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Consequences of Tillage Technology: The Sustainability Perspective (Case of Fars Province, Iran)

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Abstract

Activities to reduce soil erosion and to improve soil fertility, agricultural production and finally, crop income have been considered to be fundamental for the implementation of sustainable agriculture in Iran. This research investigates the effects of no-till (NL) technology on reducing soil erosion and increasing agricultural income and eventually achieving sustainability. Data were collected with a questionnaire. The research sample including 165 NL adopter farmers was selected using multi-stage stratified random sampling method in Fars Province, Iran. The findings revealed that this technology improves performance and reduces water, energy and input consumption. The findings contribute to understanding the effects of no-till technology on agricultural systems. Also, information is provided to help the necessary planning for more effective implementation of no-till technology. According to the results of regression, wheat yields, increased use of pesticides, awareness of the benefits, and satisfaction with NL technology are the factors underpinning farmers` willingness to keep using NL technology.

Keywords:
consequences, Iran, no-till (NL) technology, sustainability

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INTRODUCTION

Over the past few years, increased agricultural production resulting from the adoption of Green Revolution technologies has met the needs of growing community. However, today it is recognized that modern technology has led to erosion due to the indiscriminate use of natural resources (Jewitt & Baker, 2007). Demolition and conversion of forest lands into arable land, soil erosion, and water pollution caused by excessive use of chemicals and agricultural waste and sewage have taken on very serious dimensions. However, the conventional farming has ignored not only the environment but also farmers' perception of resource conservation. Given rapidly growing population, especially in third world countries, and resource degradation, the social system will face problems in food production and famine in near future (Dinpanah & Foruzesh, 2009). Soil is the most important input for agricultural production that provides the background to influence other inputs. Soil erosion is one of the key indicators of change in environmental quality and is one of the most important economic and environmental problems in many developing countries. Soil erosion threatens food security and can severely affect sustainable development. Thus, it is necessary to develop appropriate policies and programs for soil protection (Ghorbani et al., 2008).

Agricultural technologies along with lower costs, increased productivity and soil and water conservation that are causing environmental sustainability are very valuable. International research organizations have developed agricultural technologies that improve productivity, preserve natural resources, and alleviate negative environmental ramifications. The resource conservation technologies are the basis for conservation agriculture. Conservation agriculture is the term that refers to a set of production management activities including minimum movement of soil, leaving plant residues on the soil surface, and the use of crop rotation. No-tillage (NL) is one of the most successful conservation tillage practices in which the use of a new planter allows sowing seeds and applying fertilizers simultaneously in the unplowed land covered with crop residue (Erenstein et al., 2008).

Field and laboratory studies show that the crop residue remaining from the previous crop on the soil surface is very effective in alleviating soil erosion through reducing the soil carried by the drops of rain, runoff, and wind. In this method, the remaining crop residue on the soil surface and the minimized soil degraded during tillage and planting operations reduce evapotranspiration from the soil surface, so soil moisture is increased which contributes to improving soil structure. Thus, crop residue management is very important (Swan et al., 1996).

Soil erosion is the one of the main environmental threats of Iran. It is caused by desertification and deforestation (FAO, 2013). Poor soil in terms of low organic matter is an important agricultural challenge. Arable lands of Iran have been destroyed at a rate 20 times faster than its regenerative rate. For instance, in Fars province, which is the bread basket of the country, organic matter is less than 1.5 percent in more than 95 percent of the lands, while the critical threshold of 2 percent is needed for soil organic carbon in order to maintain soil texture sustainability (Nemat-Pour & Rezaei-Moghaddam, 2014). High consumption rate of chemical agricultural inputs, i.e., chemical fertilizers, is another reason for soil degradation. Agricultural crop production has been doubled by the increased use of chemical fertilizers, such as nitrogen (increased by 600 times) and phosphate (205 times) in the last 35 years (FAO, 2013). NL systems can reduce production costs, increase soil organic matter, improve soil structure, and play an important role in eliminating adverse environmental effects. NL cultivation system requires careful crop management and, in some cases, requires the use of expensive machinery. In many cases, spring temperature of plowed land is lower than that of unplowed land. This low temperature affects the germination and reduces its rate. Also, there are reports about the problems caused by rodents and insect pests. Instead, this system has benefits, such as better control of soil erosion and less damage to soils by heavy or repeated agricultural machinery passes (Anonymous, 2003).

