Original Research Article

Characterization and Taxonomy Classification of Soils under a Toposequence Located at North-Eastern Ghat Agro-Climatic zone of Odisha, India

Abstract

The present investigation was carried out to study the characterization and Taxonomy classification of soils under a Toposequence located at North-Eastern Ghat Agro-Climatic zone of Odisha, India. Three representative pedons of the Nayagarh district located in different topographic positions of upland (pedon 1), medium land (pedon 2) and low land (pedon 3) respectively were studied for their morphology, physico-chemical characteristics and taxonomic classification. Results show that the bulk density and particle density found with higher values in the lower horizon and lower values in the upper horizon. Total porosity values found to be higher in upper horizons and lower in the lower most horizons. The soil pH found to gradually increase with increasing depth in all three pedons. The OC content decreasing along with depth in all the pedons. In pedon 2 and 3, fully developed genetic horizons with distinct sub-horizons within the B horizon. However, in pedon 1, no such horizons are developed. The clay content increases in pedon 2 and 3 from upper sub-horizon to the lower sub horizon of B horizon with increasing depth which could be due to the process of illuviation of clay and development of argillic horizon (Bt). Pedon 1, are classified under order *Entisols;* while that of pedon 2 and 3 under soil order of *Alfisols.* Pedon 1, are classified under sub order *Orthents,* great group *Ustorthents* and sub group *Typic Ustorthents;* while that of pedon 2 and 3 are classified under sub order *Ustalfs,* great group *Haplustalfs* and sub group *Udic Haplustalfs.*

Key words: pedons, upland, medium land, low land, *Alfisols* and *Entisols*

1. Introduction:

Toposequence is a sequence of related soils, which differ from one another primarily in respect of topography as a soil-forming factor {Brady, (1995)}. Sehgal (1996), Catena is a sequence of soils developed from similar parent material under similar climatic conditions, but under varying conditions of relief which also causes difference in drainage where soils of different series have been located. Parent material, relief or topography, time, climate and biosphere including vegetation and organism are the five important soil forming factors (Jenny, 1941) where as in cultivated soils, human activity is also included. In the study area along the slope, three land types have been recognized. These are the upland located at the uppermost part, sloping from the ridge-crest; the medium land in between the upland and lowest part of the slope which is the low land. To achieve soil resource management in toposequences, knowledge on physical and chemical characteristics and classification is an essential requirement (Rehman *et al.* 2017).

The parent material and topography are most important factors of soil formation. In undulating land form which chiefly consists of ridges and valleys, the soil are mostly developed in the valley side from parent materials and on the valley-bottom from material transported from upslope. Such are the general feature in the North-Eastern Ghat agro climatic zone of Odisha. This zone is particularly important for agriculture due its suitability for a large variety of crops. Under such condition topography as a soil forming factor plays the most important role.

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2. Materials and method:

The study area is characterized by hot, dry and sub-humid climate with dry summer and mild winter. Average annual rainfall of Nayagarh district is 1243.3 mm in 88 rainy days, out of which 80% rainfall in monsoon season (June to September). The mean maximum temperature is 38.2°C (during summers) and the mean minimum temperature at 17°C (during winters). Three soil profiles (pedons) representing different physiographic position as found in the district were exposed based on land type located at upland (N 20^0 12.267’, E 85^0 06.542’) has 332 feet above MSL and slope of 3-5%, medium land (N 20^0 12.348’’, E 85^0 06.669’) has 360 feet above MSL, and slope of 1-3% and low land (N 20^0 12.330’, E 85^0 06.644’) has 346 feet above MSL and slope of 0-1% of the study area.

2.1 Processing of soil samples and analysis:

The soil samples collected from the profiles horizon wise and from soil surface were air dried and passed through 2mm sieve. The samples were then preserved in plastic bottles, labelled and stored for laboratory studies.

Soils were analyzed for textural class by Bouyoucos Hydrometer method (Bouyoucos 1962), pH (1 : 2) (Jackson 1973), EC (1 : 2) (Jackson 1973), Organic Carbon (Walkley and Black 1934), Bulk density (Klute 1986), Particle density (Chopra and Kanwar 1986), Water Holding Capacity (Piper 1950), Cation Exchange Capacity (Chapman 1965), Exchangeable cations (Page et al. 1982) and Exchangeable acidity (Thomas 1996). The soils were classified taxonomically up to family level following Keys to Soil Taxonomy (Soil Survey Staff 2014).

