Middle East Journal of Agriculture Research
ISSN 2077-4605
Volume : 07 | Issue : 02 | April-June | 2018
Pages:307-314

The Soils of Archeological Sites in Middle Egypt: Risk assessment

[1]Ali R.R., G. El-Bayomi[2], M.A. El Semary[1] and E.F. Essa[1]

[1]*Soils and Water Use Department, National Research Centre, Egypt*
[2]*Geography Department, Faculty of Arts, Helwan University, Egypt*

Received: 19 Feb. 2018 / Accepted: 10 April 2018 / Publication date: 23 April 2018

ABSTRACT

The current study aims to evaluate the risks related to the soils of some archeological sites in Middle Egypt. To complete this goal field investigation, laboratory analyses and Geographic Information System (GIS) were used. Soil erodability, cracking, stability and waterlogging were assessed and ordered according to their impact on the archeological sites. The results indicate that the archeological sites are subject to soil erosion (i.e. Sheikh-Abada and Bani-Hassan), soil cracking (i.e. El-Bahnasa and El-Ashmunein) and waterlogging (i.e. El-Ashmunein, Tel Al Amarna and El-Bahnasa). In general the area require high grade of liability to preserve these archaeological sites that represent a great ration of World Heritage.

Key words: soil risk, archeology, Middle Egypt

Introduction

The soil risk on the archeological sites could be evaluated through the assessment of soil erodability, soil cracking & stability and waterlogging. Erosion is the surface process by which earth material is displaced across the surface. It is mainly caused by the natural mechanical action of wind and water; however, human impact can also accelerate soil erosion rates further through farming, terracing, habitation, and deforestation. Serious erosion tends to be irreversible. The landscape history of a region could reflect in modern landforms, and can be recreated with knowledge of soil movement and erosion (Karydas *et al.,* 2009). The soil erodibility (K-factor) depends on different soil parameters in combination. While many equations exist to determine an exact value for K based on size of particles, percentage of organic matter, soil structure, and soil drainage. Soil erodibility is a measurable quality of the inherent capability of a particular soil; it is a quantity of the vulnerability of soil particles to split and moved by water and wind. For an individual soil, the erodibility factor (K) represents the rate of erosion. The K-factor reveals that dissimilar soils erode at different rates when the other factors that affect erosion (e.g. infiltration rate, permeability, water capacity, dispersion, rain splash, and scraping) are the same. Soil texture is the primary factor control K-factor; however structure, organic matter, and permeability also engage. The soil erodibility factor ranges in value from 0.02 to 0.69 (Goldman et al. 1986; Mitchell and Bubenzer 1980) where the grater the k-factor the grater the soil erosion. Various processes can crack open soils, allowing materials from upper strata and the surface to infiltrate lower levels, filling them with sediment. Temperature variation cause soil expanding with different rates, forming crevasses filled with topsoil sediments. Such cracks can grow to 30 Cm in width and 100 Cm in depth in arid climates. The clay mixing soils are in general includes very high content of clay minerals (> 50 %). Some clay hold water well, and when saturated, swell in size. Shedding water can cause the soil to contract and crack (Costa *et al.,* 2012). Soil aggregates are clusters of soil particles that join to each other more intensely than to nearby particles. Stability of aggregate represents the capability of soil to resist breakup when disruptive forces related to tillage and water / wind erosion are applied. Stability of wet aggregate show how well a soil could resist water erosion, while particle size of dry aggregates is used to describe the soil resistance to wind erosion. Variations of aggregate stability could assist as early indexes of soil resilience or degradation. Soil stability also refers to organic matter content, biological activity, and element cycling in soil. Generally, small soil aggregates (< 0.25 mm) are tied by more stable forms of organic matter. Microbial infections of organic matter produce less stable component that connect

Corresponding Author: Ali R.R., Soils and Water Use Department, National Research Centre, Egypt

minor aggregates into large one (> 2-5 mm). Large aggregates are more sensitive to rain and wind effects, it serve as a better indicator of changes in soil stability (Dan Davidson, 2014). Waterlogging is the fullness of soil with water; the soil is considered as waterlogged when the level of the groundwater is worthy high to accessibly permit the normal activity. Surface crusts impede the flow of air and water; moreover it leads to enlarged run-off and a subsequent increase in water erosion and susceptibility to wind erosion when dry (Mandal and Sharma, 2011).