A study in Mexico showed that NL with

residue management and crop rotation improved the physical and chemical soil quality. So, the sustainable production was increased when compared to conventional tillage or NL without the residue. This study reported that conserved residue was effective in increasing the population of soil microflora, resulting in higher plant growth and the suppression of the diseases. NL cultivation can produce equal or greater community of the beneficial microflora in comparison to conventional tillage when the residue is maintained. However, NL farming alone will not improve soil quality and it is necessary to maintain the residue in order to improve soil quality (Govaerts et al., 2008).

Fuentes et al. (2009) compared conventional tillage and NL practice in terms of soil quality. They reported that over 14 years of the practice of NL cultivation resulted in better quality of soil, producing more corn and wheat than conventional tillage and NL planting without residue. The most appropriate tillage practices in North China, among the recent techniques of conservation agriculture, was the four years of NL cultivation (with residue) plus a year of deep tillage to reduce compaction from machinery traffic. Compared to traditional methods of tillage, the farmers' income from corn production increases by as much as 49% when NL is used (Jin et al., 2007).

Clearly, the studies show that tillage requires less time, and it usually does not significantly reduce yield, but the climate shows different impact as some advantages of manufacturing methods or parameters will change to suit local conditions (Sadegh-Nezhad & Eslami, 2006). One of the major issues within the context of each innovation is its discontinuation. Decision to discontinue means to stop using innovation after initial adoption. The adoption is reduced when innovation is not compatible with the adopter's belief and his experience. Farmers may stop using NL when they are not satisfied with its performance. Inappropriate innovation and its small comparative advantages compared to the previous situation are the reasons for dissatisfaction. A review of the literature pertaining to discontinuing use of innovation shows that most innovations are suffering from discontinuation. An appropriate remedy to stop or reduce the growing trend of discontinued innovation is necessary (Rezaei-Moghaddam et al., 2005). It is essential to identify the structures affecting farmers' tendency to use innovation. The present study addressed the use of NL and its consequences in Fars province, Iran to determine the appropriateness of this innovation for farmers and farm conditions. Also, constructs affecting farmers' tendency to continue to use this technology are discussed.

METHODOLOGY

The present study was conducted using survey research methodology on NL technology adopters in Fars Province, Iran (Figure 1). Multi-stage random sampling technique was used to determine the sample of the study. Fars Province was divided into three major climatic categories: cold, temperate and hot climates. The cities were, then, classified into these three categories:

Table 1
Cronbach's Alpha Coefficients for the Research Variables

Variables	Cronbach's alpha
Place attachment	0.71
Value attributed to the no-till technology	0.70
Awareness of benefits	0.71
Knowledge of no-till technology	0.75
Perceived ease of use	0.66
Availability of resources	0.70
Conservational technology experience	0.74
Perceived task-technology fit	0.73
Technology property	0.76
Task property	0.65