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3. Results and discussion:

3.1 Soil physical properties

3.1.1 Particle size distribution

In pedon 1, percentage of sand, silt and clay range between 79.8 to 85.4, 2.4 to 4.0 and 12.2 to 16.2 respectively in different horizons (Table 4). In case of pedon 2 are vary from 76.9 to 84.8, 2.1 to 8.1 and 7.90 to 19.1 respectively in different horizons (Table 1 and 3). Percentage of sand, silt and clay in pedon 3 are varying from 65.2 to 83.2, 6.0 to 10.0 and 10.8 to 26.8 respectively in different horizons (Table 5).

In pedon 1, clay content gradually decreased with increasing depth up to 105 cm. In case of pedon 2 and 3, clay content gradually increased with increasing depth up to 137 and 124 cm depth and then decreased up to a depth of >150 and 180cm respectively (Table 3 and 5). Increase in percentage of clay in pedon 2 and 3 might be attributed to the process of eluviation and illuviation in medium land and low land. Similar types of findings were also obtained by Mishra (1981) and Dash *et al.* (2019).

3.1.2 Coarse fragments

In pedon 1, it ranges from 2.5 to 5.4 per cent (Table 1), in pedon 2, its range from 1.4 to 12 per cent (Table 3), in pedon 3 its ranges from 5.6 to 55.9 per cent (Table 5). In all pedons of the coarse fragments increase along with depth from upper horizon to lower horizon.

3.1.3 Bulk density

In pedon 1, it is in the range of 1.62 to 1.65 Mg m^{-3} (Table 1). In pedon 2 and 3, bulk density was in the range from 1.55 to 1.90 and 1.42 to 1.78 Mg m^{-3} respectively. Minimum bulk density in the surface horizons due to high amount of clay and organic carbon in the surface horizons. Similar results were also observed by Mishra (2005) and Dash *et al.* (2019).

3.1.4 Particle density

In pedon 1, it is in the range of 2.54 to 2.60 Mg m^{-3} (Table 1). In pedon 2 and 3, particle density are in the range of 2.46 to 2.67 and 2.40 to 2.66 Mg m^{-3} respectively (Table 3 and 5). Particle density increasing from upper horizons towards lower horizons in all the pedons which could be due to lower organic carbon in the lower horizons. Similar results were also been given by Dash *et al.* (2019).

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3.1.5 Total porosity

In pedon 1, it is in the range of 35.55 to 36.22 per cent (Table 1). In pedon 2 and 3, total porosity are observed in the range of 28.84 to 36.99 and 33.08 to 40.83 percent respectively (Table 3 and 5). The total porosity lower in the lower most horizons in all the pedons. Their might be due to lower organic carbon content and higher compactness. Similar results were also been given by Dash *et al.* (2019).

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3.1.6 Water Holding Capacity

The Water Holding Capacity values of pedon 1,2 and 3 vary from 33.4 to 35.5, 32.0 to 43.4 and 36.5 to 45.4 per cent in different horizons respectively. In pedon 1, water holding capacity was found to be decreasing with depth. In case of pedon 2 and 3, it was found to be increasing up to last part of B horizon followed by decreasing in the C horizon which might be attributed to the differences in distribution in different horizons of clay in different pedons. Similar results were also found by Dash *et al.* (2019).

3.2 Chemical characteristics

3.2.1 Soil reaction

In all the pedons pH increases along with depth from 5.25 to 5.95, 5.52 to 6.35 and 5.85 to 6.95 respectively (Table 2,4 and 6) which could be due to leaching of basic cations from upper horizons to lower horizons mostly during intensive rainfall. Similar type of results was also observed by Kumar *et al.* (2012) and Dash *et al.* (2019). Electrical conductivity in all pedons which are very low and safe for all the crops

3.2.2 Organic carbon

In pedons 1, 2 and 3, organic carbon content ranges from 1.8 to 4.2, 0.8 to 5.6 and 0.6 to 6.6 g kg^{-1} respectively (Table 2,4 and 6). Organic carbon content of soils in pedons 1, 2 and 3, decreases regularly along with depth. Organic carbon content was maximum in the surface horizons of all the pedons due to fresh accumulation and decomposition of crop residues in the surface horizons. Similar type of results was also found by Dorji *et al.* (2014) and Kumar *et al.* (2012).

