*Caspian J. Env. Sci. 2005, Vol. 3 No.2 pp. 89~97*


CJES
Caspian Journal of Environmental Sciences

**[Research]**

# Soil Physical Properties Due to Different Tillage Systems in Dryland Regions of Northwestern Iran

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## ABSTRACT
Lack of sufficient information on conservation tillage systems leads to the dominating use of conventional tillage practice in most parts of Iran. Testing other management practices may help in decision making regarding the types of tillage systems that reduce soil deterioration. A three- years field experiment was conducted to study the effects of conventional (CT), reduced (RT) and no-till (NT) tillage systems on soil physical characteristics. A split block design with three replications in a soil (fine mixed, mesic, Calsixerollic Xerochrepts) in Maragheh Dryland Agricultural Research Station (northwest of Iran) was used. Soil texture, bulk density (BD), moisture content (MC), penetration resistance (PR), organic matter (OM), mean weight diameter (MWD) and aggregate size distribution (ASD) were measured over a period of 3 years. No differences were obtained among the tillage systems for BD at 0-15 cm depth. At 15-30 cm, NT resulted in a lower (~10%) BD compared to the other treatments. Soil moisture content was about 18% higher in NT and 11% in RT compared to CT. Soil penetration resistance was 0.5 MPa higher in NT than CT or RT. No-till resulted in an increase in OM (~1 g $kg^{-1}$) compared to the other treatments. No differences were obtained among the treatments for aggregate size distribution. The relatively higher amount of moisture and organic matter for the conservational practices in this dry area may appear to be numerically low and negligible, but in a long run may improve the sustainability of beneficial soil conditions.

**Keywords**: Dryland rainfed, Iran, Maragheh, Tillage, Soil physical properties

## INTRODUCTION
Low water storage and weak structure (due to low organic matter content and intensive tillage practices) are common attributes of soils in various parts of Iran, similar to the other arid and semiarid regions (Hajabbasi and Hemmat, 2000). In Maragheh (Northwest Iran), crops are mostly grown under rain fed conditions and the main limitation for crop growth is water. Of particular concern in these dryland cropping areas are soil structural changes which reduce rainfall infiltration and plant access to stored soil moisture. Such changes have led to examination of alternative farming practices which include lay pastures, crop rotations, and reduced tillage/controlled traffic. As soil water holding capacity and depth is generally low in Iran soils, when precipitation becomes scarce, available soil water diminishes rapidly and reaches a depletion level that limits and in some cases stops crop growth. Suitable soil tillage practices can therefore, affect water availability to plants, essentially via improved soil water capture and infiltration (Dao, 1998). Soil tillage and mulching can change the capacity of the soil surface to intercept rainfall by affecting the hydraulic conductivity of the topsoil, soil roughness, and soil surface porosity. Keeping the residues on the surface is also a well- known technique for conserveing water by reducing direct evaporation (Unger and Parker, 1976) and

increasing water storage (Steiner *et al*. 1999). Conclusive evidence of declining soil physical, chemical and biological fertility under conventional cropping systems is now available (Choudhary *et al*. 1997). Lack of sufficient information regarding the application of different tillage systems leads to the dominating use of conventional practice despite its adverse effects on soil physical, chemical and biological properties (Hajabbasi and Hemmat, 2000). Thus, studying any alterations in the management practices which may enhance soil water and other properties, may assist in decision making regarding the use of different tillage practices in Maragheh region. In order to verify the effects of different methods of soil managements on soil physical properties, a three year experiment was established in 1999 to compare the influence of three types crop rotations (wheat-wheat, fallow-wheat, and cowpea-wheat) and tillage practices (conventional, reduced and no-till) on some soil physical properties.

## MATERIALS AND METHODS

### Study site

The study was conducted during three years (1999-2001) at the Maragheh Agricultural Dryland Research Station, 40 km northwest of Tabriz in Iran (37º 25´ N and 46º 40´E). The soil (Fine mixed, mesic, Calsixerollic Xerochrepts) with a xeric moisture regime that has moist cool winters and warm dry summers. Table 1 shows the yearly average evaporation, relative humidity, temperature and precipitation during the growing seasons of the study.

