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Farmers' Preferences in Adopting Conservation Tillage Systems Considering Risk Attitudes in Bakhtegan Basin

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ABSTRACT

Conservation tillage systems have been promoted by governments in many regions of the world as an effective strategy to reduce soil and water losses caused by conventional farming practices. Considering adoption of the conservation tillage system, in addition to the uncertainty in economic aspects, the attitude of farmers is also important. To assess the risk efficiency of five tillage alternatives (Low-tillage, No-tillage, Conventional tillage, and two Rotational-tillage systems), we used Stochastic Efficiency with Respect to a Function approach for the typical wheat-corn production system in Marvdasht, Bakhtegan Basin, Iran, using four-year (2010–2014) field data set. Risk-neutral farmers' preferred the conventional tillage method over conservation tillage methods, relying on the higher net return of the wheat-corn rotation. However, at the higher risk-aversion degrees, the ranking of conventional tillage tended to decline rapidly and the two rotational tillage systems were preferred over other alternatives. The comparison of certainty equivalents of conservation tillage treatments indicated the superiority of low-tillage over no-tillage at all levels of risk aversion. The results of risk premium estimation in this study revealed that providing subsidy resources is not enough to promote the adoption of conservation tillage practices, and it is necessary to support risk-averse farmers by enhancing their knowledge about the risk-efficient options.

Keywords: Adoption decision, Conversation tillage, Risk efficiency, Certainty Equivalent, Soil tillage

INTRODUCTION

In the last century, tillage-based agricultural practices have been associated with soil degradation, resulting in 1-3% drop in Soil Organic Carbon (SOC) in many regions (Palombi and Sessa, 2013). Loss of 3% SOC means not only a significant loss of water storage (432,000 L ha^{-1}), but also an increase of nearly 400 t ha^{-1} of CO_2 emitted into the atmosphere (Jones, 2006). In arid regions, high levels of soil tillage and large-scale removal of crop residues are the main reasons for poor soil fertility (TerAvest *et al*., 2019; Khorami *et al*., 2018; Kabiri *et al*., 2015; Abdullah, 2014).

Iran, with mainly arid and semi-arid climates, faces severe changes in soil structure due to activities such as irrigation, cultivation, planting, and harvesting (Kouselou *et al*., 2018), and drastic climatic variations (Abbaspour *et al*., 2009). Agricultural ecosystems in the southern half of Iran are facing severe soil degradation due to the continuous reduction of Soil Organic Matter (SOM) and poor soil structure, which has led to the abandonment of agriculture (Roozbeh and Rajaie, 2021). Low rainfall, low availability of water, and high temperature, and decrease in the amount of organic inputs from plant biomass are the main factors leading to the reduction of SOM in Iran and other arid and semi-arid climatic regions (Roozbeh and Rajaie, 2021; Alvaro-Fuentes *et al*., 2008; Hajabbasi and Hemmat, 2000). Thus, an urgent need exists

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for fundamental changes to be made in the agricultural sector to mitigate the adverse impacts of climate change; and these changes can be achieved through sustainable soil and water management. Climate-Smart Agriculture (CSA) includes conservation tillage systems, is expected to achieve the goals of increased resilience against climate change, reduced greenhouse gases emissions, and increased productivity and households farm incomes. Conservation tillage systems, promoted by governments in many regions of the world as an effective adaptation strategy, is expected to meet these objectives, since conservation tillage systems focus on lowering soil erosion, enhancing soil organic matter, and lowering fuel use (Panagos *et al*., 2021; Li *et al*., 2020; Townsend *et al*., 2016; Gandorfer *et al*., 2011).

