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DEGRADATION OF SOIL SURFACE PROFILE OF DEVELOPED LANDFORMS ON THE VERTISOLS OF GHANA

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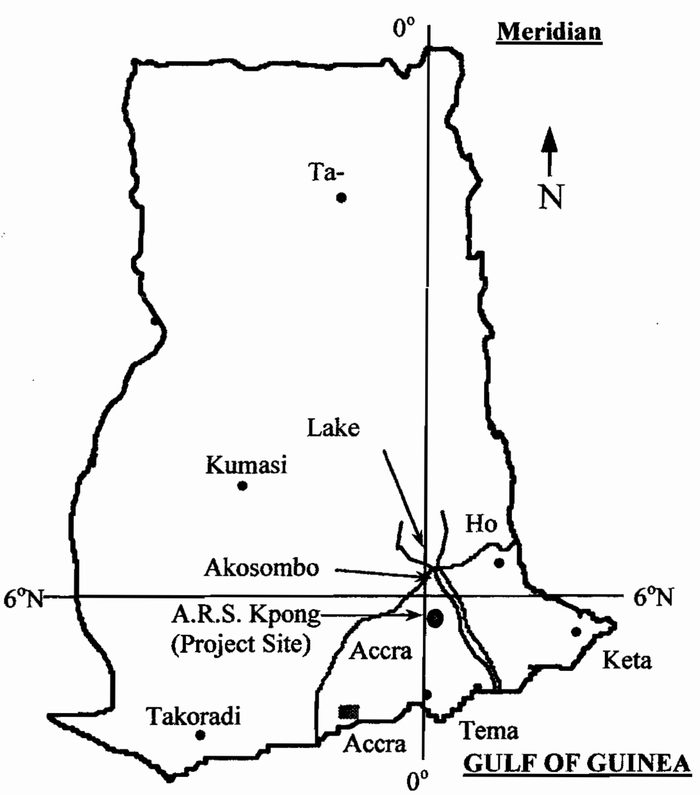
ABSTRACT:
Type and age of landform, transect position across landform and their interactive effects on soil surface profile degradation on the Vertisols in the Accra plains were examined. The average soil surface profile heights (SSPH) across landforms (Flat plots, Ethiopian Beds (EB) and camber beds (CB)) were significantly different ($p < 0.001$) at any given time among the landforms. The average SSPH across newly formed CB (0.214 m), EB (0.115 m) and flat plots (0.087 m) decreased by 23.4% (0.164 m), 25.2% (0.086 m) and 27.6% (0.063 m) respectively, after five years of formation. Soil surface profile measurements across landforms with time showed that, the order of degradation of the landforms were; flat plots > EB > CB. The degradation of the landforms was rapid at the crest of both CB and EB with flat plots having variable SSPH with no specific trend.

Keywords: Degradation; landforms; soil surface profile; transect positions; Vertisols

1. INTRODUCTION

Land-shaping technique is one of the important management practices for the vast but largely uncultivated Vertisols and vertic clays of the world for upland crop production. Increasing population pressure, resulting in diminishing agricultural land has however led to the development and cultivation of such apparent marginal lands. There are 308 million hectares of Vertisols worldwide (Coulombe *et al.,* 1996) with about 90 million hectares in Africa (Willcocks and Browning, 1986).

Figure 1. Location of the Accra plains



In Ghana, Vertisols cover 2.5% of the land area (183,000 ha) and 90% (163,000 ha) of this is found on the Accra Plains (Figure 1) (Brammer, 1967).

These soils are dominantly montmorilonitic clay with high water-holding capacity. When wet, they swell (40-50% swelling) and become very sticky for farm implement operation. Under dry conditions they produce hard consistency and cracks, again rendering them very difficult to be worked. It has been established that efficient surface drainage is the key to improving the productivity of Vertisols (Jutzi *et al.*, 1987). According to Admad (1989), Vertisols located on flat land with negligible internal drainage, require modification of the soil surface into micro-relief of varying widths and depths to provide upland crops with suitable amount of soil water during the growing season.