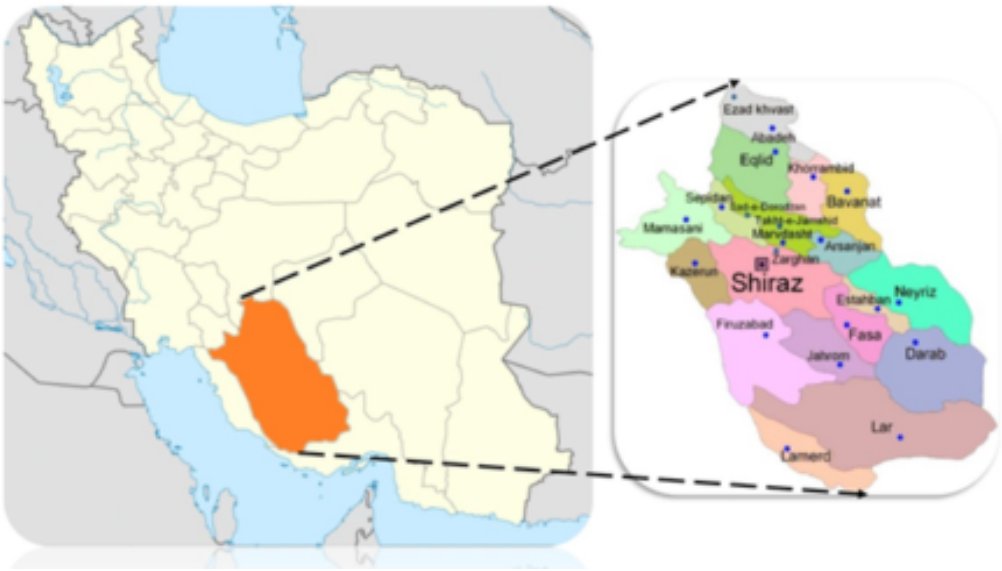

Figure1. Geographical position of the study site

two cities were placed in the category of cold climate (Eqlid, Sepidan), four cities in the temperate climate (Shiraz, Marvdasht, Farashband, Firouz-Abad), and four cities in the hot climate (Darab, Kazeroun, Khonj, Neyriz). According to the community of adopters in any climate category, the regions were randomly sampled. In total, 165 no-till technology adopters were interviewed. Data were collected with a questionnaire whose validity was confirmed by the feedback obtained from faculty members. To measure the reliability of the questionnaire, a pilot study was conducted out of the original sample, and Cronbach's alpha was estimated as presented in Table 1. Data derived from the completed questionnaires were encoded and analyzed using the SPSS19 software package.

Research variables

Factors including a)agricultural income of farmers, b) cultivating time, c) seed sowing time, d) number of the labor force, e) number of weeds, f) weed diversity, g) income before using NL technology, h) adopters' income versus that of non-adopters, i) useful area of the farm, j) the period of plant growth, k) wheat spike length, l) germination of wheat, m) tillering of wheat, n) wheat yield, o) wheat grain, p) pesticide and herbicide consumption, q)fuel consumption, r)s eed price, s) time to market, t) workload, and u)burning residue amount were examined as the consequences of NL technology. The amount and direction of the changes in variables when NL technology was used were studied. The questionnaire includes different variables with different scales. Some of the variables were asked with a direct question in ratio scale, some other were designed in many items with Likert scale and then were computed for statistical analysis.

RESULTS AND DISCUSSION

Consequences of NL technology

Results of the investigation on the consequences of NL cultivation have been shown in Table 2. Based on these findings, most NL technology adopters (86.07%) reported a reduction in cultivating time and only 10.75 percent reported that cultivators' working time was increased. It has been documented that another consequence of NL technology adoption is the reduction in planting time (Laxmi et al., 2007; Samiee & Rezaei-Moghaddam, 2017). Based on the results of this study, 82.91% of no-till adopters reported reduction, 8.22% reported no change and 8.86% reported an increase in seed planting time. It can be concluded that in most cases, the use of NL resulted in shorter seed planting time.

Another item that is expected to change when no-till technology is used is total labor requirement in wheat cultivation. The results of this study showed that 64.80% of adopter farmers have

reported reductions and 13.54% of them have reported no change in the labor requirement. Since the majority of respondents have reported reduction in the number of labor requirements in wheat cultivation, it can be concluded that the number of the workforce was reduced in some cases when NL technology was used. Change in weed is another parameter considered by many researchers in examining the consequences of no-till planters. The results indicated that 47.40% of adopters have reported a reduction in the number of weeds in their farms, while the number of farmers who have not seen any changes in the number of weeds in their farm was 41.55 percent. Although a greater number of farmers reported reductions in the number of weeds in their fields, 41.83 percent of no-till adopters were faced with an increased diversity of weeds in their farms after they used this technology. Some researchers of the effect of NL on weed concluded that some weed species have been destroyed when this technology was applied. As an example, NL reduces weed populations of *P. minor* species and increases broadleaf weeds such as *Rumex maritimus* (Laxmi et al., 2007). Researchers in India also observed that reduced soil movement was one of the most effective methods to control weeds and *P. minor* species could be controlled more efficiently (Malik, 2004). Thus, the effect of NL on weeds varies with farm conditions (e.g. climate) and various types of weeds as farmers' reports differ in different regions.