Although the environmental advantages of conservation tillage, such as increased SOC and soil water-holding capacity as well as decreased soil erosion, have been confirmed in the literature (Khorami *et al*., 2018; Leys *et al*., 2010; D'Hose *et al*., 2016), the economic benefits of the strategy remain vague (Wang *et al*., 2020; Fathelrahman *et al*., 2011; Vetsch *et al*., 2007). While some empirical works show that conservation tillage systems reduce production costs, especially energy costs, maintenance costs, labor costs, and machinery (Bermer *et al*., 2001; Williams, 1988), there are studies suggesting that reduced costs are offset by increased costs associated with increased use of pesticides and chemical fertilizers in weed and crop residue management (Hristovska *et al*., 2012; Williams, 1988). In other words, the central question about the economic impacts of conservation tillage remains unanswered. In addition, there is a significant uncertainty about the impact of conservation tillage systems on crop yield, especially in the early years of adoption. For instance, by the no–tillage system, decline in cereal yields was the most in tropical climates, while in arid climates, the yield loss was slight (Pittelkow *et al*., 2015). Furthermore, adoption of no-tillage system forms a hard plow pan and compacts the subsoil, in the long run. This compaction limits root penetration, and reduces absorption of water and nutrients from deep layers of soil (Zhang *et al*., 2018; Mu *et al*., 2016; Bengough *et al*., 2011; Yang *et al*., 2008). Afzalinia and Zabihi (2014) indicated soil bulk density and cone index increased by the no-tillage system compared to conventional tillage, because there was no soil disturbance in the no-tillage. Rotational tillage is a combination of at least two types of tillage: Shallow tillage (for example, no-tillage or low tillage) and Deep tillage, and is considered as an effective solution to reclaim the damages caused by continuous single tillage system.

Since the results about the impact of conservation tillage systems on different crops yield and in different areas are contradictory, decision about the adoption of conservation tillage practices by farmers encounters with several uncertainties that have had negative effect on adoption rate of conservation tillage systems in many regions of the world.

As far as adoption of the conservational systems is considered, in addition to the uncertainty in economic features, the attitude of farmers, as economic rational individuals, is also important (Tessema *et al*., 2015). Individual farmers are expected to take into consideration the benefits and costs related to their decision. However, some ecological benefits related to conservation tillage are not expected to be attractive to farmers in a risky environment of decision making. Therefore, allocating subsidy by government could moderate farmers' risky behavior, inclining them towards conservation tillage (Li *et al*., 2021; Nail *et al*., 2007). This measure also raises the question of how much of subsidy allocation is risk-efficient. To answer the question, Hardaker *et al*. (2004) introduced the concept of Certainty Equivalent (CE) based on Subjective Expected Utility (SEU) theory. CE is the sum of money "for sure" that makes any Decision-Maker (DM)

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indifferent to the risk or acceptance of the amount. Stochastic Efficiency with Respect to a Function (SERF) is a simple and transparent approach to order alternatives in terms of CEs. Using SERF analysis and estimation of CEs for each alternative, we will be able to determine risk-efficient economic incentives by calculating risk premiums. According to the risky nature of the conservation tillage adoption decisions and different risk preferences of farmers (Fleckenstein *et al*., 2020), estimating CEs and risk premiums at different Absolute Risk-Aversion Coefficient (ARAC) levels help make policy guidelines for justifying subsidy allocation and provide information to support farmers in decision making process. This is extremely important in regions more vulnerable to climate change such as Iran.

Contrary to the challenges faced in Iran, no such SERF study has been conducted in Iran. The few empirical works in the literature and the location-specific nature of conservation method makes the Iranian case study an interesting one that may contribute to the current literature. Furthermore, the experimental results in this area can open a new window for researchers and policy makers, both locally and regionally as well as internationally.

