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# Selection of the Most Appropriate Tillage System Based on TOPSIS Model with Emphasize on Impact of Different Tillage Systems on Yield

Ali Mirzazadeh
*University of Mohaghegh Ardabili, Iran*, ali.mirzazadeh@uma.ac.ir

Razieh Pourdarbani
*University of Mohaghegh Ardabili, Iran*, r_pourdarbani@uma.ac.ir

Salman Fekri
*Moghan Agro-Industrial & Livestock Co, Iran*, ramin_moghan_2006@yahoo.com

# SELECTION OF THE MOST APPROPRIATE TILLAGE SYSTEM BASED ON TOPSIS MODEL WITH EMPHASIZE ON IMPACT OF DIFFERENT TILLAGE SYSTEMS ON YIELD

**Ali Mirzazadeh[1*], Razieh Pourdarbani[2] , Salman Fekri[3]**

*ali.mirzazadeh@uma.ac.ir*

*[1]. Dept. of Agricultural Engineering, Faculty of Agriculture (Moghan), University of Mohaghegh Ardabili, Iran.*
*[2]. Dept. of Biosystem Engineering, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran.*
*[3]. Expert in Agricultural, Head of Agriculture Department, Moghan Agro-Industrial & Livestock Co.*

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**اختيار نظام الحراثة الأكثر ملاءمة بناءً على نموذج تابسيس مع التركيز على تأثير أنظمة الحراثة المختلفة على العائد**

**ملخص**

من بين العمليات الزراعية المختلفة ، تمثل الحراثة وحدها 60٪ من الطاقة المستهلكة في الزراعة. مخاوف أخرى ، مثل انضغاط التربة ، وإدارة الوقت ، والقضايا الاقتصادية ، والحد من المسامية ، والقدرة على تخزين الرطوبة ، بالإضافة إلى زيادة 25 ٪ في تآكل المياه والرياح ، زادت من الجهود المبذولة لتحسين أساليب الحراثة. في هذا الصدد ، يعتبر الحرث أكثر مراعاة من قبل الخبراء. أجريت هذه الدراسة لتقييم المؤشرات الهامة لإنتاج القمح بطرق الحراثة المختلفة. تم اختيار قطعتي أرض في شركة موجان أجرو وتم تقسيمهما إلى أربعة هكتارات متساوية 2.8 هكتار . أجريت التجارب في تصميم البلوك الكامل العشوائي (RCBD) مع أربعة أنظمة حرث بما في ذلك الحرث التقليدي والحرث 2 والحرث المباشر حيث تم زراعة صنفين من القمح الشائع. أشارت النتائج إلى أن تأثير جميع أساليب الحراثة الأربعة كان ملحوظًا عند مستوى الاحتمال 0.001 ومؤشرات مثل استهلاك الوقود والكفاءة وعدد حركة المرور في المزرعة ووقت تحضير الأرض وتكلفة الهكتار الواحد والمحصول وكثافة النبات وتم تحسين عدد الفلاحين باستخدام أساليب الحراثة والحراثة المنخفضة 2. كما أعيد تقييم النتائج باستخدام طريقة TOPSIS وتم اختيار نظام الحراثة مع CL بقيمة 0.98 كأفضل طريقة. لذلك ، يمكن أن تكون الزراعة المباشرة بديلاً مناسبًا للحراثة التقليدية في إنتاج القمح المستدام

**Abstract**

Among the various agricultural operations, tillage alone accounts for 60% of the energy consumed in agriculture. Other concerns, such as soil compaction, time management, economic issues, porosity reduction, moisture storage capacity, as well as a 25% increase in water and wind erosion, has further fueled efforts to improve tillage methods. In this regard, conservation tillage is more considered by experts. This study was conducted to evaluate important indices of wheat production in different tillage methods. Two plots located in Moghan Agro Co. were selected and were divided into four equal 2.8 hectares. Experiments were performed in randomized complete block design (RCBD) with four tillage systems including conventional, tillage1, tillage2 and direct tillage in which two common wheat cultivars were planted. The results implied that the effect of all four tillage methods was significant at the probability level of 0.001 and the indices such as fuel consumption, efficiency, the number of traffic on farm, land preparation time and its cost per hectare, crop yield, plant density and tiller number were improved using the no-tillage and low tillage2 methods. The results were also re-evaluated using TOPSIS method and the tillage system with CL of 0.98 was selected as the best method. Therefore, direct cultivation can be an appropriate alternative to conventional tillage in sustainable wheat production.

