

Effect of Tillage and Water Management on Aggregate Stability of a Gleyic Cambisols

Abstract

The objective of this study was to determine the effect of tillage and water management on the physical stability of irrigated lowland rice field, in Kwalkwalawa, Sokoto State. The experiment was carried out in a farmer's field, near the Usmanu Danfodiyo University Teaching and Research Farm, Kwalkwalawa, Sokoto State. The coordinates of the area were taken using global positioning system (GPS) model Garmin etrex 20.0, which shows that the area is located on (N13⁰05.963"E005⁰12.650" and at 252m asl). The soils of the study area were classified as Aeric Endoaquepts at subgroup level in the USDA Soil Taxonomy System which correlated with Gleyic Cambisols in the World Reference Base. The treatments consisted of factorial combination of two tillage systems (conventional tillage (CT) and reduced tillage (RT), three irrigation water managements (Alternate one, two and three days irrigation intervals, which were carried out from one week after transplanting to hard dough stage) and three rice varieties (FARO 44, 60 and 61) all laid in a split-plot design and replicated three times. After harvest, disturbed soil samples were collected with the aid of soil auger, prepared and passed through 5 mm sieve for aggregate stability determination. Result reveals that a consistent trend in aggregate size fraction was observed between the two tillage systems in both years, were a significant decrease in values of aggregate fractions of both the CT and RT in 2019 compared to in 2018. Aggregate size fraction of 5-2 mm had a significantly high value of RT compared to CT, 2-0.25 mm fractions were at par (0.41) while a greater value of aggregate fractions for CT in both 0.25-0.005 mm and <0.005 mm were observed compared to RT. Alternate days to irrigation and sampling depths increase with a corresponding in all the aggregate size classes in the two years of this study. A significant difference in mean weight diameter (MWD) and geometric mean diameter (GMD) between the two tillage, water management and depth was noticed in both years of the trial where RT and alternate one day had high value while MWD and GMD increase with increasing depth.

Keywords: Tillage, Aggregate Stability, agriculture, soil, water management.

1.0 INTRODUCTION

Soil aggregation is defined as the process whereby individual soil particles are joined into compound particles, clusters or aggregates (Sullivan, 2004). Aggregation is an important indicator of the soils' overall quality (Boix-fayos *et al.*, 2001). It has potential benefits on soil moisture status, nutrients dynamics, tilth maintenance and erosion reduction (Kemper and Rosenau, 1986; Zheng *et al.*, 2018). The term aggregate stability is used by soil physicists to

35 refer to the ability of the bonds of the aggregation to resist stress upon exposure (Rohoskova and
36 Valla, 2004). In determining the stability of soil aggregates, soil physicists generally subject
37 samples of aggregates to artificially induced forces designed to simulate phenomena which are
38 likely to occur in the field (Hillel, 1980). The resistance of soil solids to the mechanical abrasion
39 rising from the two forces of destruction i.e water and air for long has been used to measure the
40 stability of aggregates. The technique for aggregate stability analysis is described by Kamper and
41 Rosenau (1986). Dry sieving by White (1993) is the common method employed to simulate
42 aggregate resistance to wind erosion.

43 Numerous factors affect the stability of soils (Kay, 1997), most of which can be broadly grouped
44 into two: endogenous and exogenous factors. The endogenous factors are those that are due to
45 inherent soil properties. These factors include soil characteristics such as texture, clay
46 mineralogy and nature of exchangeable cations, and the quantity and quality of humus fractions
47 (Lal and Shukla, 2004). The exogenous factors that affect soil aggregate stability include
48 weather, biological processes, land use and management. Soil management or land use has been
49 reported to influence soil aggregate stability (Six *et al.*, 2000 and Castro *et al.*, 2002; Song *et al.*,
50 2019).

