Impact of Mechanized Rain-fed Agriculture on Some Physical Properties of Clay Soil

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Abstract: The application of an inappropriate technologies and land mismanagement altered the soil physical attributes at Goz Roum area. The objective of this study was to investigate the effect of practicing Mechanized Rain-fed Agriculture (MRA) on some physical properties of clay soil, with the aim to introduce a sustainable crop production system in an area where moisture is the limiting factor for crop production. Randomized Complete Block Design (RCBD) was used. With the help of Global Positioning System (GPS) and Auger, the continuously cultivated and adjacent non-cultivated forest soils were sampled at 0 to 25, 25 to 50 and 50 to 75 cm depths. The soil samples were analyzed at the laboratory of Agricultural Research Centre-Wad Medan. Data analysis was carried out by Personal Computer (PC) using Statistical Analysis System (SAS) - Computer Package Version 9.3. The results revealed that the cultivated soil has significant (P≤0.05) increase of coarse and fine sand at soil surface (0-5 cm), while the silt and clay fractions along with the saturation percentage (SP %) reflected significant (P≤0.05) increase at the soil subsurface (50-75 cm). For non-cultivated soil, the result displayed a significant (P≤0.05) increase of silt fraction at soil surface (0-25 cm), and the clay fraction at soil subsurface (50-75cm), while the (SP %) displayed significant (P≤0.05) increase at soil subsurface (25-50 cm). The fine sand fraction showed significant (P≤0.05) increase at soil surface (50-75 cm.). Moreover, it showed a significant (P≤0.05) increase with increasing soil profile (0-25, 25-50, and 50-75 cm). The study concluded that land mismanagement led to soil deterioration. Consequently; crop yield, socio-economic and environmental settings were adversely influenced. Therefore, the introduction of soil conservation measures and appropriate technologies are recommended.

Keywords: Soil Compaction, Porosity, Land Degradation, Conservation, Tillage.

I. Introduction:

Soil is a result of weathered minerals, which are composed of sand, silt and clay. Their relative proportions determine its texture [1]. Nevertheless, soil properties which can be influenced by soil texture, are infiltration rate, the shrink-swell rate, permeability, water retention, water holding capacity, soil porosity, soil structure, microbial activities, tillage and irrigation practices [2], [3]. Moreover, the physical properties of a soil (soil texture and structure) play a big part in the plant's ability to extract water and nutrients and to grow to their potential states [4]. Therefore; it is a crucial to thoroughly study soil attributes where ever farming is practiced.
Rain-fed agriculture is very important sector worldwide, for it comprises the biggest area for most food grain production in the world. It represents 95% of the farm land in Sub-Saharan Africa, 90%, 75%, 65% and 60% in Latin America, Near East, North Africa, East and South Asia respectively [5]. In Sudan, the Mechanized Rain-fed Agriculture was introduced in the early 1940s in Al Gedaref area in Eastern Sudan. Then it expanded horizontally in the central clay belt including Goz Rum, the study area in Northern Upper Nile during 1970s [6].

Globally, the ever increasing demand for food and energy by the world population expansion has exerted high pressure on the limited land resources. Therefore, the introduction of large scale Mechanized Rain-fed Agriculture was thought to ease the problem of food shortage. Nevertheless, despite the importance of this mode of farming, the main drawback is the failure to maintain investment-environmental balance; which manifested by soil deterioration [7].

However, in the dry regions, the development of sustainable arable Mechanized Rain-fed Agriculture can only be achieved if the field activities are well managed. One of the most important activities is soil management. Therefore, study soil properties; like soil texture, structure, and other soil attributes are useful information [8]. This is because they can be used as indicators for determining soil quality and capability, particularly in the arid and semi-arid zones, where agriculture is the predominant activity [9]. Thus, maintaining soil quality; would reduce the problems of land degradation, decrease soil fertility and the rapid decline of crop production levels that occurs in many parts of the world [10].

Studies identified several derivers of soil deterioration in the area of Mechanized Rain-fed Agriculture. They are categorized as natural and anthropogenic factors [7]. Among these, the repeated cultivation of land without fallow, monoculture, land mismanagement, population expansion, use of inappropriate technologies in land preparation, overgrazing, deforestation, and natural calamities such as frequent spells of drought, and erosion [11]. Nevertheless, under the Mechanized Rain-fed agriculture, tillage was found to have a significant effect on soil physical aspects [12].