An increase in farmers' income is expected as the result of NL because of the reduction in costs and the increased crop yield. This is confirmed by the results of this study according to which the income of most farmers (60.38%) has increased as compared to that before the application of this technology, but there were no changes in the income of 31.81% of farmers. Thus, this technology increases farmers' income. Also, 68.58% of adopters have stated that their income was more than non-adopters. Comparison between adopters and non-adopters, especially adjacent and neighboring farmers who had the same requirements, showed that adopters had a higher income than non-adopters in similar conditions. This reflects the positive impact of NL technology on farmers' income. In the pilot study, to complete the questionnaire used in this study some of the farmers expressed their concerns about the loss of the useful area of their farm as the result of the use of this technology, and they believed that one of the problems would be the lack of fitness between some types of planters and farms. Therefore, the changes in the useful area of lands were evaluated as another parameter in the investigation of the effect of no-till practice. This variable deals with the area of the land that has been properly cultivated by this technology. The results showed that 65.94% of farmers have reported an increase in the useful area of their land. Some of them (29.71%) reported no change, and others (4.34%) reported a reduction in the area of their land.

The answers of farmers to changes in crop growth period – the period between planting and harvesting of wheat – showed that 42.85% of farmers observed a reduction, 31.57% observed an increase and 25.56% observed no changes in the growth period when NL was applied. One of the assumptions, when using this technology, is changes in performance and product quality. In this study, changes in wheat panicle length, grain weight, and tillering were evaluated and it was concluded that most farmers (59.82%) reported an increase in the cluster, 60.52 percent reported an increase in grain weight, and 85.93 percent observed an increase in tillering. However, in some areas, farmers reported no changes or even a decrease in these traits. Nevertheless, according to the results of the studies, better results are expected under standard conditions. To some extent, a decrease or no change in these indicators can be attributed to the no-till planters. Also, how the device is used, farm conditions and proportionality between the device and conditions are other factors that should be considered in this case.

Farmers have expressed high satisfaction with germination rates when using NL so that 79.13% reported an increase in the rate of germination of wheat (Table 2). Most farmers (52.84%) reported no change in terms of the impact of the device on harvesting operation and crop mar-

Table 2
Consequences of NL Technology

	Increased	No change	Decreased	Total
	Percent	Percent	Percent	Percent
Cultivator working time	10.75	3.16	86.07	100
Sowing time	8.86	8.22	82.91	100
The number of labor	5.80	13.54	64.80	100
The amount of weed	11.03	41.55	47.40	100
Diversity of weed	7.18	50.98	41.83	100
Income before no-till technology	60.38	31.81	7.79	100
Income of the non-adopters	68.58	27.56	3.48	100
Useful area of the farm	65.94	29.71	4.34	100
Growth period	31.57	25.56	42.85	100
Panicle length of wheat	59.82	35.71	4.46	100
Germination of wheat	79.13	14.38	6.47	100
Wheat tillering	58.93	9.37	4.68	100
Grain weight of wheat	60.52	32.45	7.01	100
Time to market	13.82	52.84	33.33	100
Workload	9.34	7.47	83.17	100

keting, but some also believed that the crop was harvested and marketed sooner. Workload refers to types of farmers' activities during cultivation. This includes the types of activities that are necessary at the time of crop planting (plows, discs, lines, etc.) and was another variable examined for the consequences of applying NL. Farmers expressed satisfaction with NL in reducing their workload in cultivation season, and most (83.17 percent) stated that the workload could be reduced by using NL.