51 Pinheiro *et al.*, (2004) found that soil surface aggregates of >2mm fractions formed
52 (50%) soil under no-tillage compared with animal traction (35%) and conventional tillage (30%).
53 He also observed that soil organic carbon (SOC) was higher under no-tillage than conventional
54 tillage. Gajic *et al.* (2006) reported that the conversion of forest to continuous cropping by
55 conventional cultivation significantly decreased the stability of soil aggregates in the plough
56 horizon. Also, Adesodun and Odejimi, (2010) reported that mean weight diameter (MWD) was
57 significantly higher in un-cultivated land, whereas the addition of compost to the cultivated land

58 improved stability of the soil. It has been reported that soil organic matter and clay content are
59 the main soil properties affecting soil aggregation, as they bind individual particles (Fryrear *et*
60 *al.*, 1994 and Oliveira *et al.*, 2004). Any practices that reduce organic matter and disturbed clay
61 particles reduce soil aggregation.

62 This work was developed with the objectives of evaluating the aggregate size fractions,
63 MWD and GMD between the two tillage operations, water managements and depths.

64 **2.0 MATERIALS and METHODS**

65 **2.1 Experimental Location**

66 The experiment was conducted in a farmer`s field, near the Usmanu Danfodiyo
67 University Teaching and Research Farm, Kwalkwalawa, Sokoto State. The coordinates of the
68 area were taken using global positioning system (GPS) model Garmin etrex 20.0, which shows
69 that the area is located on latitude 13⁰05`N and longitude 05⁰12`E. The soils of the study area
70 were classified as Aeric Endoaquepts at subgroup level in the USDA Soil Taxonomy System
71 (USDA, 2014) which correlated with Gleyic Cambisols in the World Reference Base (FAO,
72 2015). The area experiences a long dry season from October to May and a short rainy season
73 from June to September. The dry season consists of a cold dry spell (Harmattan) roughly from
74 November to February, followed by a hot dry spell from March to May. The rainfall is erratic,
75 small in quantity and uneven distribution with a peak in August and temperature fluctuates
76 roughly between 40⁰C maximum and 15⁰C minimum (Noma, 2005).

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79 2.2 Treatments and Experimental Design

80 The treatments consisted of factorial combination of two tillage systems (Conventional
81 tillage (CT); which involves cutting, inverting, puddling and levelling the field plots and reduced
82 tillage (RT); which involves puddling and levelling of the plots all with local hoes, shovels and
83 rakes), three water managements (Alternate one day, two days and three days irrigation intervals,
84 which were carried out from one week after transplanting to hard dough stage) and three rice
85 varieties; (FARO 44, 60 and 61).

86 The treatments were laid in a split-plot design replicated three times. Tillage system was
87 allocated to the main plots, while water managements and varieties were allocated to the sub-
88 plots. Field observations and measurements were made for the two consecutive seasons using the
89 same experimental design and field layout. After each season harvest, disturbed soil samples
90 were collected with the aid of soil auger, prepared and passed through a 5mm sieve, while the
91 aggregate stability was determined by dry sieving methods as described by Van Bavel (1950) as
92 modified by Kemper and Rosenau (1986). Two hundred grams of bulk soil from the 5mm sieve
93 was weighed and transferred into the nest of sieves consisting of diameters 2.0 mm, 0.25 mm and
94 0.005 mm. The nest of sieves was placed on a mechanical shaker and shaken for 2 minutes after
95 which the weight of soil retained in each sieve was determined.

96 Aggregate size distribution was calculated as the proportion of soil retained in each sieve as:

$$97 \text{ Aggregate size distribution} = \frac{\text{Weight of soil retained in a sieve}}{\text{Total weight of soil taken}}$$

98 While the mean weight diameter (MWD) and geometric mean diameter (GMD) was calculated
99 as follows:

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101 $MWD_{dry} = \sum_{i=1}^n w_i x_i$

102 x_i = The mean diameter of the class (mm)

103 w_i = the proportion of each size class concerning the total sample

104 $GMD_{dry} = \exp\left[\frac{\sum_{i=1}^n \log x_i}{\sum_{i=1}^n w_i}\right]$

105 w_i = weight of aggregate of each size class (g)

106 $\log x_i$ = logarithm of the mean diameter of the size classes.