3.2.3 Exchangeable bases

3.2.3.1 Exchangeable calcium

The exchangeable calcium content in pedon 1, increases from 3.4 **to** 4 c mol (p+) kg^{-1}. In pedon 2, exchangeable calcium content increases from 3 to 5.0 c mol (p+) kg^{-1} in the depth zone of 104-137 cm (B_{22}t horizon). In pedon 3 exchangeable calcium content increases from 8.4 c mol (p+) kg^{-1} in the surface horizon to 14.8 c mol (p+) kg^{-1} in the depth zone of 100-124 cm (B_{23}t horizon).

3.2.3.2 Exchangeable magnesium

The exchangeable magnesium content in pedon 1, increases from 0.8 to 1.0 c mol (p+) kg^{-1}. In pedon 2, exchangeable magnesium content increases from 0.8 c mol (p+) kg^{-1} in the surface horizon to 1.2 c mol (p+) kg^{-1} in the depth zone of 104-137 cm (B_{22}t horizon). In pedon 3 exchangeable magnesium content increases from 0.6 c mol (p+) kg^{-1} in the surface horizon to 1.3 c mol (p+) kg^{-1} in the depth zone of 100-124 cm (B_{23}t horizon).

3.2.3.3 Exchangeable sodium

The exchangeable sodium content in pedon 1, increases from 0.2 c mol (p+) kg^{-1} in the surface horizons along with depth and reaches 0.24 c mol (p+) kg^{-1} in the lower horizons. In pedon 2, exchangeable sodium content increases from 0.38 c mol (p+) kg^{-1} in the surface horizon to 0.8 c mol (p+) kg^{-1} in the depth zone of 104-137 cm (B_{22}t horizon). In pedon 3, exchangeable sodium content increases from 0.4 c mol (p+) kg^{-1} in the surface horizon to 1.0 c mol (p+) kg^{-1} in the depth zone of 100-124 cm (B_{23}t horizon).

3.2.3.4 Exchangeable potassium

The exchangeable potassium content in pedon 1, increases from 0.07 c mol (p+) kg^{-1} in the surface horizons along with depth and reaches 0.13 c mol (p+) kg^{-1} in the lower horizons. In pedon 2, exchangeable potassium content increases from 0.09 c mol (p+) kg^{-1} in the surface horizon to 0.12 c mol (p+) kg^{-1} in the depth zone of 104-137 cm (B_{22}t horizon). In pedon 3, exchangeable potassium content increases from 0.3 c mol (p+) kg^{-1} in the surface horizon to 0.9 c mol (p+) kg^{-1} in the depth zone of 100-124 cm (B_{23}t horizon).

In all the pedons, concentration of exchangeable bases were found to be in order of Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}. Exchangeable bases of pedons 1 increases regularly along with depth; In pedon 3 and 4, exchangeable bases increase up to last part of B horizons (137 and 124 cm depth respectively), then decrease in C horizons due to illuviation of clay from surface horizon to B horizon. Similar type of results was also observed by Giri *et al.* (2017).

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3.2.4 Exchangeable acidity

The exchangeable acidity content decreases in pedon 1, 2 and 3, from 3.5, 3.2 and 2.8 c mol (p+) kg^{-1} in the surface horizons to 1.0, 0.3 and 0.2 c mol (p+) kg^{-1} in the lower horizons respectively. The exchangeable acidity decreasing with soil depth in all five pedons which could be due to increase in other exchangeable cations saturating the exchange sites down the depth. Similar type of results was also observed by Mishra (2005), Pattanayak (2016) and Dash *et al.* (2019).

