VOL. 4, NO. 4, JULY 2009 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

A STUDY OF THE RELATIONSHIP BETWEEN LAND MANAGEMENT AND SOIL AGGREGATE STABILITY (CASE STUDY NEAR ALBERSDORF, NORTHERN-GERMANY)

Iraj Emadodin[1], Stefan Reiss[2] and Hans Rudolf Bork[1]
[1]Department of Ecotechnology and Ecosystem Development, Ecology Centre, CAU, Kiel, Germany
[2]Ministry of Science, Research and Culture of the State of Brandenburg, Potsdam, Germany
E-Mail: iemadodin@ecology.uni-kiel.de

ABSTRACT

Soil aggregate stability is an important indicator of soil physical quality. In this study we hypothesized that land use and management influence soil aggregation and aggregate stability. The comparison between instability index in different land- use systems at the time of sampling, clearly indicates that soils under agricultural land use (0-30cm) have an instability lower than forest soils. Therefore the results confirm that land use has had a significant effect ($P<0.05$) on aggregate stability. A positive relationship ($R^2 = 0.85$) was found between soil instability index (Is) and depth (0-85 cm) in investigation sites under forest. A sharp change of the instability index between depths of 10-20 cm is important. This confirms that after the removal of the surface horizon soil is highly erodible; in this case intensive soil erosion may take place. The investigation also suggests that the soil aggregate stability is important to provide a condition for the stabilization of organic matter in soils and also for chemical, physical and biological activities.

Keywords: soil instability index, land use, soil organic matter, Germany.

1. INTRODUCTION

Soils are most important in many ecosystems as dynamic natural body and fundamental resource. Human activities often influence the natural processes in soils. According to Head (2008) humans are inextricably embedded in all earth surface processes, and often dominate them. One of the most critical natural resource management needs of the 21st century is information about the dynamic nature of soils, or simply, soil changes (Tugel *et al*, 2005).

Soil aggregate stability is an important indicator of soil physical quality (Castro Filho *et al.*, 2002). Land use and management also influence soil aggregation and aggregate stability (Bergkamp and Jongejans, 1988; Cerda, 2000). Soil organic matter certainly improves the ability of the soil to resist erosion and enables the soil to hold more water. Important is its effect in promoting soil aggregation in a granular soil and the combination of increased water penetration (Stevenson and Cole, 1999). The loss of organic matter and consequently soil fertility is often driven by unsustainable practices such as deep plowing on fragile soils and cultivation of erosion-facilitating crops and the continuous use of heavy machinery which destroys soil structure through compaction.

Soil organic matter content has a direct relationship with soil erodibility. The stability of soil aggregates is enhanced where organic material is combined with clay particles and where it contributes to chemical bonding (Morgan, 1986). Generally, soils with a higher content of organic matter and an improved soil structure have a greater resistance against soil erosion by water and wind. Continuous soil erosion has a significant effect on soil erodibility. In the research areas the material below a soil which was totally eroded is often more erodible because of its low organic matter content, its lower clay content and its different structure. Low aggregate stability enforces soil erosion.

Erodibility as a dynamic property of a soil depends on the stability of soil aggregates and the percentage of coarse primary particles that are resistant to erosion (Morgan, 1986). The soil erodibility is ‘the inherent susceptibility of soil particles or aggregates to become detached or transported by erosive agents such as rainfall, runoff, wind and etc. (Toy *et al.*, 2002; Morgan 2005). With regard to this definition it has to mention that soil erodibility usually changes with land use, because cultivation practices modify soil structure; with the continuation of this change soil erodibility will be increased. Moreover, when subsoil with different textural characteristics is mixed into the plow layer, soil structure and water regime may be affected (Schumacher, 1999). In this case it is necessary to improve our understanding of the effects of land use on soil stability in order to develop a high level of soil quality and especially productivity.