Keywords: Tillage, Wheat, Topsis, Soil, Multi alternative decision making, Agriculture.

## 1. INTRODUCTION

Tillage is the first step in the production of agricultural crops and is dedicated to those mechanical operations that provide a suitable seedbed for growth through disturbing the soil (Shafi'ei, 2016). Among different agricultural operations, tillage alone accounts for 60% of the energy consumed in agriculture (Asadi and Taki, 2000). One of the most common tillage systems is conventional tillage system in which the soil surface gets bare by weeding and returning the weed to the soil (Zakeri and Kazemi, 2007). High soil compaction prevents root propagation and penetration to lower soil depths. Low soil moisture exacerbates these effects and ultimately reduces crop production.

In general, tillage methods are divided into two categories, including conventional and conservational methods. Conservational methods are methods for managing vegetation on the surface of soil and are divided into two categories include minimum tillage and no-tillage. The use of conventional tillage due to continuous soil irrigation causes loss of moisture, accelerates the oxidation of organic matter and destroys the soil structure (Asoodar & Sabzezar, 2007). The moisture and bulk density of soil play an important role in crop systems and are significantly affected by tillage systems (Mosaddegi et al, 2009; Moreira et al, 2016; Kabiri et al, 2015). Usage of conventional tillage increases soil compaction and subsequently soil compaction increases bulk density of soil, decreases pores and water permeability (Katsvairo et al, 2002) and increases water and wind erosion by 25%. Today, in the world, minimum and no-tillage have been more considered, which is mainly due to reduced energy consumption, depreciation and time saving during operations (Tieppo et al, 2019). However, by adoption of conservation tillage, the energy consumed in the field and the wear of agricultural machinery are reduced; however, the presence of plant residues in the field (due to obstruction of the furrow openers) can negatively affect the performance of the management unit (Aikins et al, 2018).

In Iran, due to the fact that the soil is dominated by heavy soil texture, it seems that the no-tillage system is not a satisfactory result. Hemmat & Eskandari (2004) also concluded that no-tillage was less efficient than other tillage methods. Kreuz (1990) studied on the effect no-tillage on winter wheat and conclude that was not significantly different from conventional tillage. Unger (1997) studied the effects of three methods of tillage, including sweep, disc and no-tillage on the yield of winter wheat under irrigation. Highest and lowest grain yield was in sweep and no-tillage respectively. Hussain et al. (1999) examined the effect of conservational and conventional tillage systems on wheat yield and stated that in the first year, high grain yield was observed in conventional tillage due to better soil seeding and germination. But in the following years, improvement in grain yield was observed in conservational tillage due to less soil compaction and its effect on optimum seed germination. Larwrence et al (1994) investigated the effect of tillage operations on wheat yield in semi-arid regions and concluded that the use of conservational tillage led to a reduction in yield in poorly drained lands and increased yield in well-drained lands. Also Hemmat & Eskandari (2004) investigated the effect of tillage systems on wheat grain yield and reported that the yield of minimum tillage was 35% higher than conventional tillage. Patterson et al (1980) assessed the effects of conventional tillage systems, minimum tillage and no-tillage on wheat yield in dry-land conditions. They reported that all methods produced the same yield under proper moisture conditions. Alvarez et al (2009) stated that soybean yield was not different in the conventional and conservational methods, but the yield of wheat and maize in the conservational methods was lower than the conventional method. Omidi et al (2004) studied the effect of tillage systems and row space on grain yield and oil percentage in rapeseed and reported that there was no significant difference between grain yield in conventional tillage and no-tillage. Panasiewicz et al. (2020) evaluated the productivity effect of conventional tillage (CT), reduced tillage (RT) and no-tillage (NT) on NL-winter wheat (WW)-winter triticale (WT)-winter barley (WB), rotation. The results showed that the productivity of this crop rotation was lower under RT and NT systems than under CT. From a practical point of view, the reduction of cultivation in rotation with 75% of cereals caused a decrease in yield in all species, which can result in resign of using the RT and NT in conditions of Albic Luvisols soil, as classified according to the World Reference Base (WRB). The highest incomes were found when the CT system was used with NL. Although income losses exceeded the value of savings in both minimalized soil tillage systems (RT and NT), all tillage systems of NL were profitable.