3.2.5 Cation exchange capacity

Cation exchange capacity decreases in pedon 1, from 6.85 to 5.25 c mol (p+) kg^{-1} due to decreases of clay content. In pedon 2 cation exchange capacity increases from 6.5 to 9.1 c mol (p+) kg^{-1} in the depth zone of 104-137 cm (B_{22}t horizon). Cation exchange capacity in pedon 3 increases from 13.55 to 19.0 c mol (p+) kg^{-1} in the depth zone of 100-124 cm (B_{23}t horizon). In pedon 2 and 3 cation exchange capacity increases from surface horizon to lower B horizon after decreases in C horizons. Such increases in CEC are mostly due to movement of bases along with clay.

3.2.6 Base saturation

The base saturation percentage increases in pedon 1, 2 and 3, from 74.45, 68.77 and 71.59 per cent in the surface horizons to 86.48, 91.56 and 96.22 per cent in the lower horizons respectively. This could be attributed to content of different bases and clay percentage. Similar type of findings was also obtained by Dash *et al.* (2019).

3.2.7 Exchangeable sodium percentage

The exchangeable sodium percentage in pedon 1, 2 and 3, ranges from 4.53 to 95.84 to 9.14, 5.85 to 12.42 and 2.95 to 5.26 per cent in different horizons which are presented in Table 2, 4 and 6 respectively. There was a gradual increase in ESP throughout the profile found in all pedon which might be attributed to leaching of sodium ions from upper horizons towards lower horizons mostly during intensive rainfall. Similar type of findings was also obtained by Mishra (2008)

3.3 Soil classification

The soils of pedon 1, have little or no evidence of development of pedogenic horizons except ochric epipedon, therefore these soil are classified under the order *Entisols.* These soils have A-C profile with no distinct horizonation. The soils do not have cracks as wide as 1 cm at a depth of 50 cm of the soil surface under non irrigated condition nor do they have gilgai micro relief or slickensides. Hence, the soils of pedon 1, is classified under order of *Entisols*.

In pedon 1, organic carbon content decreases regularly with increasing depth and reaches a level of 2.5 g kg^{-1} or less within a depth of 125 cm (Table 2) and within 50 cm do not have mineral surface horizon and have coarse fragments within a depth of 100 cm and were never saturated with water, therefore soils of pedon 1, is classified under sub order *Orthents*.

In pedons 1, an *ustic* soil moisture regime and conductivity of less than 2 dSm^{-1} at 25^{0} C in all sub horizons and are therefore classified under great group of *Ustorthents*. They do not have a lithic contact within 50 cm of the surface, hence the soils of pedon 1, are classified under sub group of *Typic Ustorthents.*

A soil illuvial layer must have at least 1.2 times more clay if some horizon above has 15 to 40 per cent clay; 3 per cent more clay content if the eluvial layer has less than 15 per cent clay; 8 per cent more clay if, the eluvial layer has more than 40 per cent clay, in these case in order to have a argillic horizons (Soil Survey Staff, 1978). As per the above criteria, in case of pedon 2, the eluvial Ap horizon was found to be 18 cm thick and had 7.90 per cent clay and therefore, its underlying illuviated B horizon should have at least 10.90 per cent clay. As observed from Table 3, the clay content of B_1t sub horizon is 11.1 per cent. In pedon 3, the eluvial A_p horizon is 9 cm thick and has 10.8 per cent clay and therefore the underlying illuvial B_1t should contain at least 13.8 per cent clay than that of Ap horizon. In the horizon of B_1t clay content was found to be 14.8 per cent (Table 5). Hence, both pedon 2 and 3, were found to be having *argillic* horizon.

Pedon 2 and 3, have an orhric epipedon; have an argillic horizon and base saturation percentage of more than 35 percentage at a depth of 1.25 m; did not have cracks during any period of the year that are of 1 cm or more wide at a depth of 50 cm from soil surface; hence, classified under soil order of *Alfisols.*

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Soils of pedon 2, have ustic soil moisture regime; hence, classified under sub order of *Ustalfs.* Pedon 2, has a clay distribution such that it increase along with depth of soil profile up to 137 cm from 7.90 to 19.1 per cent, after that decreases up to 11.5 per cent at a depth of 150 cm from the soil surface (Table 3). The soils are found to be moist in most years in some or all parts of the moisture control section for more than 90 consecutive days during the rainy season. Hence classified under great group of *Haplustalfs.* do not have a lithic or paralithic contact within 50 cm of the soil surface; hence Pedon 3 is classified under sub group of *Udic Haplustalfs.*