107 **2.3 Data Analysis**

108 Data generated were subjected to analysis of variance (ANOVA) using SAS 9.0 software,
109 (SAS, 2002). Significant means were compared using Duncan multiple range tests (DMRT) at
110 $P < 0.05$ (Gomez and Gomez, 1984).

111 **3.0 RESULTS and DISCUSSION**

112 **3.1 Effects of Tillage, Water Management and Depths on Aggregate Size Fractions in** 113 **2018**

114 From the result (Table 1), analysis of variance revealed a significant effect of tillage on
115 aggregate size fractions in all the separates, with CT having significantly higher values, except in
116 5-2 mm fractions, where RT have a significantly higher value compared to CT.

117 The results also show a significant difference in all the aggregate size fractions with alternating
118 days of irrigations; with alternating one-day irrigation having more of the aggregates size
119 fractions within all the separates while alternating three days irrigation having the least value
120 across all the separates.

121 However, sampling depth shows significant effects as they increased with depth. The observed
 122 differences in the different aggregate separate between the two tillage and water management
 123 may be a result of the degree of soil disturbances and the variation in the timing of the water
 124 application among the treatment combination, this made the CT with alternate one-day irrigation
 125 prone to ease of removal and being dislodged. Oades, (1984) observed that macro and micro
 126 aggregates depend on organic matter for stability against destructive forces caused by quick
 127 wetting. Aggregates were more disrupted in CT compared to RT according to Mrabet, (2002).
 128 The decline in the size of the aggregates due to tillage could be credited to mechanical disruption
 129 of macroaggregates which may have exposed soil organic matter previously protected against
 130 oxidation. This is similar to the findings of Elijah (2016).

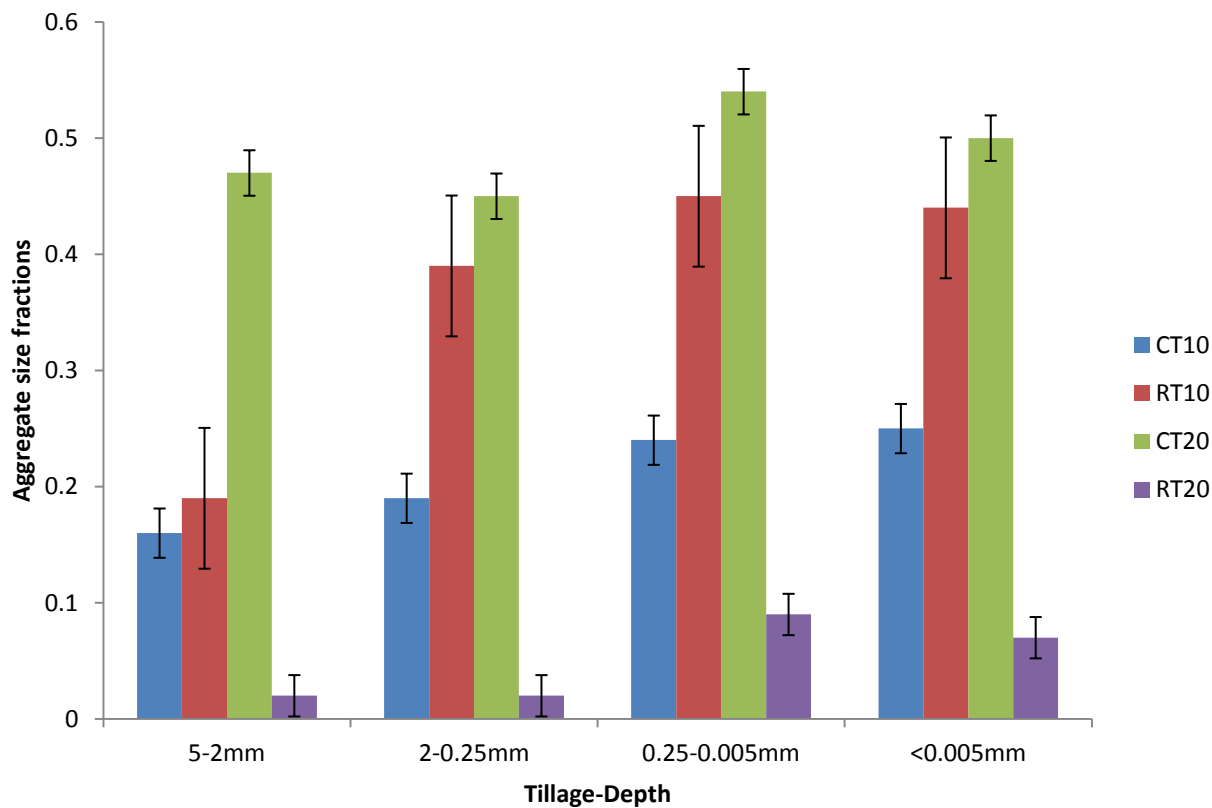
131 Significant interactions between the tillage and depth were noted among all the aggregate size
 132 fractions across all the separates as depicted in Figure 1

