Agriways 4 (2) : 159-167 (July - December, 2016)

ISSN: 2321-8614 (Print)
ISSN: 2454-2318 (Online)

MORPHOLOGICAL AND PEDOLOGICAL FEATURES OF ALFISOLS

Vipin Kumar, Surya Kant, Shikha and Achin Kumar

Department of Soil Science and Agricultural Chemistry
Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005
E-mail: vip121180@yahoo.com

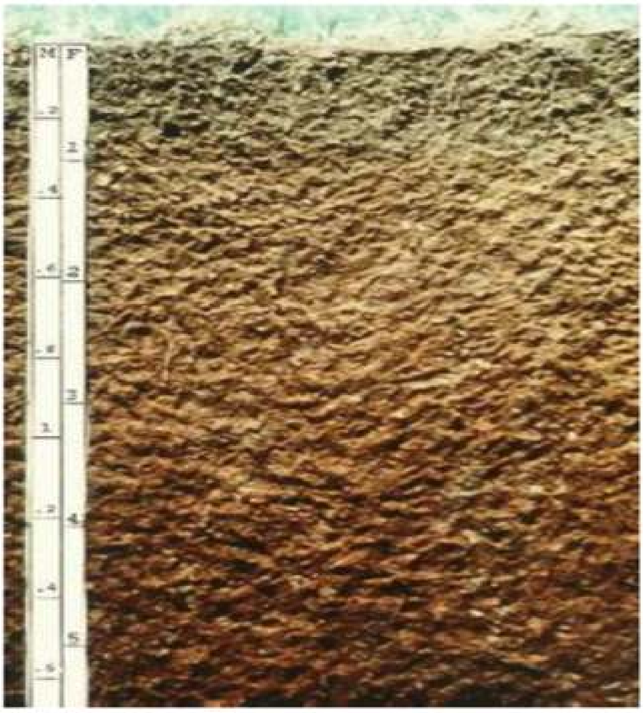
ABSTRACT

Alfisols are base-rich, timbered, mineral soils of sub-humid and humid regions. These are characterized by a light-coloured surface horizon (ochricepipedon) over a clay enriched, argillic (Bt) sub-surface horizon that is rich in exchangeable cationswith base saturation of more than 35%. Alfisols are more strongly weathered than the Inceptisols, but less than the Ultisols. Some Alfisols, on degradation, end up to form Spodosols, through the intermediate stage of Glossudalfs. The micro-febric of such soils show nice, highly-birefringent(Birefringence is the optical property of a material having a refractive index that depends on the polarization and propagation direction of light. These optically anisotropic materials are said to be birefringent or birefractive) clay coatings (cutans).An understanding of morphological and pedological behavior of Alfisols is a prerequisite for developing appropriate soilmanagement practices. These soils have high native fertility. Kind of soil management causes changes in the soilcharacteristics and can affect agricultural yield. Physical and mineralogical properties of the soil proved an effective supplementary method for assessing correlations between the soil physical and mineralogical properties.Information from the long-term studies of Alfisols can be utilized for developing appropriate and effective soil management practices and strategies for these soils in different regions.

Keywords: **Alfisols**, **Semi Arid Tropics**, **Soil Management**

Alfisols are a soil order in USDA soil taxonomy. They have a clayenrichedsub soil and relatively high native fertility. "Alf" refers to Aluminium(Al) and Iron (Fe). Because of their productivity and abundance. the Alfisols represent one ofthe more important soil orders for food and fiber production. They are widely used both in agriculture and forestry, and are generally easierto keep fertile than other humid climate soils, though those in Australia and Africa are still very deficient in nitrogen and available phosphorus. In the FAO soil classification, most Alfisols are classified as Luvisols or Lixisols, but some are classed as Nitosols. Alfisols occupy around one-tenthof the Earth 'sice-freeland surface. They are dominant in many areas, such as the Ohio River basin in the United States, Southern and unglaciated Western Europe, the Baltic region and central European Russia, the drier parts of Peninsular India, Sudan in Africa, and many parts of South America(El-Swaify et al., 1985). Alfisols support about 17% of the world's population. Alfisols have undergone only moderate leaching. By definition, they have at least 35% BS (Base Saturation) meaning calcium; magnesium and potassium are relatively abundant. This in contrast to Ultisols, Which are the more highly leached forest soils having <35% BS. The fossil record of Alfisols begins in the Late Devonian. Probably owing to their fertility, they are the oldest forest soils, vegetation on

