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EFFECT OF LAND-USE CHANGE ON WATER-STABLE AGGREGATES AND SOIL CHEMICAL PROPERTIES WITHIN OF TWO CULTIVATED FIELDS IN KHOST PROVINCE, AFGHANISTAN

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ABSTRACT

Conventional farming system may cause physical and chemical soil degradation. Plant residue retention can be used to improve soil aggregation and chemical properties. However, the effectiveness of plant residue retention in conventional farming (CF) system remains unclear. Therefore, we studied the influence of plant residue retention on the water-stable aggregates, mean weight diameter of water-stable aggregates, bulk density and soil chemical properties. Plant residue had a significant effect on the distribution of water-stable aggregates, with aggregates >4 mm and 2 mm being 10.3% and 15.4% higher with plant residue in combination with conventional farming (PRF) in 2018 than CF. Over time in 2018, the highest MWD was obtained in PRF plots, being on average 14.9% higher than in CF fields. In 2018, plant residue retention had significantly increased water content, which was 42.3% in PRF plots. In 2018, PRF and CF plots had 130.8 kg ha^{-1} and 102.8 kg ha^{-1} NO_3-N respectively. PRF had 21.5% more soil NO_3-N than CF plots. Using plant residue also increased soil P and K^+ levels as compare to CF. These results indicated that retention of plant residue can increase water-stable macroaggregates, MWD and improve soil quality.

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INTRODUCTION

Soil organic carbon (SOC) has recently gained prominence in assessment of soil quality and affects chemical, physical and biological aspects of the soil. However, carbon dioxide emissions from agricultural land have increased since the intensive of agriculture cultivation (Lal, 2004), and soil degradation has become a serious problem due to the decreasing soil organic matter in soil (Bot and Benites, 2005; Lal, 2009). Soil organic matter is an important source of inorganic nutrients for plant production in natural and managed ecosystems (Ross, 1993; Hashimi *et al*., 2019b). The conversion of conventional agriculture lands into conservation agriculture known to improve soil properties, especially increase soil organic carbon (SOC), reduce bulk density and changes in distribution and stability of soil aggregates (Yagioka *et al*., 2014; Arai *et al*., 2014).

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Increase of SOC and reduce bulk density with cultivation is connected to the construction of macroaggregates (Elliott, 1986), as a result, soil becomes more suitable for plant production and resistance to soil erosion since macroaggregates are constructed (Six *et al*., 2000). Soil aggregation has been considered as an important factor not only for increasing soil quality and productivity, but also improving nutrient availability and water use efficiency (Guo *et al*., 2019). The retention of above-ground plant residue on the soil surface increases soil C sequestration, >2-mm aggregates, and the mean weight diameter (MWD) compared with conventional management practices (Arai *et al*., 2014)

Cover crops maintain and improve soil health. They prevent soil erosion and increase organic matter, improve soil structure, and water infiltration rates. Integrating cover crop into crop rotations provide an opportunity to increase soil C sequestration and organic matter (Poeplau and Don, 2015). In low fertility soil, increasing soil organic C is important for enhancing soil quality and affects many physical and chemical processes such as the stabilization of soil structure or plant available nutrients (Lal, 2015). Furthermore, cover crop residue also improves the soil structure, including the soil aggregate stability, by enhancing soil biological activities (Børresen, 1999). Plant residue increases the water content in conventional tillage (CT) practices, and Humphreys *et al*. (2011) confirmed that rice straw residue increased the water content and this helped in the formation and stabilization of aggregates (Duiker *et al*., 2003). Moreover, in Afghanistan which has semi-arid climates, cover crop bio-mass production is low and increasing SOC is challenging. If irrigation is available, the amount of biomass can be greatly increased, but the challenge of increasing SOC remains due to rapid mineralization (Gervois *et al*., 2008). Afghanistan soils are formed under arid and semi-arid climatic conditions, and soil textural classes are mostly clay loam to sandy loam. The soil has high amount of calcium carbonate and high pH, and has low soil organic matter content ranges from 0.2 to 2.5% (Sameen and Zaghard, 2008). The low annual rain fall in Khost province, the soil has low organic matter and farmers mostly engaged with conventional cultivation system. Even, there are many sources of organic fertilizers (animal waste, green manure and chicken waste for compost). These organic fertilizers provide nutritional requirement especially contain macronutrients, essential micronutrient, and increasing yield and beneficial microorganism (Arancon *et al.,* 2003; Hashimi *et al*., 2019b). Mostly farmers, using cover crop to for animal feeding and it is help with nutrient cycling. Few farms using different cover crops to enhance soil fertility and after harvesting it remains on soil surface and as result these field has high amount of soil nutrient for suitable condition for plant production. Although many studies have examined the e□ects of organic matter on soil quality (e.g. Mahmoud *et al.,* 2009) and yield response (e.g. Shaheen *et al.,* 2014; Uddin *et al.,* 2012). However, only a few studies have been conducted in Khost, Afghanistan, and there is little data for comparing soil quality between plant residue in combination with CF (FPR) and conventional farming (CF). Therefore, the objective of this work was to determine the e□ect of replacing the traditional winter fallow in crop rotations of irrigated semi-arid areas with a cover crop. Specifically, we focused on the e□ects on soil physical properties (aggregate stability, mean weight diameter (MWD) and bulk density) and soil chemical properties (pH, NO_3, K_2O and P_2O_5).