In general, according to previous studies, it can be concluded that the effect of different tillage systems vary depending on the region investigated; therefore, the result of a study area can’t be generalized to other regions, and to obtain satisfactory results and to select the appropriate option, a comparison should be made between different tillage systems in the area in question. Therefore at present paper, the impacts of different tillage system namely conventional, minimum tillage1, minimum tillage2 and direct tillage were investigated and at the end, the appropriate system was selected

## 2. DESIGN METHODOLOGIES

### 2.1. Implementation of methods performed

Experiments were carried out through randomized complete block design in two separate fields of Moghan Agro-Industry Co (39.2872° N, 47.6174° E). and for two conventional cultivars of Shiroudi and Morvarid in four plots of 2.8 ha and three replications. The residue of previous crop had been chopped by and had been spread on the farm. The uniformity of the experimental plots in both fields was evaluated from the point of view of physical and chemical properties and the results showed the soil of these plots were uniform. Experimental factors for both cultivars and different tillage methods were determined as follows:

a. Conventional tillage: as common, the land was first plowed by a mold plow. Next, crushing the clamps was performed three times using disk and then to reduce the surface roughness caused by plowing, land leveler was used.
b. Minimum tillage1: Initially operation was performed using two-sided mold plow followed by disk and subsequent planting operation was performed using a pneumatic combinator.
c. Minimum tillage2: Compound tillage machine was used for soil preparation and a pneumatic combinator for planting.
d. Direct planting (non-tillage): Direct planting machine was used for planting.
e. Pest Control: Herbicides were used to control weeds in all experimental plots. Fungicides of 1 lit / ha were used to combat yellow rust and Fusarium. All parts were irrigated simultaneously by the Pivot Center at the same time in three periods.

**2.2. Measurement of research variables**

Filled tank method was used to measure the amount of fuel consumed in tillage and planting operations. The tractor was then leveled and its tank filled before and after each operation, and then the amount of fuel consumed was determined by measuring the amount of fuel added.

A tractor of Axion850 class was used for tillage, disk and planting operations. Also MF399 six-cylinder tractor was used for chopping previous crop residues, fertilization and leveling (conventional method). Fuel energy efficiency index was calculated according to equation 1 (Almasi et al, 2008):

$$P = \frac{Y}{F} \quad (1)$$

$P$: Energy efficiency index (kg /l); $Y$ :Yield (Kg/ha); F: Fuel consumption (l/ha).

Using a square frame with dimensions of 0.5*0.5, the number of tiller was counted in six points of each plot, and their average was considered as the average plant density per $m^2$.

Figure1. Plant density measurement

In order to obtain the yield, the plant was yellowed and the seeds were harvested before harvesting to prevent marginal effects on the yield, it was removed about 2 m from each plot margin. Then a square box of 0.5 * 0.5 * in six points of each plot was thrown randomly and the product was picked up by the sickle from the floor. The grain weight of each sample was measured and yield was calculated based on the moisture content of 14%. The harvesting performance of the combine was also measured.