Material and Methods

Study area

El Minya Governorate is located in the middle of the Nile Valley (Figure 1) including 9 administrative units. Samalout district is the largest one, covering an area of 362.5 km2, representing 15.5% of the total area. El Minya district extends in an area of 351.3 Km2 representing 15.0%. The importance of El Minya district is related to its inclusion of the Governorate capital, and El Minya University. Melawi district exhibits a coverage of 327.6 km2 representing 14.0% of the whole area. Abu Qurqas and Bani Mazar districts have mostly similar area coverage (i.e 288.8 and 282.5 km2 respectively). The districts of Maghagha, Dayr Mowas, Matay and Al-Adwah extend for relatively small areas figuring 230.2, 179.6, 171.8 and 143.8 km2 representing 9.9, 7.7, 7.4 and 6.2% of the Governorate area respectively. Six archaeological sites were selected for the current study i.e. Tuna El Gabal, Seikh Abada, Bani Hassan, El Bahnasa, El Ashmoneen, and Tel El Amarna, the geographical locations of these sites are illustrated in Table 1.

Fig. 1: Location of the study area (outlined by red line)

Table 1: Coordinates of selected archaeological sites in El Minya Governorate

No.	Location	Longitude (Decimal degrees)	Latitude (Decimal degrees)
1	El Bahnasa	30.651393	28.537123
2	Bani Hassan	30.883572	27.934541
3	Seikh Abada	30.874473	27.805324
4	Tuna El Gabal	30.739331	27.773610
5	Ashmoneen	30.802724	27.778984
6	Tel El Amarna	30.933661	27.637724

Field work and laboratory analyses

Land survey was done over the investigated area in order to gain an appreciation on the soil patterns, landforms and landscape characteristic. Six observation points were studied in the field; the morphological description was carried out according to the guidelines edited by FAO (2006). Using the soil survey laboratory methods manual (USDA, 2004) a total of 18 representative disturbed soil samples have been collected and analyzed. Soil taxonomy (USDA, 2010), were used to classify the different soil in the investigated sites. The general magnitude of the K-factor as a function of organic matter content and soil textural class was defined using the method developed by Mills *et al.* (1985) as presented in Table 2.

Table 2: Soil erodibility factor (K-factor)

Texture class	Organic matter %			Texture class	Organic matter %		
	<0.5	2	4		<0.5	2	4
Sand	0.05	0.03	0.02	Loam	0.38	0.34	0.29
Fine sand	0.16	0.14	0.10	Silt loam	0.48	0.42	0.33
Very fine sand	0.42	0.36	0.28	Silt	0.60	0.52	0.42
Loamy sand	0.12	0.10	0.08	Sandy clay loam	0.27	0.25	0.21
Loamy fine sand	0.24	0.20	0.16	Clay loam	0.28	0.25	0.21
Loamy very fine sand	0.44	0.38	0.30	Silty clay loam	0.37	0.32	0.26
Sandy loam	0.27	0.24	0.19	Sandy clay	0.14	0.13	0.12
Fine sandy loam	0.35	0.30	0.24	Silty clay	0.25	0.23	0.19
Very fine sandy loam	0.47	0.41	0.33	Clay	0.13	0.18	0.2

Digital Elevation Model

Digital Elevation Model (DEM) is a 3D electronic model of the land's surface (Brough, 1986). It provides better functionalities than the topographic maps (Lee *et al.,* 1988). The digital elevation model (DEM) of the study area was extracted from the Shuttle Radar Topography Mission (SRTM). Surface elevation, slope % and slope direction have been derived from DEM by using Arc-GIS 9.2 software.