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 134 Table 1. Effects of tillage, water management and Depths on Aggregate size fractions in 2018

Treatment	5-2 mm	2-0.25 mm	0.25-0.005 mm	<0.005 mm
Tillage (T)				
CT	0.21b	0.42a	0.51a	0.058a
RT	0.22a	0.41b	0.48b	0.048b
SE±	0.0018	0.0044	0.0021	0.0020
Water management (W)				
Alternate one day (W1)	0.22a	0.42a	0.50a	0.059a
Alternate two days (W2)	0.21b	0.42a	0.49b	0.053b
Alternate three days (W3)	0.21b	0.41b	0.48c	0.048c
SE±	0.0022	0.0054	0.0024	0.0024
Depth				
0-10 cm	0.18b	0.39b	0.46b	0.024b
10-20 cm	0.24a	0.45a	0.52a	0.083
SE±	0.0018	0.0044	0.0021	0.0020
Interaction				
T × W	NS	NS	NS	NS
T × D	**	**	**	**

W × D	NS	NS	NS	NS
T × W × D	NS	NS	NS	NS

135 Means followed by the same letter(s) within the same column are not significant at 0.05 level of
 136 probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard error



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 138 Fig.1: Interactions between tillage and depths on aggregate size fractions in 2018 (SE±
 139 represented in the bar)

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3.2 Effects of Tillage, Water Management and Depths on Aggregate Size Fractions in 2019

There was a significantly decreased in values of aggregates fractions of both the CT and RT in 2019. Table 2 reveals that aggregate size fraction of 5-2 mm had a significantly high value of RT compared to CT, 2-0.25 mm fraction was at par (0.41) while a similar trend of greater values of the remaining aggregate fractions for CT in both 0.25-0.005 mm and <0.005 mm were observed compared to RT.

Considering the alternating irrigation with the variation in all the aggregate size classes, one-day alternate irrigation had the highest mean values among all the aggregate size classes among the separates while three days alternate irrigation is the least with the value (0.045) of alternate two days irrigation for <0.005 mm fraction being similar with (0.047) of alternate three days irrigation for the same aggregate.

A similar trend was also observed in the sampling depths as in 2018, with a significant effect as they increased with depth. A significant interaction between the tillage and depth was observed among all the aggregate fractions in 2019 except on <0.005 mm aggregate fraction which shows no significant interaction. This consistent trend in the variation of all the aggregates may be as a result of the degree of disruption of all the aggregates fractions both in CT and RT, with CT been more pronounced in the second year due to continuous disturbance of those soil without subsequent addition of organic matter that will boost the bond strength of those soils. Enjugu

171 (2014) and Elijah (2016) also observed a steady increase in aggregate size fraction over two-year
 172 tillage research in Samaru.