In order to calculate the useful time of different operations on the experimental plots, a distance of 100 m inside each plot was marked from the beginning and end of the plot. The operator was then asked for performing operations at usual speed without regard to the marked symptoms. During this time, field operations were recorded. Given the machine's working width (w) and a distance of 100 m, assuming this operation is performed in t min, we can calculate the average useful operating times ($T_1$) per hectare (Eq.2).

$$T_1\left(\frac{min}{ha}\right) = \frac{100 \times t_{(min)}}{w_{(m)}} \quad (2)$$

Also, the average time for turning at the head of fields ($T_2$) and non-useful time ($T_3$) lost by failure or adjustment of the equipment were calculated. Finally, total operation times were calculated (Eq.3).

$$T_{\left(\frac{min}{ha}\right)} = T_1 + T_2 + T_3 \quad (3)$$

In order to calculate the cost of mechanized operations for each system, the prices approved by the Ministry of Agriculture were used. A questionnaire was also prepared and distributed to assess the level of tendency of experts to use tillage systems. The obtained data were entered into Excel software and after making sure that the data were normal, analysis of variance was performed using SPSS software. Multi-criteria decision making (MCDM) matrix method and TOPSIS model were also used to select the best tillage system. The TOPSIS method is a matrix consists of alternatives and criteria, which usually put the alternatives in the rows and criteria in columns. The decision maker in each matrix component introduces a numeric amount for the quantitative criterion and their preference for the quality criterion.

The steps involved in this process are as follows:

1. First, the qualitative components of the matrix are quantized, and then the resulting matrix is normalized by the Euclidean Norm method. In this method, each component of the matrix is divided by

the sum of squares of the elements of each column according equation 5:

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \quad (4)$$

2. Second step is to obtain a weighted normalized matrix in which the criterion scores are scaled down ($N_D$). $W_{n*n}$ is a diagonal matrix that reflects the weights of the decision components.

$$V = N_D \times W_{n*n} = \begin{bmatrix} V_{11} & \dots & V_{1j} & V_{1n} \\ . & . & . & . \\ . & . & . & . \\ V_{m1} & \dots & V_{mj} & V_{mn} \end{bmatrix} \quad (5)$$

3. Third step is to determine the ideal positive solution and the ideal negative solution: The best values for positive criteria, the largest values, and for the negative ones, are the smallest values. The worst for positive criteria, the smallest values, and for the negative criteria, are the largest values.

$$A^{+} = \{(\max_i V_{ij}) = \{V_1^{+}, V_2^{+}, \dots, V_j^{+}, \dots, V_{n} \quad (6)$$

$$A^{-} = \{(\min_i V_{ij}) = \{V_1^{-}, V_2^{-}, \dots, V_j^{-}, \dots, V$$

4. Forth step is to obtain the distance between each alternative and the positive ($d_{i+}$) and negative ($d_{i-}$) ideals

$$d_{i+} = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^{+})^2}; i = 1, 2, \dots, m \quad (7)$$

$$d_{i-} = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^{-})^2}; i = 1, 2, \dots$$

5. Fifth step is to determine the relative closeness of an alternative to the ideal solution defined as equation 9:

$$Cl_{i+} = \frac{d_{i-}}{d_{i-} + d_{i+}}; 0 \le Cl_{i+} < 1; i = \quad (8)$$

6. Sixth step is the ranking of alternatives; each one that has the largest CL is the best option (Asgharpour, 2003).

Table 1: Converting qualitative criteria to quantitative parameters

| Alternative | $C_1^+$ | $C_2^-$ | $C_3^-$ | $C_4^-$ | $C_5^+$ | $C_6^+$ | $C_7^+$ | $C_8^-$ | $C_9^+$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Shiroudi cultivar | | | | | |
| Conventional tillage ($A_1$) | 6752 | 400 | 111.9 | 8 | 60.3 | 4 | 216 | 3356000 | 7 |
| Minimum Tilage1 ($A_2$) | 4176 | 267 | 74.8 | 4 | 55.8 | 3 | 2.3 | 3318000 | 5 |
| Minimum Tilage2 ($A_3$) | 6520 | 158 | 56 | 3 | 116.4 | 4.3 | 226 | 3171000 | 9 |
| No Tillage ($A_4$) | 5280 | 103 | 28 | 2 | 188.6 | 3 | 243 | 1728000 | 9 |
| | | | | Morvarid cultivar | | | | | |
| Conventional tillage ($A_1$) | 7068 | 400 | 111.9 | 8 | 63.2 | 4.3 | 191 | 3356000 | 7 |
| Minimum Tilage1 ($A_2$) | 5960 | 267 | 74.8 | 4 | 79.7 | 3 | 173 | 3318000 | 5 |
| Minimum Tilage2 ($A_3$) | 7168 | 158 | 56 | 3 | 128 | 4.7 | 180 | 3171000 | 9 |
| No Tillage ($A_4$) | 6720 | 103 | 28 | 2 | 240 | 3.3 | 200 | 1728000 | 9 |