Since one of the problems of conventional agriculture is continuous cultivation in poor soil without rehabilitation, thereby reducing crop yields and soil fertility, operations such as returning the crop residue to the soil and soil fertility restoration can be effective in alleviating this problem. On the other hand, traditional methods of residue management, such as burning, is one of the conventional methods among farmers in Fars Province that aggravates environmental pollution, soil erosion, soil organic matter loss, waste soil texture, reduced permeability (penetrance), and finally crop loss. Considering these problems and their irreversible effects, strategies for crop residue management have been considered by the agricultural sector planners. One of these methods is the conservation tillage. Reviewing the effects of crop residue management techniques, it was found that most farmers reported improved residue management and stated that the use of this system reduced the burning and resulted in efficient use of residue. Hence, it would bring many improvements in soil and their crop yields.

Comparison between consequences before and after using no-till technology

Agricultural and technical-Engineering consequences of no-till technology

The area under cultivation

The results revealed that there was a significant difference between cultivation area before and after using no-till technology ($p<0.01$, $t=-3.03$). This means that the area under wheat cultivation has increased among sample farmers after using no-till technology. The area under cultivation was 2.23 hectares before using no-till while when no-till technology has used, the average area under cultivation was increased to 2.33 hectares. Further investigation revealed that the reason of this small increase in cultivated area was the lack of water; however, more land area can be planted using no-till than before because it

increases the planting rate and reduces costs.

Wheat yield

As previous studies have focused on the effects of NL technology on the wheat yield (Erenstein & Laxmi, 2007; Laxmi, 2008; Sen et al., 2002), we found a significant difference in wheat yields between after and before using no-till technology ($p<0.01$, $t=-4.30$). Wheat yield has increased after using this technology (5.42 t/ha) as compared to previous years (4.84 t/ha). The increase in wheat yields is extremely important despite interests in the problem of drought, lack of no-till planters and delays in planting. The increase in yield is significantly higher when some points are observed such as timely sowing, increasing the effectiveness of inputs, and weed control.

Herbicides consumption

In earlier studies, different results have been obtained in this regard. For example, Nakamoto et al. (2006) have pointed to its potential to reduce weeds. However, they believe the infestation of perennial weed species and the rapid increase in the supply of weed seeds near the soil surface are the disadvantage of reduced tillage. Many researchers have suggested that some weeds are difficult to control, the problem that has arisen as the result of using no-till (Chun et al., 2017; Laxmi et al., 2007). However, other researchers have considered no-till as one of the most effective ways of fighting certain types of weeds (Grabowski et al., 2016; Malik, 2004). In general, according to previous research on NL, it is assumed that weeds will be reduced over time when NL technology is used and, as a result, herbicide consumption will be reduced. This study examined this among farmers. It must be noted that a long time has elapsed since this technology has been adopted, and users are in the second or third years of utilizing this technology, but the amount of herbicide has reduced, and there is a significant difference in terms of the amount of herbicide used before and after NL ($p<0.01$, $t=3.98$). This finding suggests that using this technology has significantly increased weeds because the average rate of herbicide use was about 2.63 L/ha before no-till practice and it was decreased to 2.18 L/ha after its use. As can be inferred from the farmers' statements, in some areas farmers have reported no change or a decrease in the weeds. They have stated that weed seeds remain in the depths of the ground and do not get chance to grow. In fact, reports vary in different locations, and this technology has led to an increase in weeds in many areas; in others, there has been either no change or a reduction.

Pesticides consumption

The results of pesticides consumption confirmed that there was a significant difference between pesticide consumption after and before no-till ($p<0.01$, $t=4.16$) and no-till has reduced pesticide consumptions. As we can see, the pesticide consumptions have been decreased from 2.14 to 1.79 L/ha after the application of no-till technology.

Time and number of irrigation

The studies on no-till impact have revealed that this system is generally known to save on water consumption (Buhattchariyya et al., 2008; Erenstein & Laxmi, 2008; Karami et al., 2006). Investigation the effect of no-till technology adoption in Fars province revealed that the differences in the time and frequency of irrigation before and after the use of no-till technology were statistically significant. In this method, uniform planting of seeds, even with residue, reduced the time required for irrigation. The time of irrigation in conventional tillage (2.40 per hectare) is almost twice as great as that when NL is used (1.87 per hectares). This reduction is also observed in the frequency of irrigation (two round cuts per hectare). Irrigation is required to be done 10 times before the use of NL, but then it decreased to 8 times. Therefore, it can be expected that NL will cause a significant decrease in water consumption. This technology is more efficient than other technologies in drought conditions. So, it can be considered as an effective measure to cope with drought.