MATERIALS AND METHODS

Study area

The study area was the Mando Zayi district of Khost province, located in the south east of Afghanistan. In both study areas the major crop is wheat, cover crops and vegetable production. In both area the soil type is clay loam. Both fields are suitable for double crop rotation for main crops in summer and cover crops in winter. Field investigations were conducted in October 2016 and 2018, and details of farming practices and plant residue application were obtained from interviews with plant residue in combination of conventional farming (FPR) and conventional farmers. FPR and CF using chemical fertilizers for plant production. FPR returned cover crop residue to the field after harvesting and then mixed with soil. CF is conventional agriculture practices and all plant residue remove from field. Based on the interviewed farmers returned plant residue to keep soil moisture content.

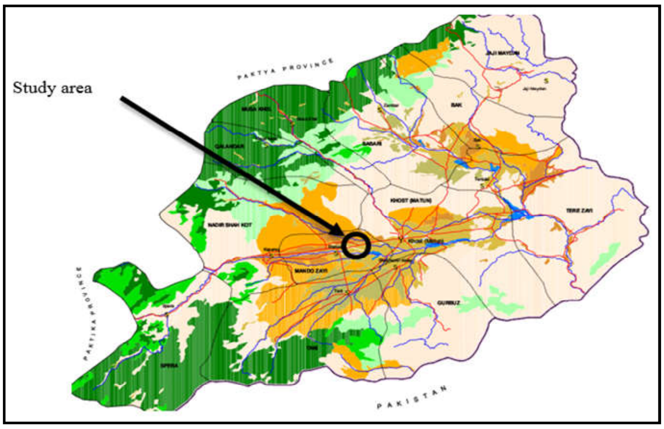

Figure 1. Geographical location of studied sites in Khost, Afghanistan

Soil sampling and measurement: Plant residue was applied to field since 2014, and we examined the 2016 and 2018 soil samples. Conventional field continued to be tilled and remove plant residue from the field. Both fields were located in the different area of the same district. Figure 2. Comparison of farm management systems between plant residue and conventional farming in Khost, Afghanistan. Topsoil samples (from a depth of 0–5 cm) were taken from three plant residue field and three conventional fields in October 2016 and 2018 by sinking a 5-cm-diameter steel cylinder. Each soil sample was kept in a plastic bag. To assess the soil water content, we took subsamples from the fresh soil samples and measured their fresh weights; we then dried these at 105°C for 72 h to obtain their dry weights. We removed 10 g of the fresh soil samples to measure the water-stable aggregates and MWD.

Figure 2. Conventional farming (CF) in (A), and plant residue in combination with conventional farming in (B)

To assess the bulk density and water content, sub-samples were taken from the fresh soil samples. The sub-samples were weighed, dried at 105 °C for 72 h, and weighed again. Bulk density was calculated as dry soil weight (g) / soil volume (cm^3) (McKenzie *et al*. 2002). For water-stable aggregates measurement, we placed 10 g of each fresh soil sample (taken from the top 0–5 cm) in the topmost of a nest of five sieves with 4, 2, 1, 0.5, and 0.25 mm mesh size, respectively, and put the sieves in water for 30 min. The nest of sieves was then slowly shaken vertically in the water 60 times, and put in a 105°C oven for 72 h to measure the dry soil weight in each size class. We determined the water aggregate stability index (WAS) using the method described by Gardi *et al*. (2002) for wet sieving with vertical oscillation, using the following equation:

$$WAS\,\% = \left(\frac{x}{y}\right) \text{x}\,100$$

where x is the amount of dry soil aggregate remaining on each sieve following treatment and shaking, and y is the total amount of soil used in the soil aggregate analysis.

The MWD of the soil aggregates (Kemper and Rosenau, 1996) was determined as

$$MWD = \sum_{i=1}^{n} Xi\,Wi$$

Where x_i is the mean diameter of each aggregate class (mm) and w_i is the weight fraction in each aggregate class.