In the same context, researches reflected that the application of farm machineries like heavy duty tractors, and wide level disc in land preparation and sowing have negative impacts on soil physical attributes [13]. An experiment at Bhilwara region in Western India showed that the use of implements like Disc and chisel ploughing affected the soil properties under rain-fed agriculture [14]. However, several studies in the tropical region, demonstrated how several methods of land preparation have adversely affected the soil properties [15]. Furthermore, studies reflected that under rain-fed agriculture, deep ploughing and leveling increase soil surface vulnerability to wind and water erosion [16].

In the same context, a comparative study between soils under rain-fed cultivation and forest non-cultivated lands regarding soil particle size and distribution were investigated in South-Western Nigeria [17]. Furthermore, the influence of land use management on some soil properties was studied at Khartoum State-Sudan [18].

Generally, the objective of this study is to know the effect of practicing Mechanized Rain-fed Agriculture on some soil physical characteristics with the aim to introduce a sustainable farming system that can address the issue of food security in the marginal and fragile ecosystems [19]. This is because the sustainability of agricultural production under Mechanized Rain-fed Agriculture; mainly rests on good field management [20].

II. MATERIALS AND METHODS

STUDY AREA
Goz Rum, the study area is located within the latitude and longitude, 11° 45’ to 11° 51’ N and 32° 52’ to 32° 56’ E; in Renk County, Upper Nile State- South Sudan (Fig.1). Where the climate is featured by short wet and long dry periods, with most rains falling during the summer, from mid-June to late October, with peak during July and August. The average annual rainfall ranges between 450- 650 mm, and an average temperature a round 28 °C (Department of Meteorology, Renk County, [21]. The area is situated in semi-arid tropical climate of central clay plain [22].
METHODOLOGY
The soil of the study area was identified as of order vertisols, suborder Usterts, Great group Chromustert, sub group Entic Chromustert, family montmorillonitic, isohyperthermic (Clay Mineral) [22].

The origin of this clay soil (cracking clay, Dinder Renk Aquil) is a controversy issue. One of the Studies demonstrated that this clay was derived from the Blue Nile alluvium, and the reddish; coarse textured soil, locally known as Azaza was (in-situ), developed from locally weathered granitic rocks in place [23], while, another study revealed that the clay soil of the study area was developed from the White Nile alluvium [24].

As far as the vegetation cover is concerned, it includes thorn Savannah, shrubs and grasses which characterize the study area by high species diversity and marked stratified grasses [25].

Generally, the study area is rich, has high potentiality of resources, including forests, availability of vast cultivable arable land, seasonal rainfall, availability of cheap labors and easy transportation. Therefore, it was selected as a center for the rain-fed mechanized agricultural production to contribute to food security in Sudan as well as the strategic plan “Sudan the World Bread Basket” [7].

Field work

Soil sampling method: Sample design and techniques:

The field work was conducted during the period 15 to 25th of May, 2011. When both, Ground Control Points (GCPs) and area of interest (AOI) were determined by Global Positioning System (GPS) receivers Garmin 60C (Fig.1). Then the study area of
4201.7 hectares (10,000 feddan) was divided into 20 equal blocks. By using Auger and spade, soil samples, each at three (3) levels of depths (0-25, 25-50 and 50-75 cm.), were collected from two sites, the cultivated, and forest non-cultivated soils. The oil samples were processed for laboratory analyses. The samples were analyzed, using the facilities of the laboratory of Wad Medani Agricultural Research Centre-Sudan, where soil texture and structure, SP% were investigated. Soil particle size distribution was determined by Mechanical Analysis using Bouyoucous hydrometer method and soil texture class was determined according to USDA methods and classification. Data analysis was carried out through ANOVA followed by Duncan's Multiple Range Test using the computer package Statistical Analysis System (SAS).

III. RESULTS and DISCUSSIONS

The results of soil data analysis are presented in table (1), figures (2) and (3).