Alfisol



an Alfisol profile

weathered Oxisols, by contrast, is not known earlier than Middle Permian. (https://en.wikipedia.org/wiki/Alfisol)

Micromorphology is concerned with the description, Measurement and interpretation of pedo features at the microscopic level(Bullock et al., 1985).The clay content of these soils usually increases with depth (Kirchmann 1991, Kirchmann and Eriksson 1993, Yli-Halla and Mokma 2001, Peltovuori et al. 2002). This feature can be caused by the different textural composition of the sedimentary parent material over time, since clay content correlates positively with the distance of the origin of the material and the depth of water during sedimentation. On the other hand, clay content can be influenced by clay translocation.

Formation

Alfisols form in loamy parent materials that are not too sandy or too clayey under semiarid to humid areas, typically under hardwood forest cover vegetation. They are prominent across the southern lower peninsular and the Western UP. Much of Michigan's most productive agriculture lands are based on Alfisols. Alfisols are forest soils that have relatively high native fertility. These soils are well developed and contain a subsurface horizon in which clays have accumulated. Alfisols are mostly found in temperate humid and sub-humid regions of the world. This, alongwith the native fertility, allows Alfisols to be very productive soils for agriculture and silvi culture. (http://geo.msu.edu/extra/geogmich/alfisols.html)

Clay eluviation and illuviation have not been documented in the clayey soils of long-termfield experiments in Sweden (Kirchmann 1991, Kirchmann and Eriksson 1993). However, argic/argillic horizons, and consequently Luvisols/Alfisols, occur in Estonia (Reintam and Köster 2006) and Luvic Stagnosols in Norway (Nyborgand Solbakken 2008). At least in Ostfold county, Southeastern Norway, soils with argic horizons (Luvic Stagnosols and Epistagnic Albeluvisols) are reported to be the most common agricultural soils in the area (Nyborg et al. 2008). Prerequisites of clay translocation are clay detachment and sufficient drying of the soil to allow the attachment of the elluviated clay particles onto the walls of micropores. Clay detachment is promoted by wetting of dry soil, low salt content of rain and snow-melt water and by soil physical disturbance(tillage), particularly autumn ploughing, which has been the traditional method of primary tillage in the cultivation of cereal crops in Finland. The impact of ploughing as compared to conservation tillage was demonstrated in a five-year study by Koskiaho et al. (2002) on a clay soil of Finland.

Further, it was shown by Turtola and Paajanen (1995) that annually upto 1300 kg ha^{-1} of soil material were transported through the drainage tile from a clay soil of Jokioinen. Up to the late 19th century, wetness and poor drainage were considered major limitations for successful crop production in southern Finland (Soininen 1974). However, currently claysoils of Finland are artificially drained to the depthof 100120 cm and much more productive. In spite of the rather humid climate, irrigation often gives rise to substantial yield increases because of seasonal summer soil moisture stress in these soils (Elonen 1967). The above studies suggest that agricultural anthropogenic activities have changed soil properties and may have had a significant influence on pedogenesis. The study has shown the effect of anthropogenic activities on the pedogenesis of aclayey soil. The specific evidence for clay translocation, conducive to the formation of argicor argillic (Soil Taxonomy) horizons. While we are reporting anthropogenic influences on pedogenesis of onlyone pedon studied with great detail, this soil condition is not an isolated example but likely extensive in northern latitudes where artificial drainage has occurred in soils that have an aquic soil moisture regime.Clay content of the pedon tends to increase with depth with a distinct increase between the Ap and Bw horizons and there is hardly any sand below the plough layer (Sippola 1974, Yli-Halla and Mokma 2001). Exchangeable Ca decreased with depth whereas exchangeable K, Mg and Na increased. These basic properties of the soil are presented in Table 1.

Table 1. Some physical and chemical properties of the Jokioinen pedon. OC = organic carbon, CEC = cation exchange capacity at pH 7.00, BS = 100 × (Ca + Mg+K+Na)/CEC. Clay, silt and sand stand for particle separates of <0.002 mm, 0.002−0.060 mm and 0.060–2 mm, respectively.