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175 Table 2. Effects of tillage, water management and Depths on Aggregate size fractions in 2019

Treatment	5-2 mm	2-0.25 mm	0.25-0.005 mm	<0.005 mm
Tillage (T)				
CT	0.20b	0.41	0.50a	0.055a
RT	0.21a	0.41	0.47b	0.043b
SE±	0.0021	0.0050	0.0026	0.0025
Water management (W)				
Alternate one day (W1)	0.21a	0.42a	0.49a	0.055a
Alternate two days (W2)	0.21a	0.41b	0.49a	0.045b
Alternate three days (W3)	0.20b	0.40c	0.48b	0.047ab
SE±	0.0026	0.0062	0.0032	0.0034
Depth				
0-10 cm	0.18b	0.38b	0.45b	0.022b
10-20 cm	0.24a	0.44a	0.52a	0.077a
SE±	0.0021	0.0050	0.0026	0.0025
Interaction				
T × W	NS	NS	NS	NS
T × D	**	**	**	NS
W × D	NS	NS	NS	NS
T × W × D	NS	NS	NS	NS

176 Means followed by the same letter(s) within the same column are not significant at 0.05 level of
 177 probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard error

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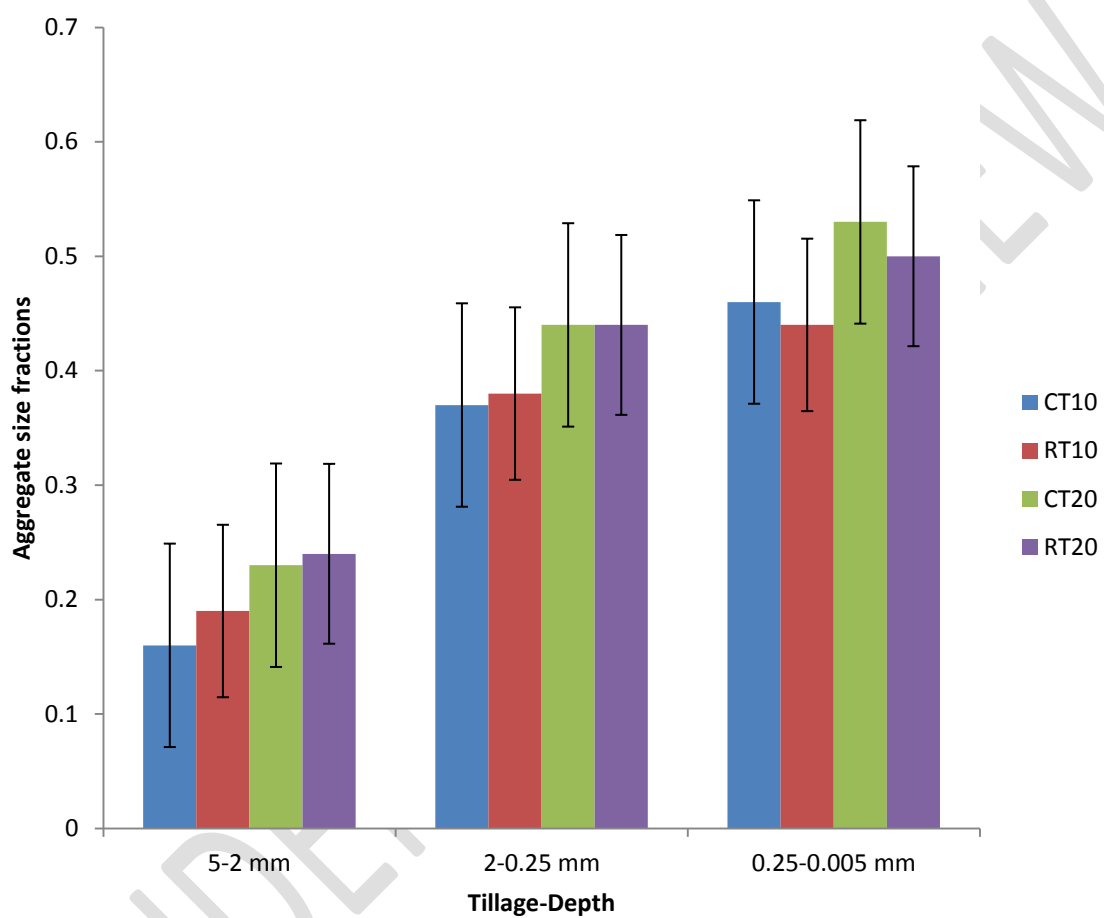
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188 Fig. 2: Interactions between tillage and depths on aggregate size fractions in 2019 (SE±
189 represented in the bar)