The soil structure depends namely on the grain size distribution, on soil formation processes and the effects of plants, animals and humans. Freezing and thawing, water movement, the growth and decay of plant roots and the activity of soil animals (e.g. Earth worms) as natural factors on the one hand and human activities (namely management practices) on the other can cause in rearranging of particles in soil aggregates. Therefore in many cases the structure of a soil directly affects its properties (Marshall *et al.*, 1996). A low status of organic matter (naturally low or due to soil degradation) is an important reason for the instability of soil aggregates. Many aricultural practices affect soil structure. Decrease in both the stability and the organic matter of soils under annual tillage has been observed by several researchers (e.g. Low, 1972; Allen, 1985; Gami *et al.*, 2001; Caravaca *et al.*, 2001).

Shrestha *et al.* (2007) indicated that the knowledge of soil aggregate stability is useful in the evaluation of soil properties with regard to land use systems. With respect to the review which was carried out by Shrestha *et al.* (2007), land use and management practices have a strong effect on soil properties, especially on aggregation and soil organic carbon dynamics. These effects vary spatially and temporally. Shrestha *et al.* (2007) also stressed that there is a lack of information on the mechanisms and magnitudes of soil organic carbon dynamics associated with aggregate- and particle size fractions under different land use systems.

2. MATERIALS AND METHODS

2.1 Study area

The research area near Albersdorf is located at 45° 06′ N and 9° 18′ E. It covers an area of about 40 ha with moderately inclined slopes on the groundmoraine plain and steep slopes bordering the valley of the Gieselau. The current land use of the study areas is dominated by different types of (coniferous and deciduous) forests and agriculture (grassland and arable land). The dominat regional species in the investigated areas include: *Erica tetralix, Calluna vulgaris, Pinus sylvestris, Picia abies, Betula Pendula, Quercus robur, Fagus sylvatica* (Reiss, 2005). These plant species reflect the edaphical sites conditions. The research area is managed by a non-profit organization, the AÖZA (Archaeological-Ecologcial-Centre Albersdorf). Near Albersdorf two sites were selected: Bredenhoop and Reddersknüll.

Bredenhoop is a small catchment with a size of 12.99 ha area which is farmland today. The central dell in this catchment which was formed in the late Weichselian by periglacial processes has a width of 150 m and a length of about 800 m in north-south direction. Reddersknüll consists of two afforested subcatchments. Reddersknüll I and Reddersknüll II cover area of 1.15 ha and 1.24 ha respectively. The dell of Reddersknüll I have a width of 50 m and a length of 80 m in west to east direction. A north-south oriented dell with a width of 50 m and a length of 100 m is located in Reddersknüll II.

The particle size distribution shows sandy loam and loamy sand textures. Gravel deposits are the result of extreme runoff events with rill and gully erosion in the past. The high pH values in agriculturally used sites are due to fertilization. Under forest soil pH values are generally lower. In agricultural land no Ah-horizons were found at the recent soil surface; Tillage practices have mixed former Ah-horizons with lower horizons. At other sites Ah-horizons were eroded.

The investigation areas are located between the North Sea and the Baltic Sea; therefore they are characterized by a moderate temperate and oceanic climate with soft and moist winters and temperate, rainy summers. The average air temperature during the summer months is 13, 0-13.5° C. July and August are the warmest months of the year with a mean air temperature of about 17-18° C. The mean air temperatures during the winter months are 2.5-3.0° C; the coldest average temperatures are about 0-1° C in January and February. The average annual precipitation in the region is between 900-1200 mm (Westenmeier *et al.,* 1999).

2.2 METHODS

The main objective of this study was to estimate the effects of land use on soil stability. Moreover, the relationship between stability and depth in a soil is also evaluated.

Two sites with different land-use systems were selected near Albersdorf. One site is covered today with forest (Reddersknüll) and another site is used as farmland (Bredenhoop). Soil samples were collected from the surface to a depth of 85 cm at three profiles in each site.
The colors of the soil horizons were described using the Munsell soil color charts (Munsell, 2000). The texture was estimated roughly in the field. In the laboratory, the four main elements were measured including particle size distribution, bulk density, pH, total nitrogen and organic matter content (Reiss *et al*, 2008). One-way analysis of variance (ANOVA) was used to test the effect of different land use on soil instability.