In this study, we aimed to use four-year field data under five tillage practices to apply SERF for a typical wheat-corn production system in Marvdasht County, Bakhtegan Basin, southern Iran (described in details in the next session). Corn-wheat rotation is the main cropping system in Marvdasht, which was ranked first in wheat and corn-wheat rotation is the main cropping system in Marvdasht. The novelty of this study is threefold. First, this is the second attempt to estimate risk efficiency of alternative conservation tillage systems in a region outside the US. Thus, the results may contribute to regions with similar soil conditions and climate in specific, and to the literature overall in developing the research design. Second, our analysis is based on a valuable four-year field data with five different tillage treatments. Despite the importance of rotational tillage for resolving the shortcomings of no-tillage practice that makes it easier to be accepted by farmers, there is no empirical work incorporating risk efficiency analysis of rotational tillage. Thus, the third contribution of the present study is the inclusion of rotational tillage system in the analysis.

MATERIALS AND METHODS

The Analytical Framework

The aim of Risky Choice is to find the decisions with the highest expected utility or, if risk neutrality can be assumed, with the highest Expected Monetary Value (EMV) in alternative courses of action. A useful technique in such an analysis is what is known as stochastic simulation. The purpose of stochastic simulation in risk analysis is to determine probability distributions of consequences for alternative decisions to enable the decision maker to make a good and a well-informed choice. The stochastic consequences can be distilled down to a single measure of the utility or CE for each choice alternative analyzed, if an appropriate utility function is available (Mustafa, 2006).

Given the importance of analyzing farmers' decisions, many attempts have been made to construct the utility function of the DM (Anderson and Hardaker 2003). When it is impossible to determine risk preference accurately, the use of stochastic models is recommended for classification. Hardaker and Russell (1969), Hanuch and Levy (1969) introduced the general criteria for first-order Stochastic Dominance (FSD) and Second-order Stochastic Dominance (SSD) (Hardaker *et al*., 2004). These methods are firmly based on the expected utility maximization, and in principle, compare alternative perspectives of risk based on the full distribution of results (Mustafa, 2006).

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SERF, which was introduced by Hardaker *et al*. (2004), imposes restrictions on ARAC in the analysis of the SSD, therefore, SERF has a higher discrimination power against the FSD and SSD. For different risk attitudes, the SERF analysis relies on utility-efficient alternatives. This strategy is claimed to have more discriminatory power since it takes into consideration the entire range of DM's preferences (Hardaker *et al*., 2015).

According to the analytical framework, in order to determine the stochastic efficiency of different tillage systems in corn-wheat rotation in Marvdasht, it is necessary to implement the following steps: (1) Preparing historical data of gross margin for different tillage systems; (2) Derivation of Cumulative Distribution Function for each alternative tillage system; (3) Calculation of CE for each alternative; and (4) SERF analysis. In the data section, the source of historical gross margin data for tillage systems used in this study is explained.

Data

To simulate the distribution of corn and wheat yield under different tillage systems, four-year data from Afzalinia (2018) were used. The research field in Afzalinia (2018) was located in Marvdasht with a longitude of 52° 47′ and latitude of 30° (Figure 1). Rainfall averages 312 mm annually with 70% occurring in winter, 24% in autumn, and 6% in spring. The average annual temperature is 17.6°C with 37.8°C maximum and 0.1°C minimum temperatures (Khalili *et al*., 2020). The study was conducted in randomized complete blocks with five treatments from 2010 to 2014. The description of treatments is presented in Table (1).

The crop residues inversion rate (the percent change in the dry weight of plant residues after tillage compared to the before tillage operation) in Conventional Tillage (CT), Low Tillage (LT), and No-Tillage (NT) was measured at 90.7, 76.3, and 29.4%, respectively. Soil texture of the field was clay. The four-year duration of the experiment has the advantage of investigating the effect of tillage rotation in RT1 and RT2 treatments, i.e., breaking the process of successive no-tillage with conventional tillage in a crop season.

Table 2 shows the descriptive statistics of the yields in the four-year rotation of wheat and corn. The highest average yield for wheat was obtained in T4, which is four-year no-tillage for corn and combination of no-tillage with conventional-tillage for wheat. However, the standard deviation is the lowest for the four-year low-tillage treatment (T1) and the highest for the four-year no-tillage treatment (T2). Comparison

Table 1. Description of tillage practices.