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3.3 Effects of Tillage, Water Management and Depths on MWD and GMD of Aggregate in 2018 and 2019

The mean weight diameter (MWD) and geometric mean diameter (GMD) were significantly affected by tillage (Table 3) in the two years of this study. In 2018, a significant difference was noticed in tillage with RT shows a significantly higher value for MWD and GMD. The alternating days to irrigation also shows a significant increase in values of both the MWD and GMD, where alternate one-day irrigation records the highest value while alternate three days irrigation had the least.

Significant increase in MWD and GMD across the two depth increase with increasing depth in 2018, and there was significant interaction between tillage and depth among the MWD and GMD of the aggregate in 2018 (Fig. 3)

A similar trend in MWD and GMD were also observed in 2019 (Table 3). This trend shows a gradual decrease in the value of both MWD and GMD for the two tillage systems across the two years. This shows the decrease of the stability of the soil to various tillage operations. Unger, (1991) reported that an increase in MWD and GMD is its ability to withstand erosion. The MWD and GMD increased as the depth of sampling increases indicating that the deeper the soil, the less vulnerable the soil will be exposed to erosion. Oguike and Mbagwu, (2009) observed that tillage with traditional hoeing and clean weeding together with reduced organic matter content, as in the case of this trial field may explain the low value of MWD and GMD observed under CT

217 compared to the RT tillage practices. Fuentes *et al.* (2011) and Enjugu (2014) also reported that
 218 soil with conventional tillage plus reduced organic matter had a low MWD and GMD compared
 219 to soil with no-tillage plus residue, which indicates that despite the incorporation of residues,
 220 there was a negative effect on soil stability with tillage.

221 The variation of MWD and GMD and soil depth could be probably due to reduced soil
 222 disturbance, redistribution of residues and homogenization effect of ploughing (Tan *et al.*, 2004)

223 Table 3 Effects of tillage, water management and Depth on Mean Weight Diameter and
 224 Geometric Mean Diameter in 2018 and 2019

Treatment	2018		2019	
	MWD	GMD	MWD	GMD
Tillage (T)				
CT	1.09b	0.80	1.08b	0.79b
RT	1.15	0.82	1.14a	0.81a
SE±	0.0011	0.0083	0.0011	0.0027
Water management (W)				
Alternate one day (W1)	1.13a	0.82a	1.12a	0.81a
Alternate two days (W2)	1.12b	0.81b	1.11b	0.80b
Alternate three days (W3)	1.11c	0.80c	1.11b	0.80b
SE±	0.0013	0.0010	0.0013	0.0033
Depth				
0-10 cm	1.09b	0.78b	1.08b	0.77b
10-20 cm	1.15a	0.84a	1.15a	0.83a
SE±	0.0011	0.0083	0.0011	0.0027
Interaction				
T × W	NS	NS	NS	NS
T × D	**	**	**	**
W × D	NS	NS	NS	NS
T × W × D	NS	NS	NS	NS