Fertilizer consumption

Phosphate fertilizer is placed just below the seed by using NL technology. Therefore, the

depletion of fertilizer is prevented and its consumption is reduced significantly in the lands of farmers in the sample study (80 kg per ha). In fact, the average consumption of phosphate fertilizer was 252.33 kg/ha before the NL adoption, but it dropped to 172.33 kg/ha after its adoption. The amount of nitrogen fertilizer was also reduced. Average rate of nitrogen fertilizer application was about 250.38 kg/ha before this technology, but after the use of this technology, it was reduced to 198.61 kg/ha. In other words, the differences between the amount of nitrogen fertilizer ($p<0.01$, $t=5.36$) and phosphate fertilizer ($p<0.01$, $t=8.66$) before and after no-till adoption were significant. So, it can be concluded that NL technology will generally reduce the amount of chemical fertilizers.

Workforce

No-till technology has also been efficient with respect to the number of farm workers. The results of this study confirmed that the difference in the number of workers before and after the NL adoption was statistically significant ($p<0.01$, $t=11.18$). The number of workforce before the use of no-till technology was 3, but after no-till adoption, farmers required only 1 labor for farm work.

The number of cultivators passes

In conventional tillage to sow the seeds in the ground, cultivators should dig the field 6 times. The use of NL technology has led to savings, and this has reduced the time required for sowing. In other words, the difference in the number of cultivators passes between before and after the use of technology is significant ($p<0.01$, $t=18.55$). This confirmed the findings of earlier studies in other places such as Laxmi et al. (2007) and Malik (2004). Reduced load traffic and consequently lower fuel consumption will also bring economic benefits.

Fuel consumption

The results of earlier studies on the effects of NL have suggested a reduction in the rate of fossil fuel consumption Epplin et al., 1982; Laxmi et al., 2007; Sen et al., 2002). This study also evaluated fossil fuel consumption and found a significant difference before and after the adoption of NL technology ($p<0.01$, $t=7.69$). In fact, consumption of fossil fuels before no-till adoption was about 201.63 L/ha, but it dropped to about 117.28 L/ha after no-till adoption. So, fuel consumption has declined by 56.63 L/ha. This decline can be attributed to the decrease in the number of cultivator commute and the reduced number of the required field operations.

The economic consequences of NL technology

NL has many economic benefits including lower costs, fewer engines and tractors, extended longevity of agricultural implements, reduction in the required labor, and comfortable workforce management. Many studies have expressed the economic benefits of conservation tillage technology rather than conventional systems (Ekboir, 2003; Erenstein et al., 2008; Erenstein & Laxmi, 2008). In this regard, this study examined the economic impact of the NL adoption as mentioned below.

Seeding costs

Land preparation costs were too high before using no-till technology. Conventional farming operations require several field operations before planting. Using NL, no land perpetration is needed, and planting costs is reduced primarily as the results of this study also confirmed. The results showed that the difference in the cost of sowing before and after the use of this technology was statistically significant ($p<0.01$, $t=8.64$). Planting cost was about 1,169,000 IRR/ha before the NL adoption, but it was decreased to about 1,093,000 IRR/ha after its adoption. A significant reduction is seen in the cost of planting on farms of adopters (Table 3).

Impact of NL technology

Agriculture impacts: The results showed that NL has many positive impacts. According to the results, this system is largely commensurate with the circumstances of Iran. Based on the outcomes of this research, we can point to an increase in wheat yield. Food and nutrition se-