After field and laboratory analysis, the soil instability index was calculated. This index was proposed by Comdeau and Monnier (1961). It is based on soil structural characteristics which have been proved useful in predicting erosion risks for a wide range of soils (Cotler, 1998). This index is obtained from the formula:

$$Is = \frac{\text{\% maximum (clay + silt)}}{\text{\% mean coarse fragments– 0.9 (\% coarse sand)}}$$

Is = Instability index
This index varies from 0 to 3; 3 is the highest structure instability.

3. RESULTS AND DISCUSSIONS

The comparison between instability index in different land-use systems at the time of sampling, clearly indicates that soils under agricultural land use (0-30cm) have an instability lower than forest soils (Table-1 a,b). Therefore, the results confirm that land use has had a significant effect ($P < 0.05$) on aggregate stability (Figure-1).

A positive relationship (Figure-2) was found between soil instability index (Is) and depth (0-85 cm). The graph in Figure-2 demonstrates that with an increase of depth soil instability increases. This could be affected by a decrease of soil aggregate size. A sharp change of the instability index between depths of 10-20 cm is important. This confirms that after the removal of the surface horizon soil is highly erodible; in this case intensive soil erosion may take place. The investigation also suggests that the soil aggregate stability is important to provide a condition for the stabilization of organic matter in soils and also for chemical, physical and biological activities.

The soil instability index in agriculturally used areas was higher than in forest area as a result of the structural degradation at the soil surface; also the soil instability index in forest areas was higher with increasing depth under the soil surface. This change in the values of the instability index is related to a change of organic matter content with depths (Figure-3).

The results show in general that human activities, with respect to past deforestation and then intensive agricultural practices have had an effective influence on the changes of soil properties. This investigations acknowledge that the change of soil management over long periods have had a significant impact on the soil aggregate stability. Evidence in our investigation areas also proves that the soil conditions have a significant relation with the decision-making in the past.

In conclusion, it could be emphasised that the impact of human activities on soils is unavoidable; in many cases negative effects will be multiplied by land mismanagement. Therefore having a good knowledge from the soil degradation helps to get a successful strategy against unwanted soil changes in order to achieve a sustainable management of the soils in the future.

REFERENCES

Allen, J. R. L.1985. Principles of physical sedimentology. Geo. Allen and Unwin, London.

Bergkamp, G. and Jongejans, J. 1988. The stability of soil aggregates in the middle mountains of Nepal. University of Amsterdam, Amsterdam, the Netherlands.

Caravaca, F., Lax, A., and Albaladejo, J. 2001. Soil aggregate stability and organic matter in clay and fine silt fractions in urban refuse-amended semiarid soils. Soil Science Society of America Journal 65: 1235-1238

Castro Filho, C., Lourenco, A., Guimaraes, M.D.F. and Fonseca I. C. B. 2002. Aggregate stability under different soil management systems in a red latosol in the state of Parana, Brazil. Soil Tillage Res. 65: 45-51.

Cerda, A. 2000. Aggregate stability against water forces under different climates on agriculture land and scrubland in southern Bolivia. Soil Tillage Res. 57: 159-166.

Colter, H. 1998. Effects of land tenure and farming systems on soil erosion in Northwestern Peru. Advances in GeoEcology 31: 1539-1543.

Combeau, A. and Monnier, G. 1961. A method for the study of structural stability: application to tropical soils. African soils 6: 33-52.

Gami, S.K., Ladha, J.K., Pathak, H., Shah, M. P.,Pasuquin, E., Pandey, S.P., Hobbs, P. R, Joshy, D. and Mishra R. 2001. Long-term changes in yield and soil fertility in a twenty-year rice-wheat experiment in Nepal. Biol. Fertil. Soils. 34: 73-78.

Head, L. 2008. Is the concept of human impacts past its use-by date? The Holocene. 18(3): 373-377.

Low, A.J. 1972. The effect of cultivation on the structure and other characteristics of grassland and arable soils. J. Soil Sci. 23, 363-380

Marshal, T.J., Holmes, J.W. and. Rose, C.W. 1996. Soil physics. Cambridge Univ. Press, Melbourne, Australia.