Results and discussion

Soil erodability risk

Soil properties such as depth (Cm), gravels %, organic matter OM %, soil texture and K-factor of the archeological sites are illustrated in Table 3. The data indicate that the value of soil erodibility (K-factor) ranges between 0.05 and 0.27; low values characterize the Typic Torriorthents soils, where the archeological sites of Bani Hasan, El -Sheikh 'Abadah and Tel El Amarna exist. The high values exhibits the rest of the area as El-Ashmunein (Vertic Torrifluvents soils), Tuna El-Gabal (Typic Quartizipsamments soils) and El-Bahnasa (Typic Petrogypsids soils) which characterized by an erodibility index of 0.27 (Figure 2 and 3). In general the investigated soils are poor in organic matter as the percent of organic matter content in the investigated soils not exceed 0.5%; so high erodibility is expected in the areas of fine texture soils (i.e. Sandy clay loam soils). It is noticed that the archeological sites that located to the east of the river Nile (Bani Hasan, El -Sheikh 'Abadah and Tel El Amarna) are attributed by low erodibility while those in the western bank of the Nile (El-Bahnasa, Tuna El-Gabal and El-Ashmunein) are of high erodibility risk. In view of this surface slope should by take in consideration when estimating the erosion hazard. Steep and extended of the slope surface increases the risk for erosion (e.g. Chavez, 2006), water erosion increases with long slope surfaces as a result of greater accumulation of runoff. Consolidation of small areas into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water, which permits a greater degree of scouring (e.g. Boggs *et al.,* 2001). The surface slope of El Minya governorate was extracted from the Digital Elevation Model (DEM). Table 4 illustrates the surface slope in the different investigated sites. The data indicate that the surface slope reach it maximum values in Sheikh-Abada (i.e. 10.5079 %) and Bani-Hassan (i.e. 10.1731 %). Moderate slope characterizes the surfaces of El-Bahnasa area (i.e. 2.7423 %) while the sites of El-Ashmunein, Tel El-Amarna and Tuna El-Gabal as they attributed by surface slope of 1.1561, 0.6195 and 0.2330 % respectively. In spite of the low soil erodibility of the sites east of the Nile bank especially in Sheikh-Abada and Bani-Hassan they suffer from high erosion due to the high degree of surface slope. Tel El-Amarna area has a low erodibility and low degree of surface slope, so low soil erosion is expected. The rest of the investigated sites are threatened by moderate erosion due to high soil erodibility and low slope degree.

Table 3: Gravel %, texture, organic matter (OM) % and soil erodibility (K-factor) of the investigated archeological sites

Site	Depth (cm)	Gravel (%)	Texture classes	OM (%)	Soil K-factor
El-Bahnasa	0 - 30	0.00	Sandy clay loam	< 0.5	0.27
	30 - 60	0.00	Sandy clay loam	< 0.5	0.27
	60 - 90	5.18	Sandy loam	< 0.5	0.27
	90 - 130	10.32	Sandy loam	< 0.5	0.27
Bani Hasan	0 - 50	10.78	Sandy	< 0.5	0.05
	50 - 100	31.17	Sandy	< 0.5	0.05
El -Sheikh ’Abadah	0 - 40	45.98	Sandy	< 0.5	0.05
	40 - 120	38.34	Sandy	< 0.5	0.05
Tuna El-Gabal	0 - 30	9.31	Sandy	< 0.5	0.05
	30 - 50	5.83	Sandy	< 0.5	0.05
	50 - 120	1.61	Sandy	< 0.5	0.05
El-Ashmunein	0 - 25	1.22	Sandy clay loam	< 0.5	0.27
	25 - 45	1.68	Sandy clay loam	< 0.5	0.27
	45 -90	4.64	Sandy clay loam	< 0.5	0.27
Tel El Amarna	0 - 30	32.76	Sandy	< 0.5	0.05
	30 - 65	35.63	Sandy	< 0.5	0.05
	65 - 85	47.22	Sandy	< 0.5	0.05
	85 - 150	54.94	Sandy	< 0.5	0.05

Fig. 2: Eroded surface filled with water in El-Bahnasa area; note that the evidence of native vegetation reduced the surface erosion

Fig. 3: Eroded surfaces; note that the evidence of native vegetation indicates the shallow water table

Table 4: Surface slope of the investigated sites

No.	Location	Surface slope (%)
1	El-Ashmunein	1.1561
2	Bani Hasan	**10.1731**
3	El-Bahnasa	2.7423
4	El -Sheikh ’Abadah	**10.5079**
5	Tel El Amarna	0.6195
6	Tuna El-Gabal	0.2330