Title	Tillage system	Description
LT	Low-Tillage	Low tillage by tine and disc cultivator, seeding wheat by grain drill, seeding corn by row crop planter
NT	No-Tillage	Direct seeding[1] of Wheat and Corn with no cultivation and planting by direct seeder
RT1	Rotational Tillage 1	Direct seeding of wheat in the first, second and fourth years, and conventional tillage in the third year and direct seeding of corn for all years
RT2	Rotational Tillage 2	Direct seeding of corn in the first, second and fourth years and conventional tillage in the third year and direct seeding of wheat for all years
CT	Conventional Tillage	Plowing by moldboard plow, disk harrow, land leveler, grain drill, seeding wheat by grain drill, seeding corn by row crop planter

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Table 2. Average of four-year yields (kg ha^{-1}) for wheat and corn under different tillage systems in Marvdasht County, Iran.

Title[a]	Tillage system	Mean	St dev	Maximum	Minimum
	Wheat yield (kg ha^{-1})				
LT	LT wheat, LT corn	5371	829	6678	4414
NT	NT wheat, NT corn	5197	1162	7058	3948
RT1	RT wheat, NT corn	5356	890	6505	4024
RT2	NT wheat, RT corn	5367	1027	7040	4436
CT	CT wheat, CT corn	5847	1133	7604	4465
	Corn yield (kg ha^{-1})				
LT	LT wheat, LT corn	47296	3165	51009	43275
NT	NT wheat, NT corn	44312	1722	46405	42187
RT1	RT wheat, NT corn	42863	1888	44211	40192
RT2	NT wheat, RT corn	43269	2978	47405	40517
CT	CT wheat, CT corn	47449	3430	51610	43209

[a] LT: Low Tillage; NT: No Tillage; RT: Rotational Tillage; CT: Conventional Tillage.

of the four-year average yield of corn between different tillage treatments indicates that the highest yields were obtained under conventional and low tillage. However, the standard deviation of corn yield under no-tillage treatment was the lowest. The results also showed that the use of tillage rotation has the lowest corn yield in four years.

Stochastic Efficiency with Respect to a Function (SERF)

The SERF approach relies on identifying efficient alternatives to different risk attitudes rather than identifying a subset of the dominant alternatives. SERF compares all alternatives within the risk aversion range at the same time, and those that are optimal for some values of the risk aversion coefficient are distinguished as efficient. SERF analysis classifies alternatives based on CEs as the selected risk aversion measures vary within a defined range. Any utility function can be used in SERF, where the inverse function calculated on the basis of a range of absolute, relative, or partial risk aversion coefficients, depending on the situation. The SERF approach is conducted by calculation of the utility for all risky alternatives for a given form of utility function (Mustafa, 2006; Hardaker, 2015):

$$U(x,r) = \int U(x,r)f(x)dx \quad (1)$$

Where, r and x are the risk aversion degree and stochastic outcomes, respectively. Then, U can be calculated for a given r or a range of r_1 to r_2. The CE for each U value is obtained as follows:

$$CE\,(x,r) = U^{-1}(x,r) \quad (2)$$

Alternatives with the highest CE values at a given range of r coefficient are included in the efficient set while other alternatives are distinguished as dominated in the SERF sense. The CEs graph provides an intuitive way of explaining how preferences among risk options vary within the range r.

Based on the hypothesis of preferring less risk to more by farmers at a given level of expected return (Schumann *et al*., 2011), we applied a negative exponential utility function in this study. A proper approximation of risk averting behavior can be found in the negative exponential function (Adusumilli *et al*., 2020). The ARAC measures a decision-maker's risk aversion degree. The DM’s are categorized as risk-averse, risk-neutral, or risk favoring, if, respectively, ARAC> 0, ARAC= 0, or ARAC< 0. Hardaker *et al*. (2004) proposed

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the following formula for calculating ARAC values:

$$ARAC = r_{r(w)}/w \quad (3)$$

Where, $r_{r(w)}$ is the relative risk aversion coefficient in terms of wealth (w), which was set to 0 (risk-neutral farmer) to approximately 4 (extremely risk-averse farmer), based on Adusumilli *et al*. (2020). Wealth (w), which was determined in this study using the respective net return, means four different tillage systems. The risk premiums for tillage systems are then determined by differencing CE values of two corresponding tillage systems at a specific ARAC value (Adusumilli *et al*., 2020).