### Experimental design

Generally, research dealing with rotations and tillage practices requires several years, to show the probable effects. Two sites about 50m apart from each other with similar genesis, topography and history of crop growth, were selected. For the year prior to begin the study (1998) and on one site (Phase 1) the field was divided into three parts for the wheat-wheat, chickpea-wheat and fallow-wheat rotations. At the same time on the other site (Phase 2) only wheat was grown. For the next year (1999) on Phase 1, wheat was planted in all plots while on Phase 2, the three rotations were implemented. For the following years (2000 and 2001) the fields were switched, in a way to acquire the defined rotations. The desired tillage systems were randomly implemented within the rotational plots. Soil samples were taken at the mid-May of each year.

**Table1. Yearly average evaporation, relative humidity, temperature, and precipitation of Maragheh region during growing seasons.**

| Year | Evaporation (mm) | RH (%) | Temp. (ºC) | Precipitation (mm) |
|---|---|---|---|---|
| 98-99 | 1054 | 52.2 | 7.4 | 265 |
| 99-00 | 1056 | 54.7 | 7.7 | 235 |
| 00-01 | 1174 | 59.3 | 7.1 | 382 |

RH: Relative Humidity

At least two years prior to apply the treatments, both fields were under fallow-wheat rotation and cultivated with chisel plow. Before the beginning of the experiment, the straw and loose previous crop residues were removed for all except no till. Experimental plots were 10m wide by 25m long with borders 6m wide and a main border 10m wide between each block. A winter wheat (*Tritcum aestivum L.*) cultivar Azar2 was seeded at a rate of 130 kg $ha^{-1}$ using a grain drill with a row spacing of 12m. In rotation with wheat, chickpea (*Cicer arietinum L.*), (ILC482 line) and fallow were used. Tillage treatments include moldboard plowing+ disk (CT) as conventional tillage, reduced tillage of chisel plowing+ disk (RT), and no-tillage (NT) as conservational tillage systems were implemented. The plowing depth in moldboard, and chisel plowing was 0.20, and 0.15m, respectively. Nitrogen 135 kg $ha^{-1}$ in the form of urea, and phosphorous 40 kg $ha^{-1}$, in the form of ammonium phosphate was applied to the soil. Half of the N, and all of the P fertilizer were added before the secondary tillage operation and other half of N was applied at the end of March of the following year as top dressing. Wheat was planted in October and harvested in July. To control broadleaf weeds, 2- 4- D was applied at a rate of 1500 mL $ha^{-1}$ in the spring of each year.

### Soil properties

Soil texture, bulk density, and organic matter were determined using the hydrometer method (Gee and Bauder, 1992), constant core (Blake, 1992), and digestion

(Walkly and Black, 1934), respectively. Other soil physical and chemical properties were determined using the methods suggested by Klute (1992). To measure soil characteristics, at the first year prior to begin the experiment, soil samples were taken at the depths, 0-20 and 20- 65cm (Table 2). Then at the end of each year, these samples were taken from 0-15 and 15-30cm for all characteristics (Table 2). A hand soil penetrometer was used to measure soil mechanical strength or compactness. Moisture content at the time of penetration resistance measurement was around 1.1 Plastic Limit (Cassagrande, 1948) at 0-30 cm, for all of the treatments. In each plot 10 insertions were used for measuring soil strength. Cone index (MPa) was calculated using the following relation: CI=0.098(F/A). Where, F is the force inserting rod into the soil (kgF), and A is the surface area of the cone (cm$^2$). Wet sieving method of Kemper and Rosenau (1992) with a set of sieves of 2, 1, 0.5, and 0.25 mm was used to determine mean weight diameter. After passing the soil samples through a 6mm sieve, approximately 50g of soil was put on the first sieve of the set and was gently sprayed to be moistened to avoid sudden rupture of the aggregates. After moistening, the set was sieved in water at 50 oscillations per minute. After 10 min of oscillation, soil remaining on each sieve was dried, and sand and aggregates were separated (Gee and Bauder, 1992).