Soil cracking risk

The clayey soils contains high quantity of smectite in its structure, that demonstrate a peculiar crystal structure, since its elementary unit is formed by layers of two sheets of silicon tetrahedra and one sheet of octahedra. However, while the interlayer space in other clays is very stable, it may vary between 14 and 18 angstroms in smectite, this is due to the bond between them is done by very weak forces (Van der Waals forces). This makes easy the ingress of water into the interlayer space (e.g. Driessen and Deckers, 2001). Thus, in dry climate, the stored water in the interlayer space of the smectite is lost during the dry interval, the space is reduced and, therefore, soil aggregates hold. Similarly, the entry of water into the interlayer space in the wet season makes the sheets to discrete the crystal structure (e.g. Boivin, 2007). The reduction of the aggregates during the dry period causes the cracks in the soil surface. In the rainy season, the water inlet in the interlayer space of the smectite produces enlargement and, therefore, the aggregates swell locking cracks. Continuous arrangements of expansion and contraction (caused by clay) lead to a identical distribution of oriented clay in the surface of aggregates, which form the shining surfaces known as slickensides, a phenomenon characterizes clayey soils. The frequent cycles of shrinkage and swelling, (opening and closing) of cracks, causes a sort of self-mulch. In the long-term, soil material sinking in cracks during dry season produces mixture of the material and the surface layer of the soil could be very deep due to the internal continuous turnover (e.g. Dinka *et al.,* 2013). The particle size of the investigated soils shows that the clay percentage is in general low. Also the regularity of the soil content plays a vital role in soil cracking, the more the heterogeneity the more of soil cracking. Considering the clay content and homogeneity of soil particles the cracking hazard of the investigated soils were classified as presented in Table 5. The acquired results indicate that the soil cracking hazard is moderate in El-Bahnasa and El-Ashmunein sites while there is a slight soil cracking hazard in Bani Hasan, El -Sheikh 'Abadah, Tuna El-Gabal and Tel El Amarna.

Table 5: Ability of soil cracking in the investigated sites

Site	Depth (cm)	Clay (%)	Soil particles	Cracking hazard
El-Bahnasa	0 - 30	>50	Heterogeneous	Moderate
	30 - 60	>50	Heterogeneous	Moderate
	60 - 90	>50	Heterogeneous	Moderate
	90 - 130	>50	Heterogeneous	Moderate
Bani Hasan	0 - 50	>50	Homogenous	Non
	50 - 100	>50	Homogenous	Non
El -Sheikh ’Abadah	0 - 40	>50	Homogenous	Non
	40 - 120	>50	Homogenous	Non
Tuna El-Gabal	0 - 30	>50	Homogenous	Non
	30 - 50	>50	Homogenous	Non
	50 - 120	>50	Homogenous	Non
El-Ashmunein	0 - 25	>50	Heterogeneous	Moderate
	25 - 45	>50	Heterogeneous	Moderate
	45 -90	>50	Heterogeneous	Moderate
Tel El Amarna	0 - 30	>50	Homogenous	Non
	30 - 65	>50	Homogenous	Non
	65 - 85	>50	Homogenous	Non
	85 - 150	>50	Homogenous	Non

Soil stability risk

Greater amounts of stable aggregates suggest better soil stability (e.g. Boško *et al.,* 2013). When the proportion of large to small aggregates increases, soil stability generally increases. Stable aggregates could provide an enormous range in soil pore space. This also includes the small pores inside soil aggregates. Pore space is important for air and water entry to soil, and for biota movement within soil. Large pores related to large stable aggregates favor high infiltration rates and proper soil aeration then it provides zones of soil weakness. Conversely, surface crusts and filled pores that occur in weakly aggregated prevent infiltration and encourage soil erosion; closed pores lower water-holding and air-exchange capacity. Aggregate stability is risky for infiltration and resistance to water and wind erosion. Unstable aggregates break during rainstorms (e.g. USDA, 2001). Dispersed soil particles block surface pores; consequently hard surface crust can develop when the soil dries. The surface crust led to reduction in Infiltration, so increased runoff and water erosion is projected. Wind typically separates only loosely held particles, but the accelerated particles by the wind strike bare soil and break other particles from softly aggregated soil. This process increases the quantity of particles that can be contract by the wind and scratch exposed soil surface. The soil aggregates could be deteriorated also by the high content of NaNO3 in the soils that disperse the soil particles (e.g. USDA, 2009) as found in Tel El Amarnan. Morphological description worked out during the field work and the soil structure where defined for the investigated sites (Table 6). The data indicate that the soil structure is slight or moderate strong with fine or medium size of aggregate in the sites of El-Bahnasa and El-Ashmunein. The structure is single grains in Bani Hasan, El -Sheikh 'Abadah, Tuna El-Gabal and Tel El Amarna. In view of these results the soils are stable in Bani Hasan, El -Sheikh 'Abadah, Tuna El-Gabal and Tel El Amarna sites in both dry and wet condition. The soils are more stable also in El-Bahnasa and El-Ashmunein sites only under dry condition, while under the wet conditions (i.e. flash flood risen of ground water) these soils are unstable.