Options for managing Vertisols in Ghana showed that, raised camber bed landforms gave superior crop yields to those obtained from traditionally cultivated flat land in a normal wet season (Ahenkorah, 1995 and Asiedu, 1995). Further studies revealed that the benefits of landforms and cultural practices under rainfed conditions gradually decreased with time as a result of gradual degradation of the developed landforms (Terry *et al.*, 2000 and Yangyuoru *et al.*, 2003). This paper therefore evaluates the rate of physical degradation of traditional flat plots, Ethiopian beds and Camber beds landforms over a five-year period.

2. MATERIALS AND METHODS

2.1 Project site description

The experiment was conducted at the University of Ghana Agricultural Research Station (ARS) Kpong located in the Accra Plains of southern Ghana, at an altitude of 22 m above mean sea level and 80 km northeast of Accra. The 1,024 ha research station is located at latitude 6° 09' North and longitude 00° 04' East. The major growing season begins from March to mid-July and the minor growing season from early September to mid-November. The mean air temperature is 27.2 °C, with mean maximum and minimum temperatures of 33.3 °C and 22.1 °C respectively. The relative humidity for the nighttime to the early hours of the day ranges from 70 to

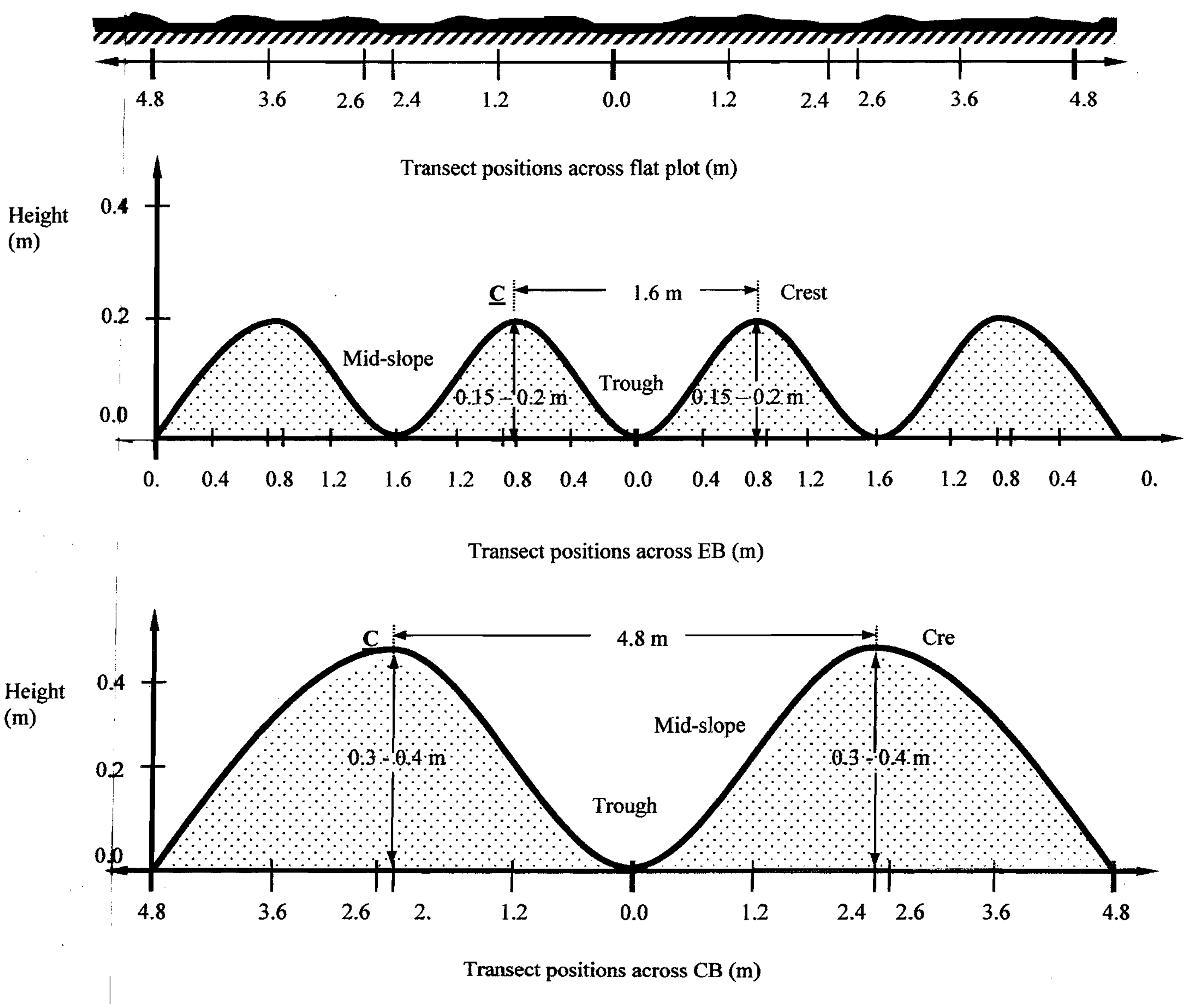
100% throughout the year. The afternoon relative humidity falls to a range of 20 to 65% during the year. The topography of the farming land is gently sloping with slopes ranging from 1% to about 5%.