Table 3
Consequences of NL Technology

Variables	NL				t	p-value
	Mean	SD	Mean	SD		
The area under cultivation (ha)	2.33	0.86	2.23	0.85	-3.03	0.003
Wheat yields (t/ha(	5.42	2.57	4.84	1.97	-4.30	0.000
Herbicide consumption (L/ha)	2.18	1.71	2.63	1.97	3.98	0.000
Pesticide consumption (L/ha)	1.79	1.59	2.14	1.59	4.16	0.000
Irrigation time (hr/acre)	1.87	0.96	2.40	1	7.50	0.000
Frequency of irrigation	8.24	5.91	9.21	6	3.46	0.001
Phosphate fertilizer (kg/ha)	172.33	113.14	252.33	131.74	8.66	0.000
Nitrogen fertilizer (kg/ha)	198.61	136.90	250.38	128.60	5.36	0.000
Workforce	1.84	0.98	3.48	1.61	11.18	0.000
The number of cultivators passes	1.96	1.26	6.76	3.33	18.55	0.000
Fuel consumption (L/ha)	117.28	105.11	201.63	151.70	7.69	0.000
Seeding costs (IRR)	1093000	0.66	1169000	0.72	8.64	0.000

curity cannot be confined just to the economic-social aspect. Recently, it has also become a political issue, and industrialized countries use it as a political tool. Because of the current economic conditions and reduced foreign exchange earnings, it is necessary to make a greater use of facilities to increase production. With more production, we can stop importation and prevent the loss of foreign exchange. Therefore, finding agricultural methods to increase the crop yields remains an objective for agriculture planners and experts. Regarding the positive influence of adoption of conservation tillage on yield improvement, it can be considered as a valuable method for crops in Iran. Consequently, it seems necessary to provide appropriate conditions for farmers to adopt this method.

Drought is a worldwide phenomenon that occurs frequently in nature and decreases agricultural production by affecting the plants, resulting in aggravated food shortage and people hunger. In fact, drought is considered a complex phenomenon, even more sophisticated than other natural disasters that threaten human life. At present, there is a general warning about the effects of drought on society and the economy. Drought is certainly one of the features of Iran's climate which has been intensified in recent years. This phenomenon will be accompanied by heavy destruction of the various economic and social sectors. To mitigate and reduce destruction, we need efficient technology to cope with drought. The results of the present study show that among all effects, NL technology can reduce water consumption by agriculture in Fars province, so farmers should be encouraged to adopt NL. This technology can encourage farmers to apply such strategies to deal with the impact of the drought.

Environmental impact: Chemical fertilizers and pesticides contaminate water, soil, and air. Toxins in the groundwater aquifers, rivers and seas are one of today's threats which have led to severe degradation including creating and expanding ocean dead zones, destructing animal and plant species, imbalance in the ecosystem, increasing toxic algae in the sea, transferring toxins through the water and destructing pristine natural areas and beneficial microorganisms.

Biological damage caused by inappropriate use of fertilizers and synthetic pesticides and inappropriate methods of conventional farming lead to severe soil erosion, infertile land, desertification, and the reduction in the amount and quality of agricultural products. Consequently, the agricultural land will eventually lose its fertility and soil restoration would depend entirely on chemical fertilizers. The indiscriminate use of synthetic fertilizers and pesticides makes pests resistant to pesticides

Table 4
Results of Regression Analysis of Variables Influencing the Farmers` Willingness to Continue Using NL Technology

Variables	b	Beta	t	p-value
Wheat yields (X1)	0.23	0.15	2.456	0.01
Increased use of pesticides (X2)	0.36	0.14	2.567	0.02
Awareness of the benefits (X3)	0.09	0.16	2.860	0.02
Satisfaction with the no-till technology (X4)	0.96	0.71	**10.569**	0.0001

and new pests will appear. Hence, the environmental specialists have tried to find a solution to this problem. According to the results, NL technology could be introduced as an environmentally friendly technology because of the positive effect on reducing the use of chemical pesticides and fertilizers.

Effects on energy inputs: Energy, economic and environmental factors are important for the description of agricultural production systems. In recent years, agriculture has had a great deal of energy consumption growth. This is due to the continuous population growth and the continuous use of new production technologies and tools. Therefore, it is important to determine the amount of energy inputs in the crop growth. This is a good reason to find ways to increase the energy efficiency of agricultural inputs or reduce energy consumption in agricultural systems. Technologies are valuable that can produce more with less energy. Based on the results of this study, NL technology could be useful in reducing energy consumption in agricultural systems in Iran. Farmers require fewer inputs by adopting this technology and energy consumption will be significantly reduced. Other advantages of the no-till technology can be listed as the reduction in the number of workers, the reduction in the number of farm operations, and the reduced fuel consumption.