Soil pH, NO_3, K_2O and P_2O_5 is measured by LaMotte field kit.

Statistical analysis: The statistical analyses were performed using STAT View (STATView for Windows, version 5; SAS Institute, Cary, NC). Analysis variance was performed within each treatment means were tested using the least significant difference test at a level of 0.05.

RESULTS

Water-stable aggregates: Plant residue had a significant effect on the aggregate size distribution in 2018, with PRF had 10.3% > 4mm water-stable aggregates while CF had 6.3% in same year (Fig. 3).

In 2016, the initial stage > 4mm water-stable aggregates were almost same in both fields (PRF and CF), which were 4.3% and 4.6% respectively. A similar trend was also observed for 2mm water-stable aggregates in 2018, which in PRF was 15.4% as compared with 2016. In contrast, in both filed in 2016, the 0.25-mm micro aggregates was same in PRF and CF. CF significantly increased the 0.25-mm micro aggregates as compared to PRF, which was 21% and 17.2% respectively. In both years, we did not observed any differences for 1 mm water-stable aggregates in both fields.

Mean weight diameter: Plant residue had a significant effect on the mean weight diameter over time consuming (Fig 4). MWD was 1.01 (mm) in PRF and 0.86 (mm) in CF in October 2018. In 2016, MWD was 0.75 (mm) and 0.76 (mm) in PRF and CF respectively. Over time in 2018, the highest MWD was obtained in PRF plots, being on average 14.9% higher than in CF fields. However, this difference was not observed in initial stage samples. In both years, macro aggregates and MWD had positive correlation among each other (Fig 5).

Soil bulk density and water content: In both years, plant residue had no significant effect on soil bulk density. Bulk density was lower in PRF than in CF plots (Table 2). In 2018, in PRF bulk density was 6.3% lower than 2016 soil samples. PRF plots had similar water content in initial soil samples. However in 2018 plant residue retention had significantly increased water content, which were 42.3% and 39% in PRF and CF respectively.

Soil chemical properties: The application of plant residue increased (but not significantly) soil nutrients levels of NO_3-N, P and K^+ (Table 1). Soil pH also showed no significant changes in response to the plant residue treatment. In both years, soil pH was not changed among the treatments and the highest pH was recorded in 2016 in PRF treatments. In 2016, soil NO_3-N was higher in PRF plots than in CF plots. Using plant residue increased the soil NO_3-N levels in the PRF plots as compared to CF plots. In 2018, PRF and CF plots had 130.8 kg ha^{-1} and 102.8 kg ha^{-1} NO_3-N respectively. PRF had 21.5% more soil NO_3-N than CF plots. The similar trend was observed for soil P. In 2016, soil P was higher in PRF plots than in CF plots. Using plant residue increased the soil P levels in the PRF plots as compared to CF plots. In 2018, PRF and CF plots had 93.4 kg ha^{-1} and 74.7 kg ha^{-1} P respectively. PRF had 20%% more soil P than CF plots.

Table 1. Effect of plant residue on soil chemical properties

Treatment	pH		NO_3-N (Kg ha^{-1})		P (Kg ha^{-1})		K (Kg ha^{-1})	
	2016	2018	2016	2018	2016	2018	2016	2018
PRF	8.3	8.2	86.0	130.8	74.8	93.4	134.5	171.9
CF	8.2	8.1	74.8	102.8	65.4	74.7	130.8	119.6
ANOVA significance								
Treatment	ns	ns	ns	ns	ns	ns	ns	ns

Note: ns indicates no significant difference among treatment.

Table 2. Effect of plant residue on soil water content and bulk density

Treatment	Water Content		Bulk density	
	2016	2018	2016	2018
PRF	39.00	42.3 a	0.67	0.63
CF	38.00	39.0 b	0.68	0.67
ANNOVA Significance				
Treatment	ns	*	ns	ns

Note: * and ns indicate significant differences at the 5% significance level and ns indicates no significant difference.

In 2016, soil K^+ amount was similar in both plots (PRF and CF) which was 134.5 kg ha^{-1} and 130.8 kg ha^{-1} respectively. Using plant residue increased K^+ levels in PRF plots. In 2018, PRF plots had 21.7% more K^+ as compared to 2016 soil samples. In 2018, CF decreased soil K^+ levels as compared to 2016 samples.