Horizon	Depth cm	Clay %	Silt %	Sand %	OC %	pH	CEC $cmol_c\ kg^{-1}$	CEC $cmol_c\ kg^{-1}$ clay	BS %
Ap1	0–10	41	45	14	2.19	6.20	24.9	(60.6)	65
Ap2	10–27	40	46	14	2.28	6.33	24.9	(62.3)	65
Bt	27–38	61	35	4	0.35	7.08	29.5	48.2	87
Btg	38–72	63	33	4	0.29	7.23	24.5	39.1	93
BCtg1	72–112	66	33	1	0.26	7.28	21.9	33.2	94
BCtg2	112–140	63	35	2	0.26	7.40	24.6	39.0	94
Cg	140–150+	79	19	2	0.25	7.32	31.2	31.2	95

A. Morphological properties

In the southern part of the Lower Peninsula, the dominant soil color changes from gray to a gray-brown, because of the change in the dominant type of natural vegetation from a pine to a deciduous or broad-leaved forest--- a combination of oak, beech, and hickory. This type of vegetation gives rise to more undecayed and partially decayed humus in the A horizon of the soil, and thus the change in color from gray to gray-brown. The soil is characterized by accumulations of clay in the B horizon, but the longer growing season and the deciduous vegetation results in a generally more productive soil. (http://geo.msu.edu/extra/geogmich/alfisols.html). Some morphological properties of the soils studied is shown in Table 2.

Table 2: Some morphological properties of soils of the study sites

Horizon	Depth (cm)	Colour (moist)		Structure*	Roots**
		Matrix	mottles		
		Arable Farmland			
Ap	0-24	10YR5/2 grayish brown	-	2cr	5mf
Bt1	24-54	10YR4/6 dark yellowish brown	mottled	2sbk	3f
Bt2	54-120	7.5YR5/6 strong brown	mottled	Ms	0
BC1	120-157	10YR6/3 pale brown	mottled	Ms	0
BC2	157-206	10YR7/3 very pale brown	mottled	Ms	0
		Teak Plantation			
Ap	0-19	10YR3/1 very dark gray	-	2sbk	5ml
Bt1	19-56	10YR4/4 dark yellowish brown	mottled	2sbk	5m
Bt2	56-103	10YR5/2 grayish brown	mottled	Ms	3mf
BC	103-147	10YR5/2 grayish brown	mottled	Ms	1f
C	147-200	10YR5/2 grayish brown	mottled	Ms	1f

*Structure: 2=moderate; cr=crumb; sbk=sub-angular blocky; ms=massive.
**Roots: 0=null; 1=few; 3=some; 5=many, fine; m=medium; l=large

B. Physical properties

Data on particle-size distribution of the soils studied areshown on Table 2. Particle-size analysis revealed that sandparticles dominated the mineral fraction in soils of the twoland use types studied probably because the soils wereformed from decomposition of granitic parent materialsrich in quartz and feldspars. The sand values in both landuse types decreased down the profiles. The trend may beattributed to sorting of fine materials, silt and clay, fromsurface horizon through action of erosion or eluviation and illuviation processes (Akinbola et al 2009).Some physical properties of the soils studied is shown in Table 3.

Table 3: Particle-size distribution in soils of the two land use types

Horizon	Soil Depth (cm)	Particle Size (g kg^{-1})			Silt/Clay Ratio	Textural Class*
		Sand	Silt	Clay		
			Arable Farmland			
Ap	0-24	794	90	116	0.77	Sl
Bt1	24-54	629	95	276	0.34	Scl
Bt2	54-120	569	55	376	0.15	Sc
BC1	120-157	509	105	386	0.27	Sc
BC2	157-206	529	90	381	0.24	Sc
			Teak Plantation			
Ap	0-19	607	144	249	0.58	Scl
Bt1	19-56	497	134	369	0.36	Sc
Bt2	56-103	417	144	439	0.33	C
BC	103-147	397	164	439	0.37	C
C	147-200	457	184	359	0.51	Sc