The soil of the experimental area is colluvial material derived from the weathering of garnetiferous hornblende gneiss (Brammer, 1955), classified as Eutric Vertisol (FAO) and Typic Calciustert (Soil Survey Staff, 1998). Locally, it is the Tropical Black Clay and belongs to the Akuse series (Adu, 1985). The high clay content (30-55%) gives rise to poor soil drainage. These physical features pre-dispose the land to occasional flooding during periods of high rainfall in flat and depressional areas.

2.2 Field experimental design and land preparation
Type and age of landform, transect position across landform and their interactive effects on soil surface profile measurements (SSPM) were studied in a 3 x 3 x 6 multi-factorial experiment. Split-split-plot design was used with four replications. Each replication consisted of a main plot (landform), a subplot (age of landform) and a sub-sub plot (transect position on landform). The main plot treatment (landform) had 3 levels namely; flat plot (Flat), Ethiopian bed (EB) and camber bed (CB). Camber beds were formed by repeated passes of a polydisc plough to make a raised profile into dimensions as illustrated in Figure 2.
Ethiopian beds were prepared with a concave mould board ridger and a disc plough was used to prepare the flat seedbeds (Figure 2).

In order to ensure that the experimental tillage strips are long enough to allow effective performance of the tractor-mounted implements, a 'criss-cross' experimental design (Pearce, 1977) was used. The field was divided into three strips measuring 20 m by 40 m for the three landforms. The sub-plot treatment (age of formation of

Figure 2: Cross-section of the landforms



the landform) had 3 levels as; newly formed landform (NL) before the cropping seasons, 2-years (or 4 cropping seasons) old landform (TL) and 5-years (or 10 cropping seasons) old landform (FL). The sub-subplot treatment (transect position on landform) consisted of 6 levels. The transect positions across the landforms are shown in Figure 2. Four pre-determined sampling sections were marked out on the field for each of the landform. For CB and EB beds, two readings were taken in the trough, mid-slope and at the crest respectively while for the 4.8-m width flat plot, readings were taken at the designated transect positions as shown in Figure 2.

Measurement of the variation in soil surface height across the landforms was by a soil surface profile gauge (SSPG). The SSPG main component comprised a 6-m straight beam marked at 0.1 m interval along its length. The portable beam was designed and made from two easily connectable 3-m length aluminium box, 0.75 m x 0.38 m x 0.03 m for easy transportation to the field. The design was based on that developed by Willcocks and Gichuki, 1986. Other items in the SSPG kit included: two wooden posts (approximately 1.5 m long), spirit level, two metal G-clamps (0.15 m) and a clearly marked 1-m ruler or tape. With the use of the spirit level and the G-clamps the beam was set horizontal at right angles across the top of landforms supported by the two posts. Measurements of the heights from the soil surface to the horizontal beam were taken using the 1-m rule. The measured data were then analysed statistical.