Soils of pedon 3, have ustic soil moisture regime; hence, classified under sub order of *Ustalfs.* Pedon 3, has a clay distribution such that it increase along with depth of soil profile up to 124 cm from 10.8 to 26.8 per cent, after that decreased up to 20.5 per cent at a depth of 180 cm from the soil surface (Table 5). Hence classified under great group of *Haplustalfs.* do not have a lithic or paralithic contact within 50 cm of the soil surface; hence classified pedon 3, under sub group of *Udic Haplustalfs.* Similar type of soil classification as of pedon 2 and 3, was also observed by Mishra (2005) and Dash *et al.* (2019).

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Table 1. Physical properties of pedon 1 (Upland)

Horizon	Depth (cm)	Per cent (%)			Coarse Fragment (Vol. more than 2mm) (%)	Texture class	Mg m^{-3}		Per cent (%)	
		Sand	Silt	Clay			Bulk Density	Particle density	Porosity	WHC

A_p	0-15	79.8	4.0	16.2	2.5	Sandy loam	1.62	2.54	36.22	35.5
C_1	15-54	81.6	4.2	14.2	4.5	Loamy Sand	1.65	2.56	36.15	33.9
C_2	54-105	85.4	2.4	12.2	5.4	Loamy Sand	1.66	2.60	35.55	33.4
C_3	105-152	Partially weathered parent material								

Table 2. Chemical properties of pedon 1 (up land)

Horizon	Depth (cm)	pH (1:2)	EC (dSm^{-1})	OC($g\ kg^{-1}$)	Exchangeable bases [c mol (p+) kg^{-1}] in soil					Exchangeable acidity [c mol (p+) kg^{-1}]	CEC [c mol (p+) kg^{-1}] in soil	Base Saturation (%)	ESP (%)
					Ca	Mg	Na	K	SUM				
A_p	0-15	5.25	0.07	4.2	3.4	0.8	0.2	0.07	5.1	3.5	6.85	74.45	5.84
C_1	15-54	5.60	0.11	2.0	3.8	0.8	0.22	0.1	4.93	2.4	5.76	85.59	7.64
C_2	54-105	5.95	0.14	1.8	4	1	0.24	0.13	4.33	1.0	5.25	86.48	9.14
C_3	105-152	Partially weathered parent material											

Table 3. Physical properties of pedon 2 (Medium land)

Horizon	Depth (cm)	Per cent (%)			Coarse Fragment (Vol. more than 2mm) (%)	Texture class	$Mg\ m^{-3}$		Per cent (%)	
		Sand	Silt	Clay			Bulk Density	Particle density	Porosity	WHC
A_p	0-18	84.0	8.1	7.90	1.4	Loamy sand	1.55	2.46	36.99	33.5
B_1t	18-60	84.8	4.1	11.1	1.5	Loamy sand	1.68	2.52	33.33	37.6
$B_{21}t$	60-104	82.0	2.1	15.9	4.1	Sandy loam	1.75	2.56	31.64	42.3
$B_{22}t$	104-137	76.9	4.0	19.1	5.3	Sandy loam	1.85	2.61	29.12	43.4
IIC	137-150	84.0	4.2	11.8	6.7	Loamy sand	1.88	2.65	29.06	33.5
IIIC	>150	83.0	5.5	11.5	12.0	Loamy sand	1.90	2.67	28.84	32.0

Table 4. Chemical properties of pedon 2 (Medium land)

Horizon	Depth (cm)	pH (1:2)	EC (dSm^{-1})	OC (g kg^{-1})	Exchangeable bases [c mol (p+) kg^{-1}] in soil					Exchangeable acidity [c mol (p+) kg^{-1}]	CEC [c mol (p+) kg^{-1}] in Soil	Base Saturation (%)	ESP (%)
					Ca	Mg	Na	K	SUM				