The mean weight diameter (MWD) was calculated by the relationship: **MWD=Σ (XiWi).** Where, **X** (in mm) is average diameter of the pores of two consecutive sieves, and **W** is the weight ratio of aggregates remained on the **i$^{th}$** sieve. For determination of aggregate size distribution (ASD) the weight ratio of aggregates of each sieve (>2, 2-1, 1-0.5, 0.5-0.25, and <0.25 mm) to the total weight of aggregates was calculated. Analysis of variance of the results was done using the SAS (SAS, 1995) program, and the means of the results were compared using the Duncan new multiple range test (Steel and Torrie, 1986).

## RESULTS

Analysis of variance at 0.05 level of probability showed some significant differences in the parameters as affected by tillage systems. The effects of different tillage practices on soil characteristics are discussed separately in the next sections.

### Texture and pH

No changes were obtained in soil texture during the period of study. This might be due to the lack of suitable climatic conditions and especially the time for this component to be changed. Soil pH in no-till treatment for the 0-15 cm depth was numerically lower (7.2) comparing the beginning to the end (7.4) of the experiment (Table 2). This could be due to a higher amount of OM of no-till treatment. Angers and Mehuys (1989) reported that due to the higher accumulation, decomposition of the residues and production of organic acids, in no-till, the pH

**Table 2. Comparing the results of soil acidity (pH), electrical conductivity (EC), calcium carbonate ($CaCO_3$), available nitrogen (N), phosphorous (P), and potassium (K) at the beginning (1998), and the end of the experiment (2001)**

| | Sand (g kg$^{-1}$) | Clay ( g kg$^{-1}$) | pH | N (μg g$^{-1}$) | P ( mg kg$^{-1}$) | K ( mg kg$^{-1}$) |
|---|---|---|---|---|---|---|
| **Year 1998** | | | | | | |
| 0-20 cm (Depth) | 240 | 360 | 7.4 | 50 | 8 | 300 |
| 20-65 cm(Depth) | 120 | 440 | 7.6 | 40 | 7 | 310 |
| **Year 2001 (Depth 0-15 cm)** | | | | | | |
| Conventional | 230 | 380 | 7.4 | 94 | 12.6 | 397 |
| Reduced | 215 | 392 | 7.3 | 91 | 10.2 | 419 |
| No-till | 210 | 385 | 7.2 | 91 | 12.1 | 417 |
| **Year 2001 (Depth 15-30 cm)** | | | | | | |
| Conventional | 185 | 413 | 7.4 | 70 | ND* | ND |
| Reduced | 173 | 415 | 7.3 | 90 | ND | ND |
| No-till | 169 | 428 | 7.3 | 90 | ND | ND |

* not determined

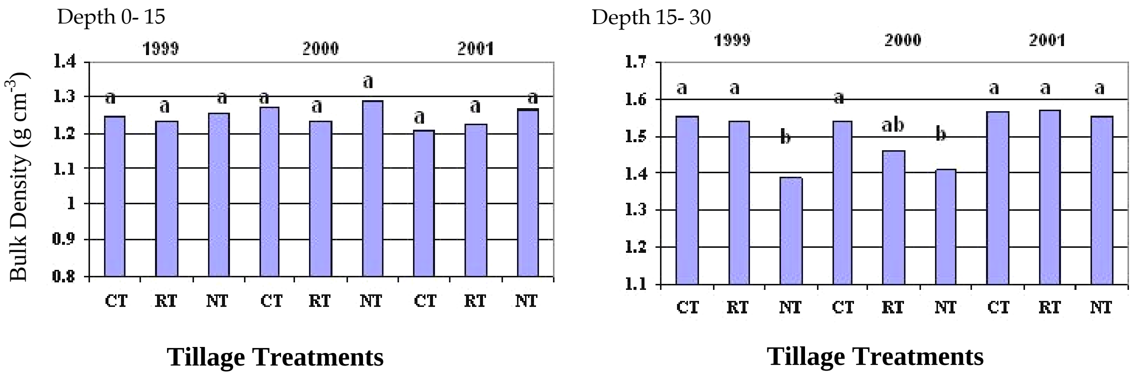


**Fig 1. Soil bulk density changes during three years of tillage study at two depths. Values of each year followed by similar letter are not significantly different (at P<0.05). (CT, RT and NT are conventional, reduced and no-till tillage, respectively).**

could be significantly lower than conventional management.