Economic impacts: One of the factors determining farmers' willingness to use new technologies in agriculture has always been their economic aspect which is particularly important in the case of environmental technologies. Farmers tend to use technologies with higher economic benefits. The investigation into the effects of tillage technology showed improvement in the economic situation of farmers in the use of NL. According to the results of this study, NL reduced the cost and increased the income of farmers. In fact, this technology reduced production costs because of the reduction in the number of field operations, workforce, and inputs. Furthermore, it enhanced the income of farmers by increasing the yields.

Farmers` tendency to continue using NL

Farmers' tendency to keep using the NL technology which implies their satisfaction with this technology and also represents the future of this technology has been reviewed as another aspect of this technology.

To determine the effects of all variables that affect farmers' willingness to keep using the NL technology and predict variations in each variable, the regression equation between the independent variables and farmers' willingness to keep using the NL technology was analyzed as the dependent variable. Four variables, including wheat yields, increased use of pesticides, awareness of the benefits and satisfaction with the technology, were included in the equation (Table 4). In total, these variables captured 66% of the variation in farmers' willingness to keep using the no-till technology (F = 31.99, Sig F = 0.0001). Beta values show one standard deviation increase in these variables, increases 0.15, 0.14, 0.16, 0.71 in the standard deviation of willingness to keep using the NL technology. Beta coefficients indicate that the satisfaction with the NL technology variable is the most important variable affecting the farmers' willingness to keep using the NL technology. Thus, the regression equation is as follows:

$$Y = 0.15\,x1 + 0.14\,x2 + 0.16\,x3 + 0.71\,x4$$

CONCLUSION

Conventional agriculture relies significantly on inappropriate use of the primary sources (such as soil and water) as well as inputs derived from fossil fuels such as fertilizers, pesticides and agricultural machinery with high fuel consumption. In other words, conventional farming systems have accelerated the environmental degradation. This has led to the erosion of natural resources. Consequently, in recent years interests have been aroused to the use of agricultural technologies that preserve the environment, soil, and water with lower costs and improve productivity. Many emphasized production technologies that contribute to achieving sustainability.

To realize sustainable agriculture, it is crucial to apply appropriate policies and programs to protect soil as one of the most important and expensive inputs for agricultural systems. One of the most effective methods of soil protection is conservation tillage such as NL. However, based on various studies, the choice of conventional tillage methods and conservation tillage method is still in the preliminary phase because there is no stable solution for all situations and according to the different climates, different results are expected from the technology. Based on our findings, the application of this technology has many positive effects on sources such as fuel, resources such as fuel consumption, cultivators working time, fertilizer and pesticide. Thus, the adopter farmers require fewer inputs and also have a significant reduction in their energy consumption. Despite the increase in crop yield, savings in water consumption is the most important result of NL as compared to conventional farming systems. Besides, the use of this technology has changed the weeds. In this regard, although reductions have been reported in the number of weeds in many areas, some farmers have also noted an increase in the number of weeds.

Despite the many positive effects of NL technology, one of the major topics in the field of innovation is discontinuation of its use. Hence, in this study, we tried to identify factors affecting farmers' willingness to keep using NL technology. Among the factors that seemed to be effective on continued use of the NL technology, the four factors including crop yields, increased use of pesticides, the knowledge of the usefulness of technology, and satisfaction with NL accounted for a large part of farmers' willingness to keep using the NL technology.

Therefore since satisfaction with NL technology is the most important factor affecting farmers' willingness to keep using the NL technology, it is suggested to hold gatherings for farmers who have used this technology and who are satisfied with its applications to explain the reasons for their satisfaction and explain how to achieve these results for others. It is also recommended that farmers' awareness of the benefits of this technology be increased, even after single use of this technology. In this regard, it is necessary to consider the long-term benefits that will be realized.

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