*sl=sandy loam; scl=sandy clay loam; sc=sandy clay; c=clay

C. Chemical properties

The result of the chemical properties of the soils studied isshown in Table 3. The soil reaction was moderately toslightly acidic in both land use types studied. The resultimplied that the soil pH was influenced more by parentmaterial, granite which weathered to produce acidic soils,rather than the influence of land use (Adeboye et al, 2009) generally, the organiccarbon content in soils decreased with the soil depth for each of land use studied. The higher organic carbon in thesurface horizon was as a result of increased organic matterinputs and its decomposition (Groenendijk et al, 2002, Samndi and Jibrin, 2012). Some chemical properties of soils are shown in table 4

Table 4: Some chemical properties of soils of the study site

Land use	Horizon	Depth (cm)	pH ($CaCl_2$) 1:2.5	Org. C ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)	Av. P ($mg\ kg^{-1}$)	Exchangeable cations Ca^{2+}	Mg^{2+}	K^+	Exch. Acidity (H+Al)	ECEC
							← ($cmol_{(+)}\ kg^{-1}$) →				
Arable Farmland	Ap	0-24	6.0	22.05	0.65	9	8.00	3.50	0.15	0.89	4.35
	Bt1	24-54	5.6	22.05	0.61	14	8.00	4.00	0.15	0.76	5.72
	Bt2	54-120	5.5	15.44	0.37	10	6.40	3.10	0.46	0.71	6.69
	BC1	120-157	6.4	15.44	0.19	10	7.20	2.85	0.35	0.65	5.70
	BC2	157-206	6.5	8.82	0.05	13	10.20	4.28	0.03	0.63	6.31
		Mean =	**6.0**	**16.76**	**0.37**	**11**	**7.96**	**3.55**	**0.23**	**0.73**	**5.75**
		*SD =	±0.45	±5.53	±0.26	±2.17	±1.42	±0.60	±0.17	±0.10	±0.89
Teak Plantation	Ap	0-19	5.9	19.30	0.30	8	2.76	0.38	0.05	1.80	13.86
	Bt1	19-56	5.8	14.30	0.10	7	3.68	0.98	0.04	1.20	13.74
	Bt2	56-103	5.8	9.30	0.10	6	3.90	1.76	0.05	1.16	11.52
	BC	103-147	5.9	8.30	0.10	7	3.84	1.06	0.03	1.36	12.14
	C	147-200	5.9	7.10	0.10	7	4.06	1.48	0.02	1.20	15.80
		Mean =	**5.9**	**11.66**	**0.14**	**7**	**3.65**	**1.13**	**0.04**	**1.34**	**13.41**
		*SD =	±0.05	±5.07	±0.09	±0.71	±0.51	±0.53	±0.01	±0.27	±1.67

D. Hydrological behaviour

Alfisols, the most abundant soils in the semi-arid tropics(SAT), cover nearly 33% of the SAT region. To develop appropriate and more effective soil and water management strategies and practices, a better understanding of the hydrological behavior of soils is extremely important (Purandara and Kumar, 2003; Pathak et al., 2004). At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) research station in Patancheru, India, long-term hydrological studies have been conducted on small agricultural watersheds on Alfisols. Rainfall is variable spatially and temporally and occurs in high intensity. During the experimental period (1976-2008), the annual rainfall ranged from 558 mm to 1473 mm with a co-efficient of variation of 25% (Fig.1).