Morgan, R. P. C. 1986. Soil degradation and soil erosion in lomay belt of northern Europe. In: Chisci, G. and Morgan, R.P.C. (eds.) 1986. Soil erosion in the European community, impact of changing agriculture. A.A. Balkema, Rotterdam. pp. 165-172.

Morgan, R. P. C. 2005. Soil erosion and conservation. (Third Edition), Blackwell publishing Lrd. p.304.

Munsell, 2000. Munsell soil color charts. Gretag MacBeth, NY.

Reiss, S. 2005. Langfristige Wirkungen der Landnutzung auf den Stoffhanaushalt in der Dithmarscher Geest seit dem Neolithikum. EcoSys, Beiträge zur Ökosystemforschung suppl. Bd. 44.

Reiss, S, Dreibrodt, S, Lubos, C and Bork, H. R., 2008. Land use history and historical soil erosion at Albersdorf (northern Germany). Ceased agricultural land use after the pre-historical period Catena. 77: 107–118.

Shrestha, B.M., Singh, B.R., Sitaula, B.K., Lal, R. and Bajracharya, R.M. 2007. Soil aggregate- and particle-associated organic carbon under different land uses in Nepal. Soil Science Society of America Journal. 71(4): 1194-1203.

Stevenson, F.J. and Cole, M.A. 1999. Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients, Second Edition. John Wiley and Sons, INC.

Toy, T.J., Foster, G.R. and Renard, K.G. 2002. Soil Erosion: Processes, Prediction, Measurement, and Control, New York: John Wiley and Sons. p. 338.

Tugel, A. J., Herrick, J. E., Brown, J. R., Mausbach, M. J., Puckett,W. and Hipple K. 2005. Soil Change, Soil Survey, and Natural Resources Decision Making: A Blueprint for Action. Soil Sci. Soc. Am. J. 69: 738-747.

Westenmeier, M., Kris, G.A and Dittmann, E. 1999. Klimaatlas Bundesrepublik Deutschland, DWD, Offenbach.

Table-1. Results from the calculation of the soil instability index a) in two current land use systems in the surface layer (0-30cm) b) in forest area from the surface to a depth of 85 cm.

a)

Forest			**Agriculture**		
IS	**Org. M** (%)	**N** (%)	**IS**	**Org. M** (%)	**N** (%)
0.34	9.3	0.47	1.56	1.4	0.09
0.38	11.9	0.55	1.67	0.7	0.04
0.53	1.2	0.04	1.16	0.8	0.06
1.48	1.9	0.07	0.86	1.1	0.07
1.18	2.4	0.09	-	-	-
0.89	1.4	0.05	-	-	-
0.66	1.2	0.05	-	-	-
0.07	11.6	0.55	-	-	-
0.69	**5.11**	**0.23**	**1.32**	**1**	**0.06**

b)