### Bulk density

Tillage treatments had no significant effects on soil compactness, at 0-15 cm depth. Soil bulk density of the NT treatment increased by 0.03 g $cm^{-3}$, while no changes were observed for CT and RT when comparing the years (Fig 1). This could be due to the yearly plowing of soil in CT and RT tillage systems. This effect was more pronounced for the depth of 15-30cm.

According to Logsdon and Cambardella (2000), many farmers are reluctant to switch from disk or chisel systems to no-till practices because of concerns about compaction, especially in the early years after conversion. Bruce *et al.* (1990) observed that the top 20 cm of a sandy soil, after 8 years was denser for no-till than the disk treatment. After 10 years on a silt loam soil, no-till system had a higher effect on compaction of soil compared to the disk and harrow systems (Horne *et al.*, 1992). Documentation of management practices on soil bulk density is obscured by natural variations in soil type (Logsdon *et al.*, 1992; Franzluebbers *et al.*, 1995). Soil water content at the time of tillage or traffic, depth of winter freezing, water content before winter freezing, shrinking and swelling, and action of soil fauna and roots all cause variations in density, apart from the direct-management effect (Logsdon and Cambardella, 2000). Voorhees and Lindstrom (1984) hypothesized that a no-tillage system may result in higher bulk densities due to incomplete amelioration of compacted soil over the winter. Bauer and Black (1981) reported that cultivating could loosen the topsoil for a specific period of time, then due to heavy traffic (Soane *et al.*, 1982) the soil will be compacted again. In this study also, the bulk density was significantly lower for NT

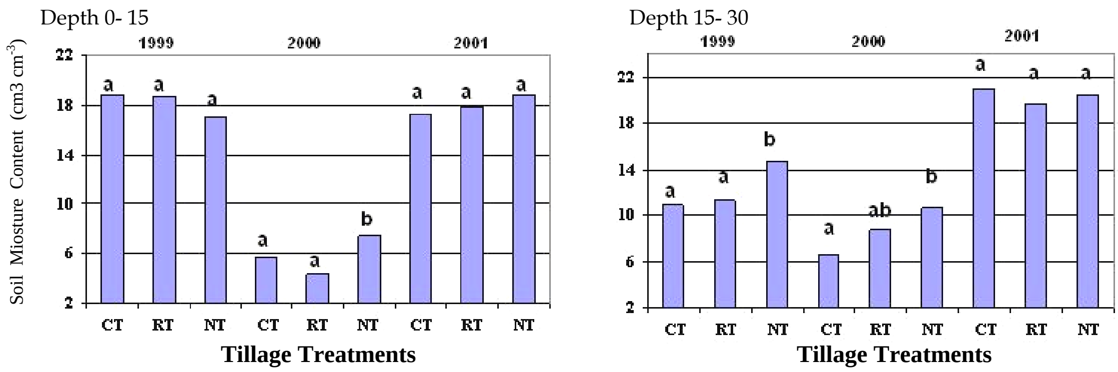


**Fig 2. Soil moisture content for two depths and three years of tillage study. Values for each year followed by similar letter are not significantly different (at P<0.05).(CT, RT and NT are conventional, reduced and no-till tillage, respectively).**

compared to the CT and RT treatments, at the first and the second year, but at the third year no changes were observed among the treatments.

**Moisture content**

Volumetrically stored soil moisture was found to be dependent on total precipitation of the region. In the first, second and third year of the study, the percentage (mean values of both depths) of soil moisture were 14.9, 7.3, and 19.3 ($cm^3\ cm^{-3}$) respectively (Fig 2). Although no changes were seen in the evaporation, relative humidity or average temperature, the monthly averaged precipitations for the mentioned years were 26.5, 23.5 and 38.2 cm, respectively (Table1). Low water content can result in decreasing photosynthetic translocation and consequent-ly low crop production (Azevedo, *et al.*, 1996).