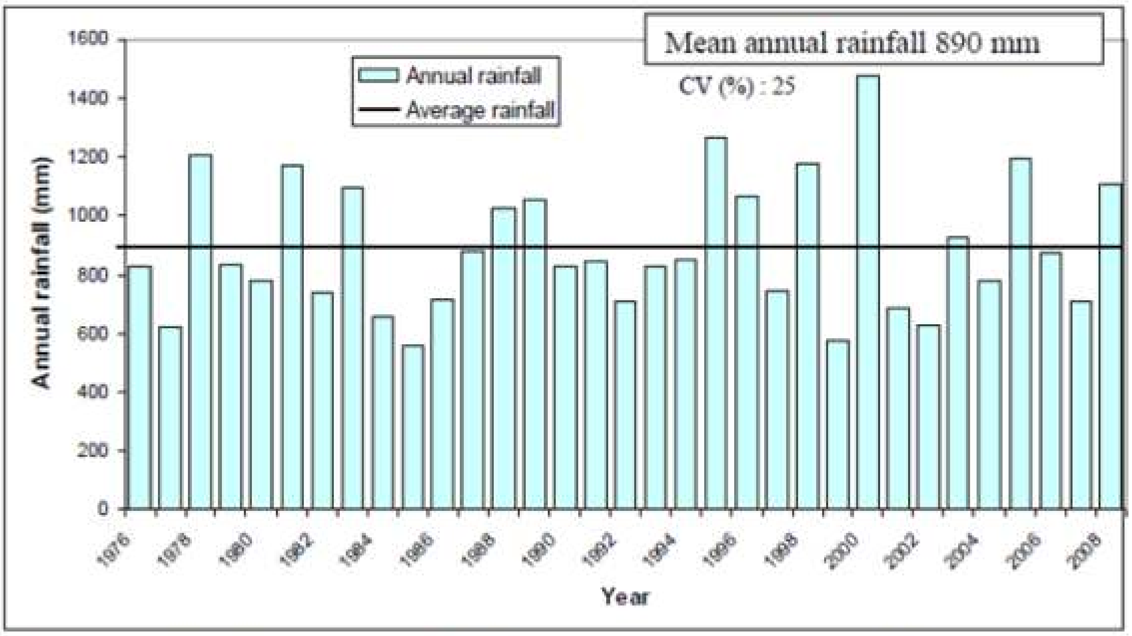


Fig. 1. Annual rainfall during the study period (1976-2008) at the ICRISAT center, Patancheru, India.

Table 5: Saturated hydraulic conductivities of Alfisols at the experimental watersheds ICRISAT

Soil depth (cm)	Alfisols (mm hr^{-1})
0 – 15	17.1
15 – 30	6.7
30 – 60	6.1
60 – 90	8.3
90 – 120	-

Table 6: Physical properties of Alfisol watershed at the ICRISAT farm in Patancheru, India

Soil depth (cm)	Particle size distribution percent of total				Moisture holding capacity		Bulk density
	Clay (<.002mm)	Silt (.05-.002mm)	Sand (2-.05mm)	Coarse Fragments (>2mm)	1/3 bar	15 bar	(g cm^{-3})
0-15	13.2	6.1	75.7	5.0	11	4.4	1.50
15-30	22.3	9.7	63.0	6.0	14	7.2	1.58
30-60	31.1	9.0	51.9	8.0	15	8.1	1.59
60-90	38.3	8.8	41.9	12.0	14	8.2	1.46

Table 7: Mean annual rainfall, runoff, soil loss and peak runoff rate from the Alfisol watersheds at the ICRISAT Center, Patancheru, India (1976-2008)

Soil type and watersheds	Mean annual rainfall (mm)	Mean annual runoff		Peak runoff rate ($m^3 s^{-1} ha^{-1}$)	Mean annual soil loss ($t\ ha^{-1}$)
		Runoff (mm)	Runoff as % of rainfall		
Alfisol watersheds with BBF system	881	196.5	22.3	0.21	4.62

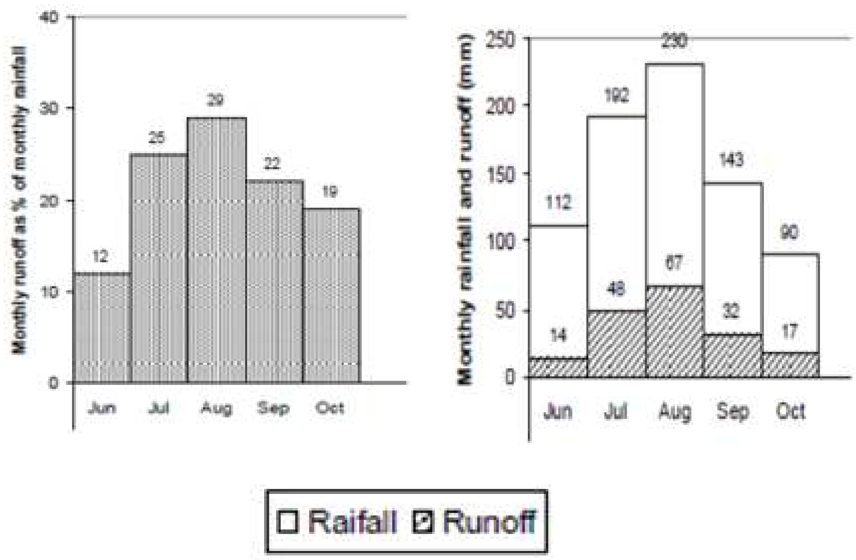


Fig. 2. Mean monthly runoff characteristics of the Alfisol watersheds (1976-2008)