DISCUSSION

It has previously been shown that plant residue application can bring about key changes in the physical properties of soil, such as the bulk density, water holding capacity, and soil aggregation (Trojan and Linden, 1988; Wander *et al*., 1988). Aggregate stability is the key indicator of good soil structure, stabilization, and SOC storage over a long period of time (Balesdent *et al*., 2000). In this study, we found that plant residue had a significant effect on soil water stable aggregates. Our data showed that the >4-mm and 2-mm water-stable aggregate size fractions were higher in PRF than in CF (Fig. 3). This agrees with the findings of Pinheiro *et al*. (2004) and Aziz *et al*. (2013), as well as Kabiri *et al*. (2015), who reported that reduced tillage and plant residue intensity led to increased macro aggregates and decreased micro aggregates. During plant residues decomposition it release cementing materials (polysaccharides and organic acids) which play a major role in the stabilization of macroaggregates (Cheshire, 1979).

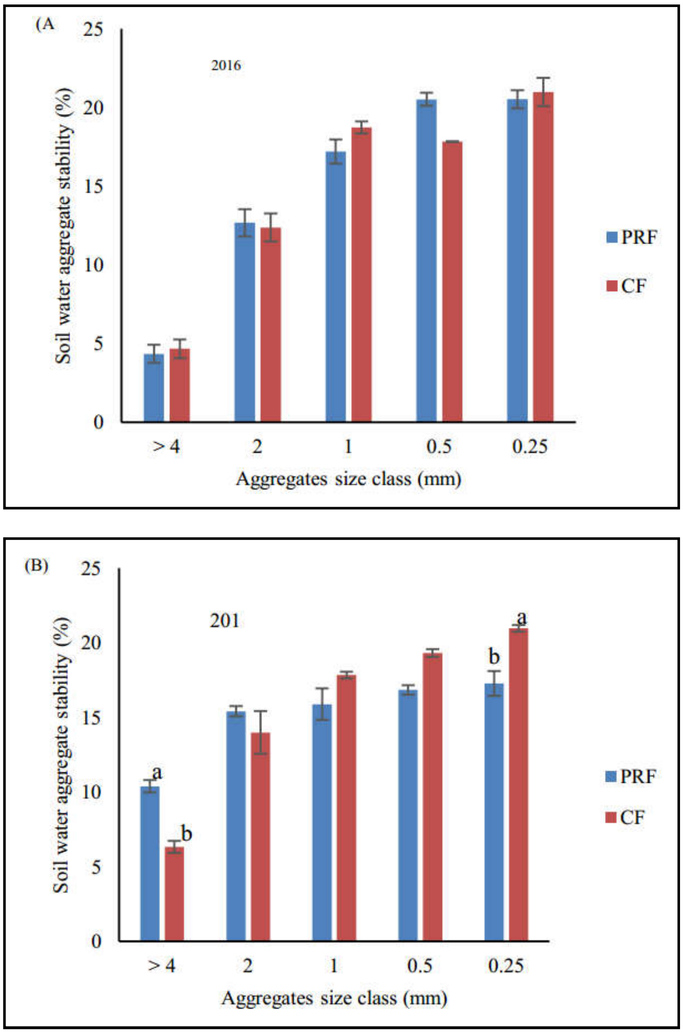

Figure 3. Effect of plant residue on the stability of different sized soil water aggregates in (a) October 2016, (b) October 2018. Values by different letters indicate significant differences between treatments at 5% using the Tukey Kramer test

On the other hand, in CF, mechanical disruption and extensive tillage practices break up the macroaggregates, resulting in an increased amount of microaggregates (Blanco-Canqui and Lal, 2006). We did observe a significant effect of plant residue on the 4-mm water-stable aggregate size fraction in PRF plots in over time. Choudhury *et al*. (2014) reported that long term field experiment soil with residue retention resulted in higher levels of water-stable macroaggregates than non-residue treatments. Therefore, the use of plant residue in CF plots may provide a better physical environment for long-term sustenance. Our result indicate that plant residue significantly promotes MWD compared with CF (Fig 4). In 2018, the highest MWD was obtained in PRF plots, being on average 14.9% higher than in CF fields. Choudhury *et al*. (2014) reported that wheat residue retention resulted in a greater MWD than conventional tillage. Pinheiro *et al*. (2004) also reported that plant and weed residue retention had greater soil MWD compare with conventional farming system. Thus, plant residue was a better agricultural management practice for improving MWD in the long term. In this study we indicated that plant residue retention increased (but not significantly) soil nutrients levels of NO_3-N, P and K^+ (Table 1). Soil pH showed no significant changes in response to plant residue retention, suggesting that changes in pH was not been easily detected in the short term experiment. These results are in line with those of Chen *et al*. (2010). Ghuman and Sur (2001) reported that crop residue retention increased soil nitrate levels than without crop residue retention. Matsuura *et al*. (2017 suggested that regular input of organic matter is crucial for maintaining soil fertility. Application of crop residues released nutrients especially NO_3-N after decomposition, retained moisture, facilitated root development, and provided optimal conditions for plant growth (Carter and Stewart, 1995; Agehara and Warncke 2005). Hashimi *et al*. (2019b) also reported that additional weed residue retention in no-tillage increased soil NO_3-N levels as compared with no additional weed residue. Thus, in our study soil NO_3-N levels increased when plant residue incorporated in the field. Using cow manure in pot experiment increased soil NO_3-N as compared with control pots (Hashimi *et al*., 2019a). These results suggested that crop residue retention provided adequate soil conditions for crop growth and maintain soil fertility.