225 Means followed by the same letter(s) within the same column are not significant at 0.05 level of
 226 probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard error
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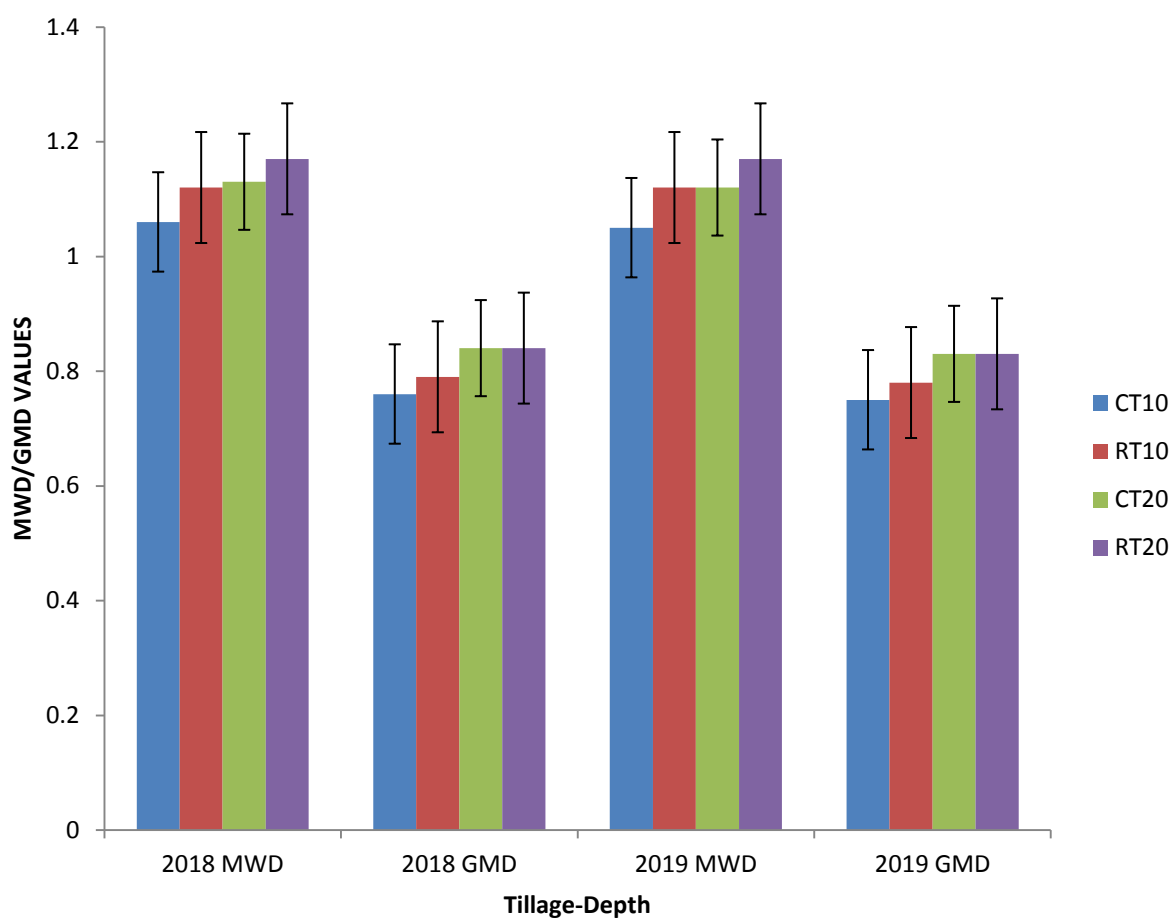
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234 Fig. 3: Interactions between tillage and depths on MWD and GMD in both 2018 and 2019 (SE±
235 represented in the bar).

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237 **4.0 CONCLUSION**

238 The use of tillage implements interferes with the stability of the soil aggregate, where
239 reduced tillage have higher MWD and GMD compared to conventional tillage.

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