According to Walley *et al.* (1999), applying tillage systems along with proper rotation can enhance water use efficiency in soil. In this study and for the dry year of 2000, about 100 and 50% more water was stored in soil treated with no-till respectively compared to the RT and CT systems (Fig 2**)**. Lafond *et al*. (1992) reported that a 9% increase in soil moisture at spring, in no-till compared to the conventional tillage systems, raised the production of wheat and cowpea by 21 and 9%, respectively. Residue management of reduced and no-till systems resulted in higher water efficiency of up to 25- 50% (Naderman, 1991). Residue management can also cause a lower evaporation via decreasing the effect of wind

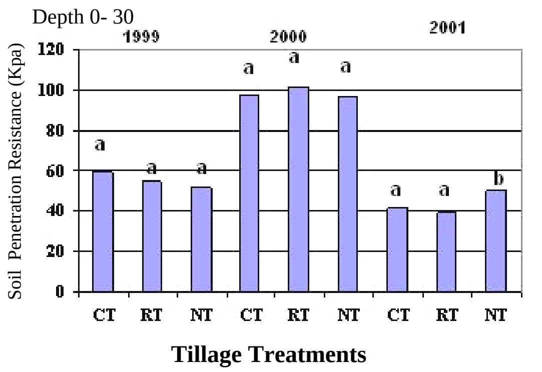


**Fig 3. Soil penetration resistance three years of tillage study (average of 0-30 cm).Values for eachyear followed by similar letter are not significantly different (at P<0.05). (CT, RT and NT are conventional, reduced and no-till tillage, respectively).**

and temperature (Brun *et al.* 1986; Smart and Bradford, 1996).

**Soil strength**

Soil strength and bulk density are two major soil physical factors known to affect crop root development (Taylor, 1974; Jones, 1983). The amount and type of soil organic matter (SOM) is a parameter influencing soil strength properties and rooting characteristics (Gerard *et al*., 1982). Figure 3 shows the effect of three tillage systems on soil strength as represented by cone index at the third year of the study. Despite equal amount of SOM on the surface for NT relative to the other systems, at the third year of the study, the cone index at the surface layers was significantly higher for this tillage system. This is due to the nature of the soil in the region, with high amount of clay and low amount of OM (around 1%), which provides a thick layer of sealing on the surface. There were no significant differences in cone index (CI) between CT and RT. This indicates that as far as root penetration resistance is concerned, a kind of cultivation at autumn or winter, for this soil is necessary (Hajabbasi and Hemmat, 2000). According to Karlen (1990), soil compaction is considered to be the more serious problem limiting the adoption of no-till system. Hajabbasi and Hemmat (2000) concluded that although adopting no-till system in many cases improves SOM and consequently aggregation, due to an initial weak structure and low organic matter, a complete or at least partial amelioration of soil at winter is necessary. Soil strength is highly dependent on precipitation of the region and thus, stored soil moisture. Although there were no differences among the tillage systems at one specific year (except for NT at 2001 which was higher than the other two), at the second year (2000) with the lowest precipitation (Fig 3), average (mean of three tillage systems) of soil strength was significantly higher compared to the first and the third year of the study. This is because at that year (2000), the precipitation in the region was quiet low, compared to the other years (Fig 2).

**Soil organic matter content**

Tillage activities influenced the quantity of soil organic matter (SOM). This is via physical (crushing and mixing) and chemical