E. Pedological properties

On uncultivated sites: A very thin O horizon is common; On cultivatedsites: no O horizon, thin A (less than 15 cm) weaklyexpressed crumb or granularstructure.Moderate thin E horizon (15-25cm), platy structure, light-colouredB horizon, usually with severalsub-divisions, which is normally between 25-75cm thick, moderateto strong angular or sub-angularblocky structure, a lower case 't' isused to denote for an accumulation ofsilicate clay. In most Alfisols there is also a removal ofFeand Al from the E horizon to the B horizon. This can be attributed to the eluviation ofmetal ions and organic colloids that formmetal-organiccomplexes which aretranslocated. Generally, a widevariety of clay minerals ranging fromkaolinites, hydrous micas, montmorillonitesto vermiculites can occur. It should bestressed that several clay minerals do havea potential to adsorb exchangeable bases (High CEC), which is acriteria that should be met to qualify for anAlfisol. High base status: > 35 % BS at a depth of 125 cmbelow the upper boundary of theargillic, natric or kandic horizon. An argillic horizon is not under aspodic or oxic horizon. Any soil temperature regime isallowed, except pergelic.

Vegetation: deciduous forest (prairie,grassland)

Climate: thermic or warmer, mesicor cooler

Soil moisture regime: erratic soilmoisture regime

Major soil property: medium to highbase saturation

Diagnostic horizons: albic, argillic(natric, kandic)

Epipedon: ochric (mollic, umbric)

Major processes: weathering,eluviation/illuviation (https://soils.ifas.ufl.edu/faculty/grunwald/teaching/eSoilScience/alfisols.shtml)

Suborders

Aqualfs: Alfisolswith a water table at or near the surface for much of the year. Aqualfs occur in manyparts of the world, mostly in latePleistoncenedeposits.

Cryalfs: Alfisolsof cold climates. More or less freely drained Alfisols of cold region. Cryalfs are notextensive, forming in N. America, Eastern Europe and Asia above the 49 N latitude and in some highmountains south of that latitude. Most Cryalfs are or have been under a coniferous forest. Cryalfs in theUSA generally formed in Pleistocend deposits mostly of Wisconsinan age.

Ustalfs: Alfisolsof semiarid and sub humid climates. Many of these soils have or have had a savannavegetation and some were grasslands. Tend to form a belt between the Aridisols of arid regions and theUdalfs, Oxisols and Inceptisols of humid regions. May be in areas of erosional surfaces or deposits oflateWisconsinanage. Many are on old surfaces and the minerals may be strongly weathered.

Xeralfs: TemperateAlfisols with very dry summers and moist winters. Most of these soilformationsborder the Mediterranean Sea or lie to the east of an ocean at mid-latitudes. Found in Mediterranean, parts of South Africa, Chile western and southern Australia and in the western USA. As a whole, Xeralfs arenot globally extensive, but in regions where they occur, they are extensive or moderatly extensive. Formed on surfaces are of different ages. Some formed on erosional surfaces or in deposits of lateWisconsinan age, or in Australia, formed on old surfaces that may reflect an environment greatlydifferent than the present one.

Udalfs: Alfisolsof humid climates. Principally in areas of latePleistocenedeposits and on erosional surfaces of around the same age. Very extensive in the USA and in Western Europe. All of them arebelieved to have supported forest vegetation at some time during development.

Reference

Adeboye M K A, Osunde A O, Ezenwa M I S, Odofin A J and Bala A (2009). Evaluation of the fertility status andsuitability of some soils for arable cropping in the southernGuinea savanna of Nigeria.*Nigerian Journal of Soil Sci*., **19(2)**:115 120.

Akinbola G E, Anozie H I and Obi J C (2009). Classificationand characterization of some pedons on basement complex in theforest environment of south-western Nigeria.*Nigerian Journal ofSoil Science*, **19 (1)**: 109-117.