RESULTS AND DISSCUSSION

Summary statistics of four-year net return for wheat-corn production system under different tillage treatments are presented in Table 3. Comparison of the four-year average net return of wheat-corn rotation under different tillage practices showed that the average net return per hectare under conventional tillage is about 4.6% higher than that of low-tillage. The corresponding values for NT, TR1 and RT2 are 12.6, 16.2, and 15.6%, respectively. Although conventional tillage has the highest net return, it is also accompanied with higher variability measured by standard deviation. Four-year low-tillage also has higher net profit than four-year no-tillage, however, this profit advantage is available to farmers at the cost of accepting greater profit variability. Both Rotational Tillage systems (RT1 and RT2) create lower net return than other tillage methods, accompanied with the lower standard deviation as well. In general, there is a trade-off between average return and the degree of tillage intensification. However, there is no such a relation between the degree of tillage intensification and Coefficient of Variation (CV).

For a risk-neutral farmer who is a profit maximizer, CE indicates the expected mean net return at the risk-aversion level of 0. Therefore, with increasing the level of risk-aversion, the net return amount falls (Hristovska *et al*., 2012). Using SERF based on a negative exponential utility function, the calculated CE values for different tillage systems are plotted over a defined range of ARAC to facilitate rankings for DMs with varying risk attitudes (Figure 1).

As shown in Figure 1, conventional tillage system was the most preferred for risk-neutral farmers, with risk aversion extending off to 0.002. The attractiveness of conventional tillage among farmers with risk aversion higher than 0.002 falls gradually, ranked as the choices with the lowest priority for ARAC higher than 0.005. By the ARAC of 0.002 to 0.008, the most preferred tillage system was low-tillage for wheat-corn rotation. The results indicate that, initially, the four-year continuous no-tillage treatment for both wheat and corn is the least preferred among risk-neutral farmers, but, by increasing risk aversion, no-tillage

Table 3. Descriptive statistics of net returns (1000Rls/ha) for different tillage systems in Marvdasht County, Iran.

Title [a]	Tillage system	Mean	St dev	CV	Maximum	Minimum
LT	LT wheat, LT corn	51574	27803	54	85050	25964
NT	NT wheat, NT corn	47922	26676	56	82269	24202
RT1	RT wheat, NT corn	46425	24670	53	76270	24777
RT2	NT wheat, RT corn	46693	24808	53	79087	22754
CT	CT wheat, CT corn	53964	31875	59	92980	22506

[a] LT: Low Tillage; NT: No Tillage; RT: Rotational Tillage; CT: Conventional Tillage.

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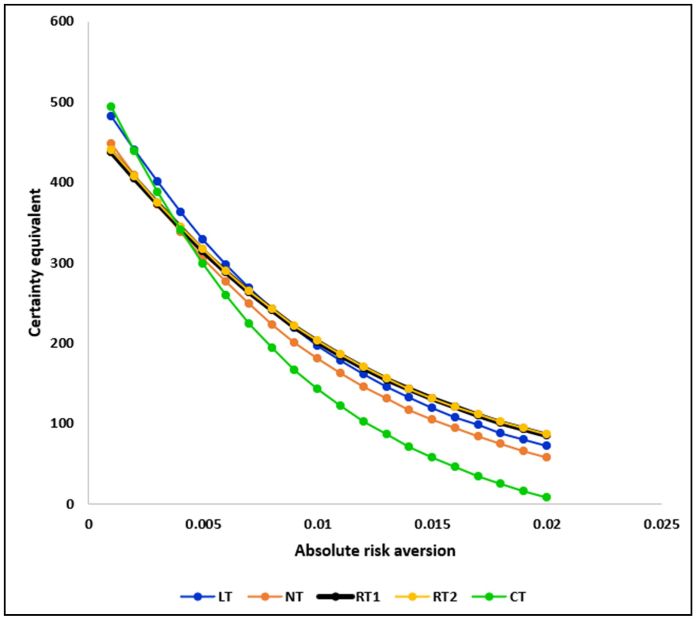