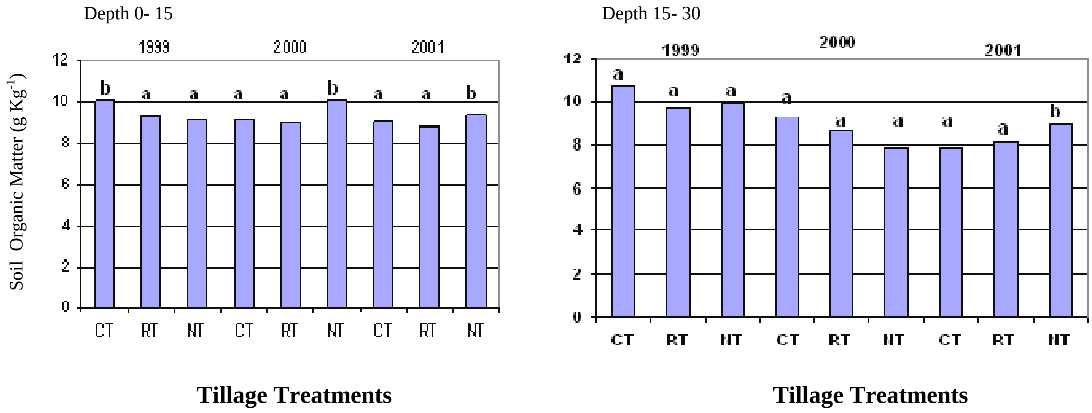


**Fig 4. Soil organic matter changes during three years of tillage study at two depths.Values of each year followed by similar letter are not significantly different (at P<0.05). (CT, RT and NT are conventional, reduced and no-till tillage, respectively).**

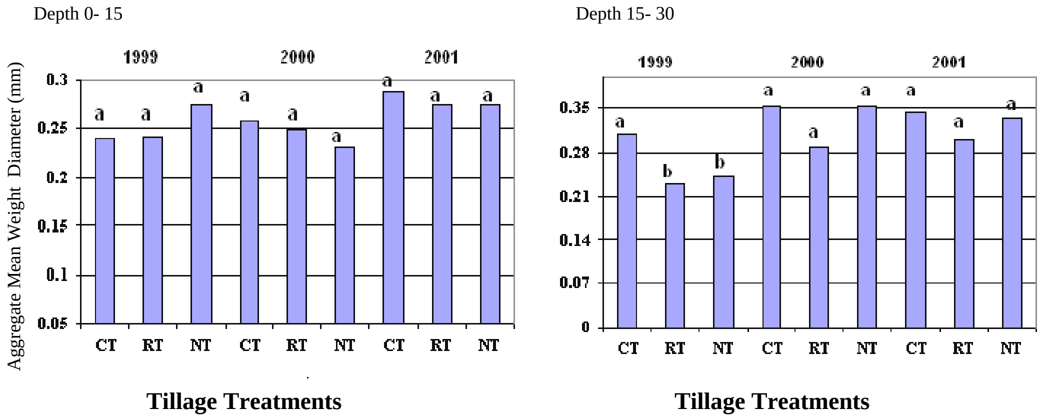


**Fig 5. Soil aggregate stability (MWD) changes during three years of tillage study at two depths. Values of each year followed by similar letter are not significantly different (at P<0.05). (CT, RT and NT are conventional, reduced and no-till tillage, respectively).**

(oxidizing and burning) processes occurring in soil during the practices. After the first year, SOM in the surface soil (0-15 cm) for the CT system was significantly higher than the other treatments, while after the second and third year SOM in the CT it was reduced by almost 1g $kg^{-1}$ (Fig 4). In contrast, for the NT, soil organic matter was increased by almost 1 g $kg^{-1}$comparing the first to the second and third years of the study. No differences were obtained at the second depth (15- 30cm), among the tillage treatments comparing different years of the study (Figure 4).

Many other studies indicated that, the use of reduced or no-tillage practices better protect the soil resources by conserving SOM compared to the moldboard plow (Paustian *et al.*, 1997). Yang and Wander (1999) reported that the use of no-till practices increased SOM concentrations in top few centimeters (0-5cm), as compared to the disk and moldboard plow systems.

### Aggregate mean weight diameter

Although, in all tillage treatments mean weight diameter was increased with the depth, tillage operations appeared to have no effects on MWD of the aggregates, in each depth (Fig 5). A direct correlation between the stability and size of the aggregates to soil organic matter has been reported by several authors (Angers and Mehuys, 1989). In this study no correlation was seen between the SOM and MWD. This could be due to the