3. RESULTS AND DISCUSSION

3.1 Soil surface profile measurements

The effects of age on soil surface profile degradation of landforms are presented in Figure 3 with standard error bars. In general, the measured average soil surface profile heights of the landforms (Flat, EB and CB) were significantly different ($p < 0.001$) at any given time among the landforms. For individual landforms, the average soil surface profile height degradation did not show significant difference with time because of the cumulative effects of the transect positioning. Nevertheless, the decreasing trend of the heights with time gives an idea of the rate of degradation of these individual landforms. The average soil surface profile height (0.214 m) across newly formed camber beds decreased by 13% to 0.185 m and by 23.4% to 0.164 m after two and five years respectively of formation. This trend indicates the rate of disintegration of the soil physical parameters. Asiedu, 1995 and Yangyuoru *et al.*, 2001, had earlier on demonstrated that the soil structure, bulk density and porosity of landforms deteriorated with time,

although the particle size analysis and soil texture may not be affected. The average soil surface profile height of newly formed Ethiopian beds (0.115 m) degraded to 0.095 m (17.4% reduction in height). This further deteriorated to 0.086 m (25.2% reduction of the original height) after 5 years of formation. The trend of degradation of the Ethiopian beds were similar to that of the camber beds but at a faster rate, and this had been shown by Asiedu, 1995 to be due to the degradation of the soil physical properties. The average soil surface profile height of newly tilled flat plots of 0.087 m deceased by 23.0% to 0.067 m and by 27.6% to 0.063 m after two and five years respectively. The degraded flat plots and Ethiopian beds can be subjected to frequent inundation during the rainy season rendering them unsuitable for crop production (Yangyuoru *et al.*, 2003). The flat plots degraded faster than the Ethiopian Beds while the Camber beds were the most stable landform based.

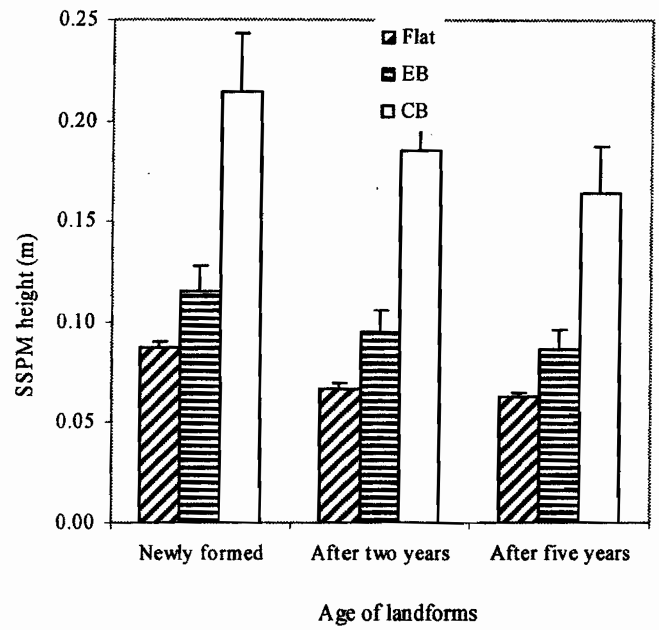


Figure 3: Average soil surface profile degradation of landforms with time

3.2 Interaction effects

The soil surface profile measurements of the landforms resulting from the treatment interactions are presented in Table 1. Apart from flat plots, there were generally significant differences ($p < 0.001$) between landforms heights and age of formation for most of the transect positions. For camber beds, the average initial height at the trough (0.386 m) decreased to 0.35 m after two years of formation, this decreased further by 23% (0.296 m) of the initial height after five years of formation. At the mid-slope of the camber beds the degradation was gradual with an initial height of (0.213 m) decreasing to 0.18 m after two years of formation, this decreased further to about 19% 0.173 m) after five years of formation. The degradation at the crest of camber beds was most conspicuous dropping from an initial height of 0.045 m to 0.029 m (36%) after two years and to 0.024 m (47%) after five years of formation.

The changes in the dimensions of the landform height and slope with time reduces the water shedding potential as had also been observed by Terry *et al.*, 2000 using soil surface roughness indices. Ethiopian beds of initial height of 0.194 m at the trough degraded to 0.163 m after two years of formation, and further to 0.15 m (23%) after five years. At the mid-slope of Ethiopian beds, deterioration of the soil surface profile was gradual from an initial height of 0.111 m to 0.082 m after two years of formation and further to about 29% (0.078 m) after five years. At the crest, the degradation was from an initial height of 0.043 m to 0.04m after two years and 0.033 m (24%) after five years.