Figure 1. Certainty Equivalents of wheat-corn rotation by tillage systems over ARAC levels. LT: Low Tillage; NT: No-Tillage; RT: Rotational Tillage; CT: Conventional Tillage.

achieves higher priority than the conventional tillage. However, at all levels of risk-aversion, no-tillage is less preferred than the low-tillage method, indicating that the no-tillage cropping system is absolutely less preferred. This result was slightly different for the two Rotational Tillage treatments (RT1 and RT2). By increasing the ARAC, these rotational tillage systems become more preferred, so that for ARAC values of higher than 0.01, RT2 is the most preferred method from the farmers' point of view. In the rotational tillage system, one of the crops (wheat or corn) was cultivated with no-tillage during the entire research period (without any tillage system change) and another one is cultivated with conventional tillage in the third year and with no-tillage system in other years. Both Rotational Tillage systems (RT1 and RT2) were characterized by higher average yields and lower variability compared to the no-tillage system. In other words, lower variability of the net return has left no room for risk-aversion to have an effect. As far as no-tillage is considered, the no-tillage system over consecutive years creates a compact plow pan and increases soil compaction, which reduces root penetration and reduces the absorption of water and nutrients from deep soil layers, thus adversely affecting yield and reducing drought tolerance (Afzalinia and Zabihi, 2014) .

Table 4 shows the estimated CEs and risk premiums for selected ARAC levels. In general, the positive values of CEs indicate that farmers need premiums to change their current tillage system. The absolute values of risk premium illustrate how much money is needed to encourage farmers to change their current method of tillage. The premiums to change to no-tillage were estimated by subtracting the CE of the no-tillage system from the examined tillage system. For example, a risk-neutral farmer who currently utilizes conventional tillage in a wheat-corn rotation would require 46 million Rls (494-448= 46) premium per hectare to move to a no-tillage system (Table 4) The exchange rate at the date of conducting this study was 2.9×10^{-5} US dollars. In other words, a risk-neutral farmer

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Table 4. Certainty equivalents of different tillage systems and no-tillage risk premiums for various ARAC levels in Iranian currency (Rls).

Title	Tillage system	Absolute Risk Aversion Coefficient			
		0.00	0.01	0.02	0.03
		Certainty Equivalent (Million Rls ha^{-1}) [a]			
LT	LT wheat, LT corn	482	197	72	18
NT	NT wheat, NT corn	448	181	59	5
RT1	RT wheat, NT corn	438	202	86	34
RT2	NT wheat, RT corn	441	203	87	35
CT	CT wheat, CT corn	494	143	8	-49
		No-tillage risk premiums (Million Rls ha^{-1})			
LT	LT wheat, LT corn	34	17	13	13
NT	NT wheat, NT corn	0	0	0	0
RT1	RT wheat, NT corn	-10	21	27	29
RT2	NT wheat, RT corn	-7	22	28	30
CT	CT wheat, CT corn	46	-38	-51	-54

[a] The exchange rate at the date of conducting this study was 2.9×10^{-5} US dollars. LT: Low Tillage; NT: No Tillage; RT: Rotational Tillage; CT: Conventional Tillage.

would be willing to pay 46 million Rls in lost revenue to remain in the conventional tillage system. Thus, a risk-neutral farmer's least expected net return in no-tillage system is 46 million Rls. A 34 Million Rls premium is needed for a farmer currently using low-tillage system to move to a no-tillage system. The higher value for the conventional tillage system is because of the higher net return under conventional tillage system. At the higher levels of ARAC, the risk premium for a farmer currently using conventional tillage becomes negative, while it remains positive for a farmer currently using low-tillage system. Accordingly, risk-averse farmers prefer low-tillage to no-tillage and need to be compensated to move to no-tillage system.