## 3. Result and Discussion

### 3.1. Analysis using multi alternative decision making matrix-Topsis method

The results of analysis of variance are shown in Table 2 by cultivar and tillage system. According to table2, the effect of four tillage systems on production was significant at the probability level of 0.001. Table 3 also gives the results of Duncan test at 5% probability level. As can be seen in table3, the highest yield of Morvarid cultivar is related to minimum tillage2 ($A_3$) with amount of 7168 kg ha-1 and the lowest yield is related to conventional tillage with value of 5960 kg ha-1. Also the highest yield of Shiroudi cultivar is related to conventional system (6752 kg/ha) and $A_3$ (520 kg ha-1); and the lowest yield was related to (4176 kg/ha). Therefore, it can be mentioned that the best tillage system for both Shiroudi and Morvarid is $A_3$. For both cultivars, the maximum time consumed for preparing the land and planting is conventional tillage (400 min/ha), and the lowest (103 min/ha) is for no-tillage (Table3). The time consumed in the conventional tillage is 50% more than that of $A_2$ and 153% more than that of $A_3$ and nearly 400% more than the of $A_4$; this is particularly important in the management of huge farms such as the Moghan Agro Co., which owns over 7000 ha of autumn crop annually. The highest fuel consumption is related to conventional tillage (111.9 lit/ha) and the lowest is related to No tillage (28 lit/ha). High fuel consumption is a negative parameter that causes air pollution and other environmental problems. From a traffic standpoint, conventional tillage with 8 number of traffic was ranked highest and no-tillage with 2 times was ranked lowest. Increasing farm traffic, in addition to crushing the soil and over compressing it, increases the total time of operation and replacement and adjustment of equipment. The highest plant density was obtained by No-tillage method and the lowest density was related to the minimum tillage1 ($A_2$). Density with less than optimum reduces crop yield by reducing the number of spikes per unit area. But increasing density increases yield if other conditions including nutrition and irrigation are appropriate while over-density (lower seed consumption) also results in reduced grain weight and reduced tiller strength. Comparison of tiller number of wheat in different tillage methods also showed that both wheat cultivars had the highest tiller using minimum tillage 2 (Table 3). Table 4 shows the results of the TOPSIS for both cultivars. The systems of no-tillage ($A_4$) was ranked in first priority and minimum tillage2 ($A_3$) at second priority. The results of this section are in accordance with the results of the ANOVA analysis.

Table2. Final ranking of different tillage systems based on Topsis model

| Shiroudi cultivar | | | Morvarid cultivar | | |
|---|---|---|---|---|---|
| Rank | $CL_i^*$ | Tillage system | Rank | $CL_i^*$ | Tillage system |
| 1 | 0.98 | A4 (No Tillage) | 1 | 0.98 | A4 (No Tillage) |
| 2 | 0.68 | A3 (Min Tillage 2) | 2 | 0.63 | A3 (Min Tillage 2) |
| 3 | 0.43 | A2 (Min Tillage 1) | 3 | 0.42 | A2 (Min Tillage 1) |
| 4 | 0.04 | A1 (conventional ) | 4 | 0.029 | A1 (conventional ) |