Water logging risk

In archaeology, waterlogging refers to the long-term exclusion of soil air by groundwater, which generates an anaerobic setting that can reserve artifacts perfectly. Surface crusts restricting water infiltration may cause waterlogging creating an anaerobic situation (e.g. Holden, 2006). Waterlogging hazard was observed in the archeological sites of Tel Al Amarna, El-Ashmunein and partly in El-Bahnasa (Figure 4). The evidence of waterlogged areas indicates bad drainage condition and also refers to human constructions. The degree of waterlogging hazard is very high in El-

Ashmunein and Tel Al Amarna while it moderate in El-Bahnasa. The causes of this phenomena differ from site to another, it found in El-Bahnasa and El-Ashmunein due to the geographical locatins closed to the cultivated areas, where the water seepage from the nearby irrigation canals. In Tel Al Amarna the water logging is mainly related to the evidence of hard pans near the soil surface. The anaerobic and wet conditions accelerate the degradation of archaeological constructions. Field studies of the archeological sits (Bani Hasan, Shiek Abada and Tuna El-Gabal) indicate that there is no evidence of waterlogged areas.

Table 6: Soil structure and stability in dry and wet conditions

Site	Depth (cm)	Soil structure	Soil stability	
			When dry	When wet
El-Bahnasa	0 - 30	Slightly strong fine to medium granular	Stable	Unstable
	30 - 60	Slightly strong fine sub angular blocky	Stable	Unstable
	60 - 90	Single grains	Stable	Unstable
	90 - 130	Single grains	Stable	Stable
Bani Hasan	0 - 50	Single grains	Stable	Stable
	50 - 100	Single grains	Stable	Stable
El -Sheikh ’Abadah	0 - 40	Single grains	Stable	Stable
	40 - 120	Single grains	Stable	Stable
Tuna El-Gabal	0 - 30	Single grains	Stable	Stable
	30 - 50	Single grains	Stable	Stable
	50 - 120	Single grains	Stable	Stable
El-Ashmunein	0 - 25	Moderately strong fine to medium granular	Stable	Unstable
	25 - 45	Moderately strong medium sub angular blocky	Stable	Unstable
	45 -90	Moderately strong medium sub angular blocky	Stable	Unstable
Tel El Amarna	0 - 30	Single grains	Stable	Stable
	30 - 65	Single grains	Stable	Stable
	65 - 85	Single grains	Stable	Stable
	85 - 150	Single grains	Stable	Stable

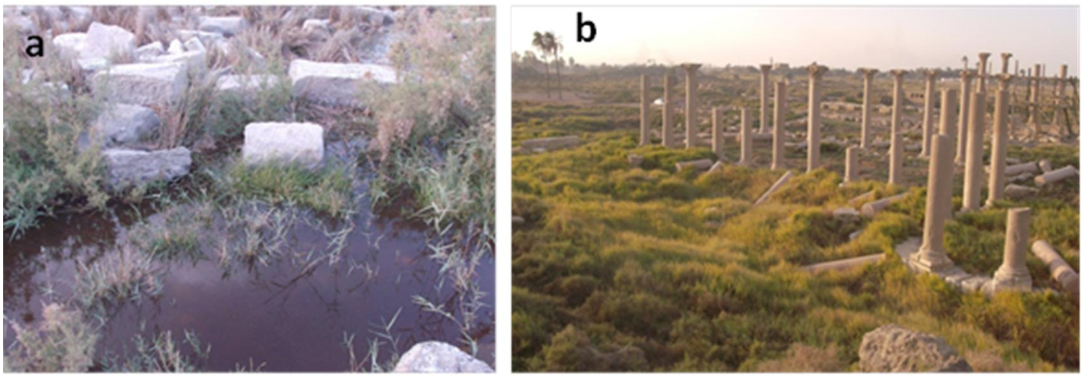

Fig. 4: Water ponds (a) and common native vegetation (b) indicate the waterlogged areas in El-Bahnasa and Tel Al Amarna sites

Conclusion

Archeological sites in El Minya governorate are exposed to soil erosion, cracking and waterlogging. In contrast, most of the investigated soils are stable. In spite of the low soil erodibility in Sheikh-Abada and Bani-Hassan areas they suffer from high erosion due to the high degree of surface slope. Low soil erosion was expected in Tel El-Amarna area because of its relatively flat surface. The rest of the investigated sites are threatened by moderate erosion. Soil cracking risk is slight in Bani Hasan, El -Sheikh 'Abadah, Tuna El-Gabal and Tel El Amarna due to the high homogeneity of soil texture. Except wet conditions the investigated soils are stable due to the dominant single grain structure. Waterlogging occurred when the archeological site closed to the cultivated areas (e.g. El-Ashmunein) or when the area is characterized by hard pans. Measures to protect archaeological sites from soil erosion and the risk of waterlogging are required.