A risk-averse farmer whose current system is conventional tillage would prefer to move to no-tillage without receiving a premium. While this may sound controversial, it is a result of the risk-averse farmers' preferences for less variability at the expense of lower returns. Another reason for preference is that growers may consider the current conventional system as a system that will experience more variability in productivity, which may cause lower net return. In other words, the risk-averse farmer exchanges short-term variability for long-term variability. This hypothesis deserves to be addressed more deeply in future studies. Insufficient practical cases exist to demonstrate to the crop growers and to predict the yields and returns of different tillage systems as a tool to persuade growers to adopt. This study makes steps to fill parts of this gap using an experimental experience. However, an urgent need exists to continue the work.

For a risk-neutral farmer whose current tillage system is RT1 or RT2, the premiums are negative, indicating that this farmer would pay to move to a no-tillage system from a rotational tillage system, when there are low levels of risk-aversion. At the higher risk aversion coefficients, farmers would be less inclined to change their tillage method from rotational tillage to no-tillage. The underlying reason is that the farmers experience a low return variability with rotational tillage methods. The lower variation in net return is extremely important for the risk-averse growers. Since a majority of farmers are risk-averse (Li *et al*., 2021),

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they are inclined to adopt practices with higher CEs at a given ARAC level. The results of our study revealed that the CE of low-tillage and rotational tillage are higher than conventional and no-tillage systems. A contributor to the lower adoption rate for no-tillage is the lack of knowledge about risk-efficient practices. Hence, risk-averse farmers would likely change their tillage practice to low-tillage or rotational tillage methods if they are informed about lower net return variability of these tillage systems.

The results obtained for conservation tillage and conventional tillage can be contradictory when viewed across regions. However, increasing evidence support low-tillage and no-tillage systems over conventional tillage systems (Grandy *et al*., 2006; Quincke *et al*., 2007). Adusumilli *et al*. (2020) concluded that the CE value of conventional tillage systems is higher than that of no-tillage systems. While, Williams *et al*. (2009) and Watkins *et al*. (2008) found that in a rice and soybean rotation and a three-year wheat and sorghum rotation, the no-tillage system was preferred over the conventional tillage system at all levels of ARAC. The results of Williams *et al*. (2009) and Watkins *et al*. (2008) confirm our analysis on the preference of conservation tillage systems over conventional tillage for risk-averse farmers. However, our results on the higher ranking of low-tillage over no-tillage at all ARAC levels and increasing attractiveness of rotational tillage systems over other conservation tillage methods at high levels of risk-aversion contributes to the existing literature. Furthermore, our results indicating that allocating subsidies is not enough to spur adoption of conservation tillage systems is consistent with Zeweld *et al*. (2017).