Is	**Depth (cm)**
0.4	5
1	15
0.8	25
1.1	35
1.2	45
1.3	55
1.4	65
1.5	75
1.5	85

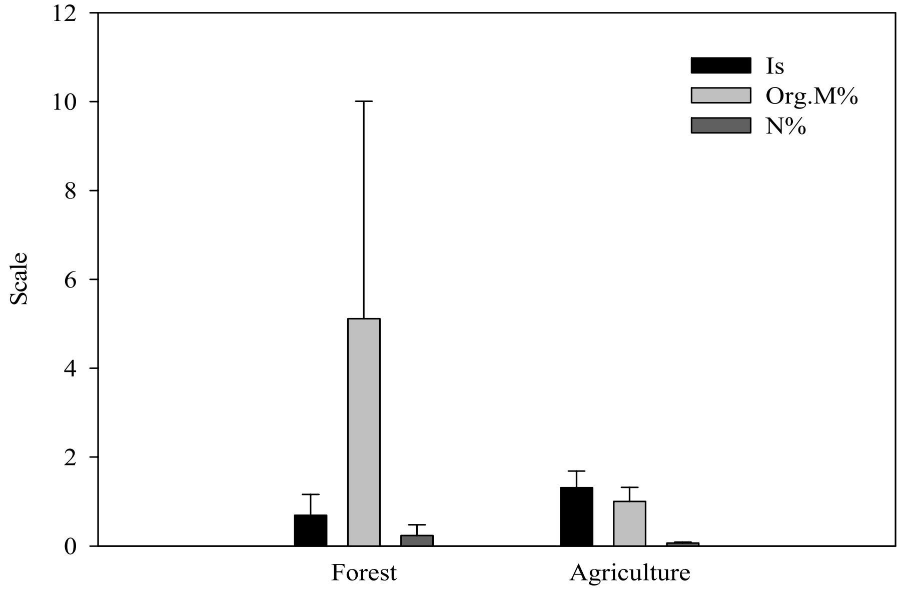

Figure-1. Comparison of soil instability index, total nitrogen and organic matter content of two land-use systems.

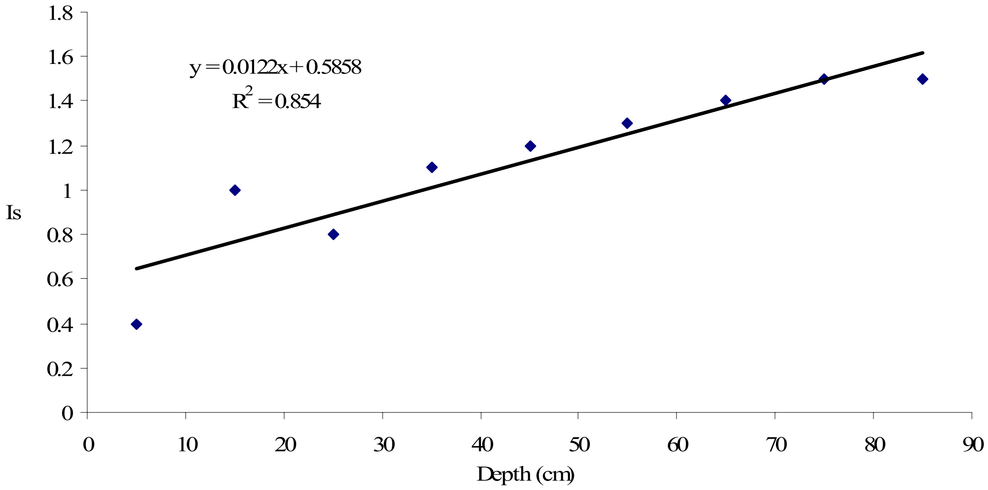

Figure-2. A positive linear relationship ($R^2 = 0.85$) between the soil instability index (Is) and depths in soils of the forest ecosystem.

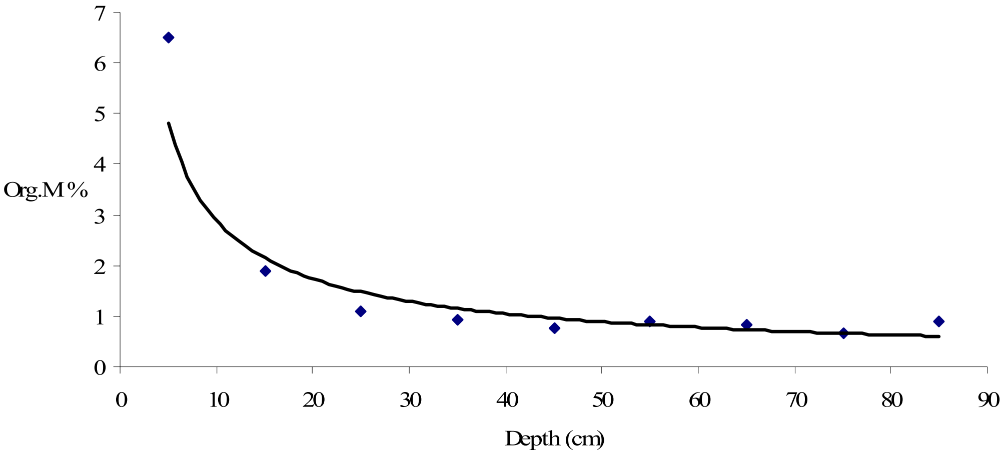

Figure-3. Comparison of organic matter content and depth in soils of the forest ecosystem.