References

Boggs, G., C. Devonport, K. Evans and P. Puig, 2001. GIS-Based Rapid Assessment of Erosion Risk in Small Catchments in the Wet/Dry Tropics of Australia. Land Degradation & Development. v. 12, p. 417-434.

Boivin, P., 2007. Anisotropy, cracking, and shrinkage of vertisol samples. Experimental study and shrinkage modeling. Geoderma 138, 25-38.

Boško G., T. Angelina, T. Zorica, K. Branka, V. Dragan and P. Borivoj, 2013. Land use effects on aggregation and erodibility of Luvisols on undulating slopes. AJCS 7(8):1198-1204.

Chavez, R., 2006. Modeling Soil Erosion Risk in Los Maribios Volcanic Chain, Nicaragua. Tropical Resources Bulletin, v. 25, p. 50-56.

Costa, S., J. Kodikara and B. Shannon, 2012. Salient factors controlling desiccation cracking of clay in laboratory experiments, Geotechnique, Vol. 63, No. 1, pp. 18-29.

Dan Davidson, 2014. Evaluating the quality of your soils. Crops & Soils Magazine, Vol. 47 No. 2, p. 4-13.

Dinka, T.M., C.L.S. Morgan, K.J. McInnes, Kishné, A. Sz. and R.D. Harmel, 2013. Shrink–swell behavior of soil across a Vertisol catena. Journal of Hydrology 476, 352-359. DOI: 10.1016/j.jhydrol.2012.11.002.

Driessen, P. and J. Deckers, 2001. Lecture notes on the major soils of the world. World Soil Resources Report 94. Food and Agriculture Organization of the United Nations. Rome.

FAO, 2006. Guidelines for soil description. Fourth edition, FAO, Rome Italy.

Goldman S.J., K. Jackson and T.A. Bursztynsky, 1986. Erosion and Sediment Control Handbook. McGraw Hill Book Co., New York.

Holden, J., L. West, H. Jared, J. Andy, E. Maxfield, I. Panter and J. Oxley, 2006. Hydrological controls of in situ preservation of waterlogged archaeological deposits. Earth-Science Reviews, 78 (1-2). pp. 59-83.

Karydas, C. G., T. Sekuloska and G. N. Silleos, 2009. Quantification and site-specification of the support practice factor when mapping soil erosion risk associated with olive plantations in the Mediterranean island of Crete. Environmental Monitoring and Assessment 149 (1-4): 19-28.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie and D.A. Haith, 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water - Parts I and II. EPA/600/6-85/002a&b.

Mitchell J.K. and G.D. Bubenzer, 1980. Soil loss estimation. In: Kirkby M.J., Morgan R.P.C. (eds): Soil Erosion. John Wiley and Sons Ltd., London, 17–62.

Stewart, B.A., D.A. Woolhiser, W.H. Wischmeier, J.H. Caro and M.H. Frere, 1975. Control of Pollution from Cropland. U.S. EPA Report No. 600/2-75-026 or U.S.D.A. Rep No. ARS-H-5-1. Washington, DC.

USDA, 2004. Soil Survey Laboratory Methods Manual. Soil Survey Investigation Report No. 42 Version 4.0.

USDA, 2001. Rangeland Soil Quality-Aggregate Stability. Natural Resources Conservation Service, available at: http://urbanext.illinois.edu/soil/sq_info/RSQIS3.pdf.

USDA, 2009. Soil Quality Indicator Sheets. Natural Resources Conservation Service, available at: http://theallnaturalfertilizercompany.com/wp-content /uploads/ 2014/04/ Secrets-in-the-Soil.pdf.

USDA, 2010. Keys to Soil Taxonomy. United State Department of Agriculture, Natural Resources Conservation Service (NRCS) eleventh edition.