A_P	0-18	5.52	0.12	5.6	3	1	0.38	0.09	4.47	3.2	6.5	68.77	5.85
B_1t	18-60	5.86	0.21	4.6	3.2	1	0.45	0.13	4.78	1.6	7.8	61.28	5.77
$B_{21}t$	60-104	6.02	0.16	3.2	4.6	0.4	0.57	0.11	5.68	0.9	8.1	70.12	7.04
$B_{22}t$	104-137	6.26	0.18	2.0	4.6	0.8	0.75	0.11	6.26	0.9	8.2	76.34	9.15
IIC	137-150	6.28	0.17	1.0	4.6	0.8	0.8	0.09	6.29	0.5	6.95	90.50	11.51
IIIC	>150	6.35	0.11	0.8	4.5	0.6	0.81	0.06	5.97	0.3	6.52	91.56	12.42

Table 5. Physical properties of pedon 3 (Low land)

Horizon	Depth (cm)	Per cent (%)			Coarse Fragment (Vol. more than 2mm) (%)	Texture class	$Mg\ m^{-3}$		Per cent (%)	
		Sand	Silt	Clay			Bulk Density	Particle density	Porosity	WHC
A_P	0-9	83.2	6	10.8	5.6	Loamy sand	1.42	2.40	40.83	36.5
B_1t	9-20	75.2	10	14.8	12.5	Sandy loam	1.52	2.42	37.19	37.5
$B_{21}t$	20-51	73.8	8	18.2	25.6	Sandy loam	1.61	2.54	36.61	40.5
$B_{22}t$	51-100	71.7	6	22.3	45.7	Sandy clay loam	1.66	2.58	35.66	45.0
$B_{23}t$	100-124	65.2	8	26.8	47.2	Sandy clay loam	1.72	2.62	34.35	45.4
IIC	124-151	73	6	21.0	51.5	Sandy clay loam	1.74	2.62	33.59	42.5
IIIC	151-180	73	6.5	20.5	55.9	Sandy clay loam	1.78	2.66	33.08	41.8

Table 6. Chemical properties of pedon 3 (Low land)

Horizon	Depth (cm)	pH (1:2)	EC ($dS\ m^{-1}$)	OC ($g\ kg^{-1}$)	Exchangeable bases [c mol (p+) kg^{-1}] in soil					Exchangeable acidity [c mol (p+) kg-1]	CEC [c mol (p+) kg-1] in soil	Base Saturation (%)	ESP (%)
					Ca	Mg	Na	K	SUM				
A_P	0-9	5.85	0.06	6.6	8.4	0.6	0.4	0.3	9.7	2.8	13.55	71.59	2.95
B_1t	9-20	6.11	0.07	6.2	10	0.8	0.7	0.5	12	2.6	14.25	84.21	4.91
$B_{21}t$	20-51	6.25	0.06	4.2	10.8	1	0.9	0.8	13.5	2.2	15.66	86.21	5.75
$B_{22}t$	51-100	6.61	0.07	1.2	12	1.2	0.9	0.8	14.9	1.7	16.26	91.64	5.54
$B_{23}t$	100-124	6.82	0.19	1.0	14.8	1.3	1	0.9	18	1.3	19	94.74	5.26
IIC	124-151	6.85	0.19	0.6	12.5	1	0.6	0.5	14.6	0.5	15.26	95.6	3.93

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IIIC	151-180	6.95	0.23	0.6	12.4	0.6	0.5	0.5	14	0.2	14.55	96.2 2	3.44

Conclusion.

- The BD and PD increase gradually with slope. The soil pH increases along with depth. The OC, exchangeable acidity decrease with depth. In pedon 1, CEC decreased from upper to lower horizons. In pedon 2 and 3, CEC increases from upper to lower B horizon due to movement of bases along with clay. The upland soils classified under order *Entisols*, sub order *Orthents*, great group *Ustorthents* and sub group *Typic Ustorthents*. The medium and low land soils classified under order *Alfisols*, sub order *Ustalfs*, great group *Haplustalfs* and sub group *Udic Haplustalfs.*

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Comment [u13]: t is necessary to unify the writing of the reference in terms of the year in the text as well as in the list of references, is it the year 1978 or 2014.