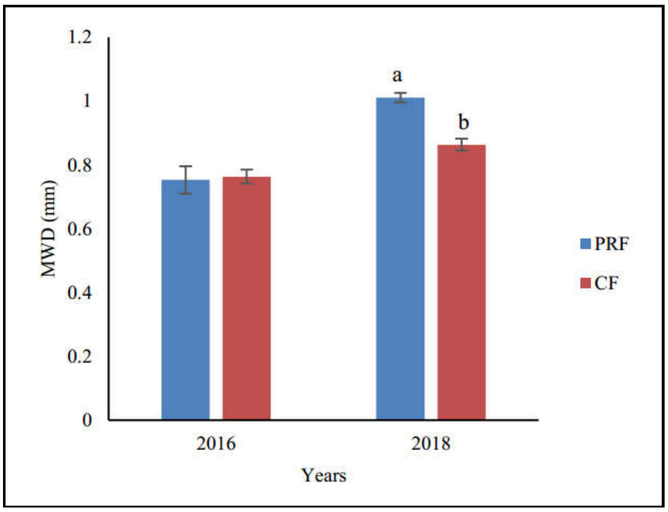

Fig. 4. Effect of plant residue on mean weight diameter

Zsolnay and Görlitz (1994) reported that incorporation of manure and crop residues has been shown to increase the amount of soluble organic matter and improves the available P content in the soil. In this study, the highest amount of P exist in PRF plot in 2018, which was 20% higher than 2016 plot. In 2018, PRF plots, being on average 20% higher P than in CF fields. Iyamuremeye (1996) reported that the use of organic materials, including plant residues increase availability of P in soils. Thus in our study using plant residue increased P level in soil. These results suggested that plant residue retention provided adequate soil conditions for soil sustainability. In our study, K^+ was affected by the plant residue treatments. K^+ increased when plant residue returned to soil.

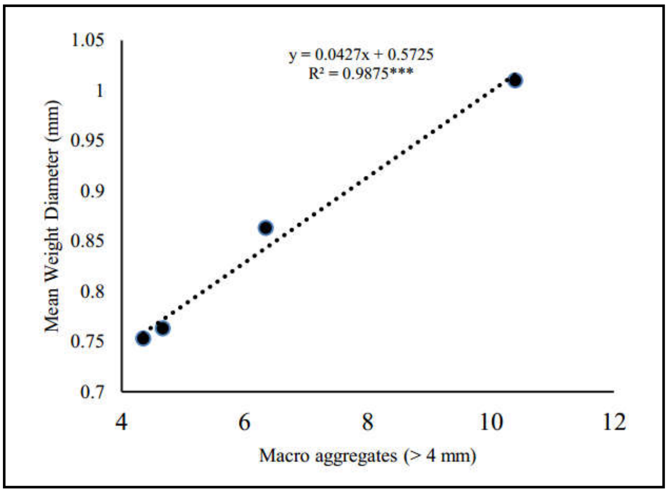

Fig. 5. Correlation between MWD and macro aggregates

The CF plots decreased the K^+ when plant residue was removed from the field. This agrees with the findings of Kong (2004) and Hiel *et al*. (2018) who reported that plant residue intensity led to increased soil nutrients especially soil K^+ in the soil. Therefore, the use of plant residue in CF plots may provide a better environment and improve soil chemical properties for long-term sustenance.

Conclusions

The use of plant residue system would be very valuable in conventional farming, as it is a suitable management practice for increasing water-stable macroaggregates, MWD, and soil chemical properties compared with a conventional tillage system with clean weeding. The plant residue retention enhanced the soil aggregate stability by increasing soil cementing material, and increased soil nutrients. Whereas CF increased soil microaggregates and did not effect on soil chemical properties. Therefore, the use of plant residue in conventional farming system represents an alternative approach that will improve the soil quality and ensure a good crop yield.

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