 pp.

Li, C., Hao, X., Zhao, M., Han, G., Willms, W.D., 2008: Influence of historic sheep grazing on vegetation and soil properties of a Desert Steppe in Inner Mongolia. Agric. Ecosyst. Environ., 128: 109–116. doi:10.1016/j.agee.2008.05.008

Li, X.R., Jia, X.H., Dong, G.R., 2006: Influence of desertification on vegetation pattern variations in the cold semi-arid grasslands of Qinghai-Tibet Plateau, North-west China. J. Arid Environ., 64: 505–522. doi:10.1016/j.jaridenv.2005.06.011

Noy-Meir, I., Gutman, M., Kaplan, Y., 1989: Responses of Mediterranean grassland plants to grazing and protection. J. Ecol., 77: 290–310. doi:10.2307/2260930

Parsons, A.J., Dumont, B., 2003: Spatial heterogeneity and grazing processes. Anim. Res., 52: 161–179. doi:10.1051/animres:200301

Pavlů, V., Hejcman, M., Pavlů, L., Gaisler, J., Nežerková, P., 2006: Effect of continuous grazing on forage quality, quantity and animal performance. Agric. Ecosyst. Environ., 113: 349–355. doi:10.1016/j.agee.2005.10.010

Perevolotsky, A., 1994: Proceedings of workshop on arid lands management toward ecological sustainability. Jerusalem, p. 145–150.

Schlesinger, W.H., Reynolds, J.F., Cunningham, G.L., Huenneke, L.F., Jarrell, W.M., Virginia, R.A., Whitford, W.G., 1990: Biological feedbacks in global desertification. Science, 247: 1043–1048. doi:10.1126/science.247.4946.1043

SPSS Inc 2002. Systat, version 11.5. SPSS Inc., Chicago, IL.

Sternberg, M., Gutman, M., Perevolotsky, A., Ungar, D., Kigel, J., 2000: Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. J. Appl. Ecol., 37: 1–15. doi:10.1046/j.1365-2664.2000.00491.x

Tucker, C.J., Dregne, H.E., Newcomb, W.W., 1991: Expansion and contraction of the Sahara Desert from 1980 to 1990. Science, 253: 299–301.

Valentin, C., 1985: Effects of grazing and trampling on soil deterioration around recently drilled water-holes in the Sahelian zone. In Swaïfy, S.A., Moldenhauer, W.L., Lo, A. (eds), Soil erosion and conservation. Soil Conservation Society of America, Ankeny, p. 51–65.

Valentin, C., 1985a.: Organisations pelliculaires superficielles de quelques sols de région subdésertique. Etudes et thèses. ORSTOM, Paris, 259 pp.

Valentin, C., Casenave, A., 1990: The impact of soil surface deterioration on runoff production in the arid and semi-arid zones of Africa. In The state of the art of hydrology and hydrogeology in the arid and semi-arid areas of Africa. UNESCO/International Water Resources Association, Urbana, Illinois, p. 126–134.

Zhang, Y.M., Wang, H.L., Wang, X.Q., Yang, W.K., Zhang, D.Y., 2006: The microstructure of microbiotic crust and its influence on wind erosion for a sandy soil surface in the Gurbantunggut Desert of Northwestern China. Geoderma, 132: 441–449.