Bullock P, Fedoroff N, Jongerius A, Stoops G and Tursina T (1985). Handbook of Soil Thin Section Description. Waine Research Publication, 152 pp.

Elonen P (1967). Sprinkler irrigation on clay soils in southernFinland. *Journal of the Scientific Agricultural Societyof Finland* **39**: 6577.

El-Swaify S A, Pathak P, Rego T J and Singh S (1985). Soil management for optimized productivityunder rainfed conditions in the semi-arid tropics. *Adv. Soil Sci*. 1, 1-64.

Groenendijk F M, Condron L M and Rijkse W C (2002). Effects of afforestation on organic carbon, nitrogen and sulphur concentrations. *New Zealand Hill*, New Zealand.

Kirchmann H (1991). Properties and classification of soilsof the Swedish long-term fertility experiments. I. Sitesat Fors and Kungsängen. *ActaAgriculturaeScandinavica* **41**: 227242.

Kirchmann H and Eriksson J (1993). Properties and classificationof soils of the Swedish long-term fertility experiments.I. Sites at Örja and Orup. *ActaAgriculturaeScandinavica*43: 193205.

Koskiaho J, Kivisaari S, Vermeulen S, Kauppila R, Kallio K and Puustinen M (2002). Reduced tillage: Influenceon erosion and nutrients lossess in a clayey fieldin southern Finland. *Agricultural and Food Science inFinland* **11**: 3750.

Nyborg Å, Solbakken E, Svendgård-Stokke S, Lågbu R, Klagegg O and Sperstad R (2008). Jordsmonnatlasfor Østfold. *Atlas from Norwegian Forest and LandscapeInstitute* 01/08. 207 p.

Pathak P, Sudi R, Wani S P and Sahrawat K L (2013). *Hydrological behavior of Alfisols and Vertisols in the semi-aridzone: Implications for soil and water management, Agricultural Water Management*. **118**: 1221.

Pathak P, Wani S P, Piara Singh and Sudi R (2004). Sediment flow behavior from small agriculturalwatersheds. *Agricultural Water Management*. **67**:105-117.

Peltovuori, T., Uusitalo, R. and Kauppila, T. (2002) Phosphorusreserves and apparent phosphorus saturationin four weakly developed cultivated pedons. *Geoderma***110**: 3547.

Purandara B K and Kumar C P(2003). Hydrologic characteristics of soils under different land covers inGhataprabha basin. IE(I) Journal-CV. **84**:1-5.

Reintam E and Koster T (2006). The role of chemical indicatorsto correlate some Estonian soils with WRB and SoilTaxonomy criteria. *Geoderma***136**: 199209.

Samndi A M and Jibrin J M (2012). Pedogenesis andclassification of soils under Teak (*Tectonagrandis*Linn. f)plantation of various Ages in the southern Guinea savanna ofNigeria.*Asian Journal of Agricultural Sciences*, **4(1)**: 16-25

Sippola J (1974). Mineral composition and its relation to textureand to some chemical properties in Finnish subsoils.*AnnalesAgriculturaeFenniae***13**: 169234.

Soininen A (1974). Oldtraditional agriculture in Finland in the 18th and 19th centuries. *Journal of the Scientific Agricultural Societyof Finland* **46** (Supplement). 459 p.

Turtola E and Paajanen A (1995). Influence of improvedsubsurface drainage on phosphorus losses and nitrogenleaching from a heavy clay soil. *Agricultural WaterManagement* **28**: 295310.

Tsado P A, Lawal B A and Ezenwa M I S(2014).Assessment of Properties of Alfisols as Affected by Landuse in Minna, Southern Guinea of Nigeria.*International Journal of Research in Agricultural Sciences*1(2) : 82-86

Yli-Halla M and Mokma D L(2001) Soils in an agriculturallandscape of Jokioinen, south-western Finland. *Agriculturaland Food Science in Finland* **10**: 3343.

Yli-Halla M, Mokma D L, Alakukku L, Drees R and Wilding L P (2009). Evidence for the formation of Luvisols/Alfisols as aresponse to coupled pedogenic and anthropogenicinfluences in a clay soil in Finland. *Agricultural and Food Science18: 388401*.