Table1. Mechanical analysis and Saturation Percentage (SP %) of soil samples of both cultivated and non-cultivated soils at soil depths 0-25, 25-50 and 50-75 cm.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Coarse sand</th>
<th>Fine sand</th>
<th>silt</th>
<th>clay</th>
<th>SP%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cultivated soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-25 cm</td>
<td>15.3 b</td>
<td>5.5 a</td>
<td>20.3 b</td>
<td>57.8 b</td>
<td>70.8 b</td>
</tr>
<tr>
<td>25-50 cm</td>
<td>15.2 a</td>
<td>5.3 a</td>
<td>19.7 b</td>
<td>57.8 b</td>
<td>70.1 b</td>
</tr>
<tr>
<td>50-75 cm</td>
<td>15.2 b</td>
<td>5.3 a</td>
<td>20.6 b</td>
<td>59.5 a</td>
<td>73.3 a</td>
</tr>
<tr>
<td>SE ±</td>
<td>1.2</td>
<td>0.24</td>
<td>0.5</td>
<td>0.9</td>
<td>1.6</td>
</tr>
<tr>
<td>CV (%)</td>
<td>16.6</td>
<td>11.7</td>
<td>11.8</td>
<td>8.5</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>Non cultivated soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-25 cm</td>
<td>13.5 a</td>
<td>3.3 b</td>
<td>21.7 b</td>
<td>61.8 c</td>
<td>77.3 b</td>
</tr>
<tr>
<td>25-50 cm</td>
<td>9.5 c</td>
<td>3.7 ab</td>
<td>21.5 b</td>
<td>63.8 b</td>
<td>80.1 a</td>
</tr>
<tr>
<td>50-75 cm</td>
<td>11.0 b</td>
<td>4.3 a</td>
<td>21.0 b</td>
<td>64.4 a</td>
<td>79.8 a</td>
</tr>
<tr>
<td>SE ±</td>
<td>0.66</td>
<td>0.15</td>
<td>0.36</td>
<td>0.45</td>
<td>0.5</td>
</tr>
<tr>
<td>CV (%)</td>
<td>8.7</td>
<td>14.2</td>
<td>6.8</td>
<td>9.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Means superscripted by the same letter(s) in the same column are not significantly different at P≥ 0.05, according to Duncan's Multiple Range Test.
Fig. (2): Coarse sand in both cultivated and non-cultivated soils - Goz Rum area (2011)
In this study, both cultivated and non-cultivated soils showed accumulation of sand fractions at the soil surface (0-25 cm.), but the cultivated soil revealed higher percentage (mean value of sand 22.0%), compared to non-cultivated soil (mean value of sand 17.0%) (table 1, fig 2 and fig. 3). This indicates that, the cultivated soil has been subjected to mismanagement; including deforestation, application of inappropriate farm machineries and implements. However, the complete removal of vegetation covers during the field clearance; has left the soil bare, exposed, and accelerated its erodibility. Consequently, soil stability was reduced and it became vulnerable to both wind and water erosion [26].

Soil behavior such as soil crusting, hydraulic conductivity, soil compaction, water retention, and workability are influenced by the soil particles [26]. The use of Wide Level Disc (WLD) in land preparation and sowing operation breaks down the big soil clogs into small fine particles that ready for transportation by run-off, leading low fertile soil and poor crop yield. Moreover, the repeatedly use of WLD for several years; means continuous land preparation at the same depth. This operation leads to the formation of hard pans; which reduces water infiltration and retards crop roots development.

Soil saturation percentage which characterizes the soil texture; is a useful indicator for changes in soil characteristics with depth and soil water retention. In this study, the cultivated soil has low SP% (70.8%, 71.1% 73.3%) at all soil depths (0-25, 25-50 and 50-75 cm.). Thus; the cultivated soil has lower water holding capacity compared to non-cultivated soil. These results agree with the results of Soil Testing and Analysis at Tehama County -California [27].

Furthermore, the up and down movement of the heavy duty machines in the field; during land preparation and sowing, causes soil compaction; which reduces water infiltration; consequently, the soil moisture content will be low. This is a common phenomenon in the area of rain-fed mechanized farming.

Obviously, the accumulation of higher percentage of sand at soil surface (0-25 cm.) in
the cultivated soil is an indication of lower fertility

IV. CONCLUSIONS AND RECOMMENDATIONS

The study revealed different signs of land degradation in the study area as judged by change in soil physical properties. These changes eventually will have negative effect on crop yield, and vegetation cover. They may cause water logging and lower infiltration rate. The study concluded that; due to land mismanagement, the cultivated soil became less potential compared to non-cultivated soil.

Based on the above findings, the following recommendations can be stated:

- Sub-soiling or ripping to a depth of 50 to 75 cm or more to be practiced in order to break soil compaction, and hard pans to improve water infiltration rate.
- Application of organic manure (farmyard and chicken manures) which can improve the physical, chemical and biological properties of the depleted soils.
- Development of new strategies for rain-fed mechanized agriculture.
- Introduction of conservation measures such as terraces, a forestation.
- Further in-depth research including modeling and simulation is recommended.

V. REFERENCES


[22] Department of Soil Survey at Wad Medani-Sudan (1972).