The water shedding ability of EB, which are similar but less vigorous than CB as discussed by Ahenkorah, 1995 will need to be rebuilt after two years, from the above rate of degradation. The heights of flat plots were very variable with no specific trend of degradation. After two years of cultivation the initial flat plot height of 0.087m decreased to about 0.067m (23%) and further to 0.064 (27%) after five years. With such variable flat plots heights with no given trend of degradation, yearly land preparation by tillage will improve on the soil physical properties for crop production. Even though there were some significant differences in the soil surface profile measured heights after two-years of formation of the landforms, almost all the transect positions gave significantly lower heights than the initial heights after five years, thereby reducing the efficacies of the landforms. This was mostly prominent at the bottom, mid-slopes and crest of both camber and Ethiopian beds landforms.

4. CONCLUSION

The effects of age, type of landform, transect position across landform and their interactive effects on soil surface profile height were studied. The measured average soil surface profile heights of the landforms were significantly different at any given time among the landforms. The average SSPH across newly formed CB (0.214 m), EB (0.115 m) and flat plots (0.087 m) decreased by 23.4% (0.164 m), 25.2% (0.086 m) and 27.6% (0.063 m) respectively, after five years of formation. The order of degradation of the landforms were; flat plots > EB > CB.

The SSPM of the landforms resulting from the treatment interactions showed that, the maximum average initial height at the trough of CB (0.388 m) and EB (0.203 m) degraded to minimum values of 0.345 m and 0.160 m respectively after two years and further deteriorated from the initial CB and EB height by 24% (0.293 m) and 27% (0.148 m) respectively after five years of formation. At the mid-slope, the maximum average initial SSPH of CB (0.22 m) and EB (0.118 m), decreased to minimum values of 0.17 m (23% reduction) and 0.078 m (34% reduction) respectively after two years and further to 0.015 m (75%) for CB and 0.025 m (57%) for EB after five years of formation. Degradation was rapid at the crest of both CB (0.06 m) and EB (0.058 m) to minimum values of 0.018 m (70%) and 0.028 m (52%) respectively after two years. After five years of formation, the maximum initial crest height of CB and EB decreased by 75% to 0.015m and 57% to 0.025m respectively.

The SSPH across flat plots were very variable with no specific trend of degradation and it is recommended that yearly land preparation by tillage will improve on the soil physical properties. The rapid degradation of EB and CB requires reformation of the beds after two and five years respectively. Further studies will be to estimate the landforms runoff coefficients with time, so as to help explain their stability and water-shedding abilities.

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Table 1: Soil surface profile heights across landforms with time

Transect Position (m)	Flat Plot (F)			
	NL	TL	FL	LSD 0.05
0.0	0.090	0.070	0.065	0.006
1.2	0.083	0.063	0.063	0.008
2.4	0.085	0.065	0.060	0.013
2.6	0.088	0.068	0.065	0.013
3.6	0.080	0.060	0.055	0.013
4.8	0.095	0.075	0.073	0.005
LSD 0.05	0.022	0.022	0.014	
Transect Position (m)	Ethiopian Beds (EB)			
	NL	TL	FL	LSD 0.05
0.0	0.203	0.165	0.148	0.012
0.4	0.118	0.080	0.078	0.020
0.8	0.030	0.028	0.025	0.009
1.0	0.058	0.050	0.040	0.017
1.2	0.103	0.083	0.078	0.019
1.6	0.185	0.160	0.150	0.017
LSD 0.05	0.020	0.013	0.014	
Transect Position (m)	Camber Beds (CB)			
	NL	TL	FL	LSD 0.05
0.0	0.388	0.353	0.298	0.018
1.2	0.220	0.183	0.175	0.007
2.4	0.030	0.018	0.015	0.012
2.6	0.060	0.040	0.033	0.017
3.6	0.205	0.175	0.170	0.017
4.8	0.383	0.345	0.293	0.015
LSD 0.05	0.026	0.021	0.022	