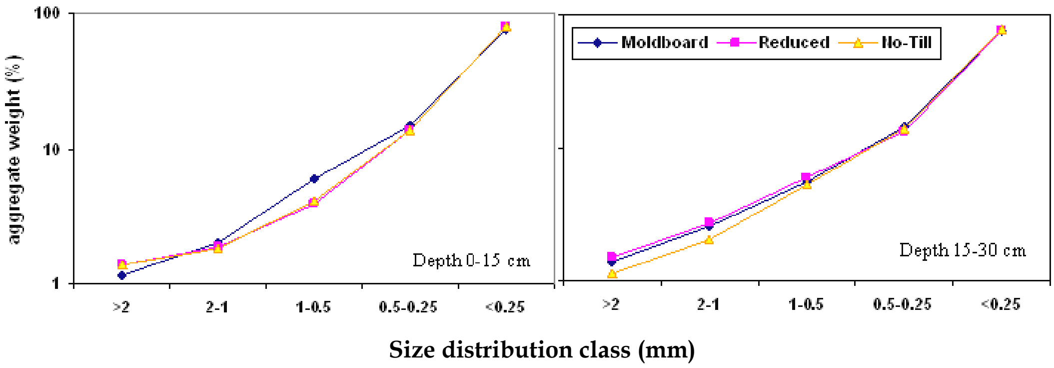


**Figure 6. Aggregate size distribution curves of the third year of tillage study at two depths.**

initially low SOM and structurally crushed aggregates (more than 75% of aggregates are < 0.25 mm) in the region (Figure 6). Overall (average of both depths), mean weight diameter was not significantly higher comparing the third to the first and second years, but at the second depth (15- 30cm), and for the first year, MWD was higher for the CT compared to the RT and NT. This might be due to the higher amount of organic matter and/or more compacttion at this site and depth. At the second and the third year no differences were obtain among the treatments for mean weight diameter (Fig. 5).

## Aggregate size distribution

As shown in Figure 6, about 75% of the aggregates had a diameter smaller than 0.25mm. Aggregates of >2, 2-1, 1-0.5 and 0.5-0.25 mm in diameter were 1.5, 2.5, 7 and 14% respectively. Tisdall and Oades (1982) concluded that the stability of macro-aggregates (>0.25mm) is controlled by soil management such as tillage and rotation, and that of micro-aggregates (<0.25mm) depends on the amount and stability of organic cementing agents and appeared to be independent of soil management. Although no significant differences were seen between the values, the curve of the aggregate size distribution for all treatments in the lower depths were smoother compared to the surface layer (Fig 6). According to Hillel (1998), soils having a rpopenderance of particles of one or several distinct sizes, indicating a steplike distribution curve, are called poorly graded, while soils with a flattened and smooth distribution curve, are called well graded soils. Most studies regarding the effects of tillage on aggregate stability are conducted on soils with a relatively high organic matter and good structure (Medeiros *et al*., 1996; Unger *et al.* 1998; Six *et al.*, 1999). But in this study, the size of the MWD was found to be about one tenth to one fifth of the one reported in literature. The reason could be an initially low organic matter and thus a weak structural stability (Hajabbasi and Hemmat, 2000).

## Conclusion

To explain variations in crop yield due to different crop rotation and soil cultivating practices in the dryland region of Maragheh (Northwest of Iran) some of the soil characteristics were studied. Three types of crop rotation and tillage systems were evaluated for their effects on soil texture, pH, water content, strength, bulk density, organic matter, and aggregate stability. The application of no-till system resulted in an increase in soil moisture content and organic matter but had no effect on aggregate stability and size distribution. After three years of applying no-till system in this region soil became more compact, compared to the yearly cultivated systems. Soil conservation practices including residue management and no-till management may help to conserve or improve soil structure, in a longer period of time. These effects in the region appear to be numerically low and negligible. Thus, reduced tillage as a conservational soil management practice can be recommended in this region for crop production. It is because reduce tillage has the benefits of conventional system but at the same time has less soil disturbance compared to the CT system.

**ACKNOWLEDGMENT**

This research project has been supported by Grant # NRCI- 1141 of National Research Projects and with the support of National Research Council of Islamic Republic of Iran. The author would like to appreciate A. Eskandari, and A. Sadeghi (Maragheh Rainfed Institute) for their assistances in the field. And a special thank to the Soil Science Department of Isfahan University of Technology for the laboratory works.

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(Received: Aug. 10, Accepted Nov. 10, 2005)