**Table 3. Analysis of variance of indices investigated in different tillage systems**

| Mean Square | | | | | | | | df | S.O.V |
|---|---|---|---|---|---|---|---|---|---|
| Cost (IR. Rials/ha) | tillering | Plant density ) num/m$^2$ ( | Fuel energy efficiency index | Traffic | ) lit/ha ( F.C. | ) min/ha ( Operation time | ) kg/ha ( mean yeild | | |
| Shiroudi cultivar | | | | | | | | | |
| 1800008333 | 0.00 | 12.3 | 0.00 | 0.00 | 0.03 | 145.6 | 25 | 2 | Block |
| ***18300945277 | ***1.4 | ***854 | ***11537.3 | ***20.7 | ***3699.4 | ***51454.1 | ***427678 | 3 | Factor |
| 362595277 | 0.01 | 6.9 | 1.3 | 0.67 | 5.8 | 489.6 | 225 | 6 | Error |
| Morvarid cultivar | | | | | | | | | |
| 1482300000 | 0.01 | 16 | 1 | 0.00 | 16.03 | 285.7 | 100 | 2 | Block |
| ***1829502750 | ***1.9 | ***426 | ***19075.6 | ***20.7 | ***3681.8 | ***51566 | ***899084 | 3 | Factor |
| 1482300000 | 0.01 | 12.7 | 1 | 0.67 | 0.03 | 400.7 | 100 | 6 | Error |

**Table 4. Comparison of mean traits in different tillage systems with Duncan test at 5% probability level**

| Cost (IR. Rials/ha) | tillering | Plant density (num/m²) | Fuel energy efficiency index | Traffic | F.C. (lit/ha) | Operation time (min/ha) | mean yield (kg/ha) | Alternative |
|---|---|---|---|---|---|---|---|---|
| | | | | **Shiroudi cultivar** | | | | |
| 3356000[a] | 4[b] | 216[c] | 60.3[c] | 8[a] | 111.7[a] | 400[a] | 6752[a] | Conventional tillage ($A_1$) |
| 3318000[a] | 3[c] | 203[d] | 55.8[d] | 4[b] | 74.8[b] | 267[b] | 4176[d] | Minimum Tilage1 ($A_2$) |
| 3171000[a] | 4.3[a] | 226[b] | 116.4[b] | 3[bc] | 56[c] | 158[c] | 6520[b] | Minimum Tilage2 ($A_3$) |
| 1728000[b] | 3[c] | 243[a] | 188.6[a] | 2[c] | 28[d] | 103[d] | 5280[c] | No Tillage ($A_4$) |
| | | | | **Morvarid cultivar** | | | | |
| 3356000[a] | 4.3[b] | 191[b] | 63.2[d] | 8[a] | 111.7[a] | 400[a] | 7068[b] | Conventional tillage ($A_1$) |
| 3318000[a] | 3[d] | 173[c] | 79.7[c] | 4[b] | 74.8[b] | 267[b] | 5960[d] | Minimum Tilage1 ($A_2$) |
| 3171000[a] | 4.7[a] | 180[c] | 128[b] | 3[bc] | 56[c] | 158[c] | 7168[a] | Minimum Tilage2 ($A_3$) |
| 1728000[b] | 3.3[c] | 200[a] | 240[a] | 2[c] | 28[d] | 103[d] | 6720[c] | No Tillage ($A_4$) |

## 4. Conclusion

With the increasing emphasis of environmental and agricultural experts on soil conservation, the tendency to prepare the land with minimal crop operation has increased. In recent years, the sustainability of agricultural systems has been given particular attention. In fact, sustainable agriculture emphasizes the conservation of resources. According to the results of the research and prioritizing conservation tillage, and considering that the system reduces the corrosion of the soil, reduces the potential for erosion of water and wind, increasing water permeability in the soil, and improves the soil structure and ultimately increases the yield to the maintenance of vegetation on the soil, and it is also in line with sustainable agriculture, so it is suggested that this system, which has been tested experimentally in a small segment of land, is spread across the region.

The coefficient of final ranking of different tillage systems based on Topsis model was 0.98 for both cultivars.

The highest yield of both cultivars is related to Minimum Tilage2. And the lowest cost per ha is related to no tillage. Since minimum tillage and no tillage are a type of conservation tillage, therefore no tillage system was selected as the best system. The obtained results are consistent with Hemmat & Eskandari (2004).

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