CONCLUSIONS

In order to investigate the risk efficiency of five different tillage systems for a wheat-corn rotation in Marvdasht County, Iran, we applied SERF analysis. SERF analysis showed that risk-neutral farmers preferred conventional tillage to conservation tillage systems, relying on the higher net return in the wheat-corn rotation. However, at the higher risk aversion coefficients, the ranking of conventional tillage tends to decreases rapidly. This implies that risk-averse farmers give more weight to risk when trading higher average net returns with less variability. Comparing the CEs of four conservation tillage systems indicated the superiority of low-tillage over no-tillage at all levels of risk aversion. In other words, while the conventional tillage system is not preferred in some situations, at the opposite end, the no-tillage system also has little room to be preferred. It is also worth noting that if the ultimate desired goal is the adoption of a no-tillage system, a possible means to achieve the goal is to recommend a middle ground system like low-tillage and then focus on the no-tillage system in subsequent steps. In addition, adoption of a low-tillage system, a type of limited tillage compared to conventional tillage, leads to more awareness about the advantages of a reduced tillage system and paves the road for a no-tillage option. Therefore, advising low-tillage methods to wheat and corn farmers in Marvdasht is a stronger argument than advising them to adopt no-tillage. Hence, policy-makers are advised to consider this group of farmers to inform them about the risk efficiency of the low-tillagesystem compared to conventional tillage systems. It is noticeable that rotational tillage systems dampened the disadvantages of continuous no-tillage in a clay soil by breaking the no-tillage with conventional tillage once in a four-year wheat-corn rotation. This implies that low-tillage accompanied by a proper rotational tillage may even increase the acceptability of the conservation tillage systems.

The Iranian government has planned to enhance the adoption rate of conservation tillage systems, especially in the dry regions. Thus, it is necessary to support risk-averse

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farmers in the sense of compensating any variability of gross margins and crops yield resulting from adoption of new tillage systems. In this regard, estimating risk premiums could be a guideline for policy makers to allocate subsidies in a way that incentivizes farmers to move to more risk-efficient tillage systems. As far as the adoption of conservation tillage systems is considered, informing risk-averse farmers about the lower variability of low-tillage and rotational tillage net returns is more important than encouraging these farmers by reward. Accordingly, officials and governmental bodies should target risk-averse farmers to inform them of risk-efficient alternatives. The officials should also focus on risk-neutral farmers to inform them about the adverse effects of conventional tillage systems in the sense of decreasing yield resulting from SOM and fertility depletion in long term. In this regard, providing some experimental case studies and establishing limited tillage demonstrations may pave the way for widespread acceptance of the new tillage systems.

It is imperative to note that, while our study has a significant contribution to the literature, it can be extended to additional fields for future studies. Although wheat and corn are the main crops, other crops may also be taken into consideration, leading to more choices and higher adoption of lower tillage systems. Furthermore, a SERF approach was found to be useful to prioritize climate-smart agricultural strategies from a farmer's point of view. We suggest SERF be applied to other CSA technologies.

As mentioned in the introduction, conventional tillage operation is an intensive tillage that has negative effects on SOM and soil fertility. Considering the food crisis caused by population increase and climate change, there is an urgent need to move from conventional tillage to conservation tillage. Considering that this study has examined various forms of conservation tillage including no tillage, low tillage and rotational tillage, it can definitely open a window for other countries including developing countries with similar climatic conditions. In this regard, this study provides researchers with a general guideline for conducting the following studies:

- Conducting field research to investigate the effects of different tillage methods on yield and soil characteristics in major crops
- Investigating the stochastic efficiency of tillage systems
- Estimation of CE and risk premiums
- Presenting the results to the policy makers to adopt appropriate policies to increase the adoption rate of appropriate conservation tillage in that area and to find appropriate tools to motivate farmers to accept risk-efficient conservation tillage systems.

It should be noted that the SERF approach offers risk-efficient options for a wide range of risk-aversion levels. However, we recommend investigating the risk attitude of farmers towards conservation tillage methods in further studies.

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ترجیحات کشاورزان در اتخاذ سیستم های خاکورزی حفاظتی با در نظر گرفتن نگرش ریسکی در حوضه آبریز بختگان

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چکیده

سیستم های خاکورزی حفاظتی در بسیاری از مناطق جهان، توسط دولت‌ها به عنوان یک استراتژی مؤثر برای کاهش تلفات خاک و آب ناشی از شیوه‌های کشاورزی مرسوم ترویج شده است. در اتخاذ سیستم خاک‌ورزی حفاظتی توسط زارعین، علاوه بر عدم قطعیت در عوامل اقتصادی، نگرش ریسکی کشاورزان نیز حائز اهمیت است. برای ارزیابی کارایی تصادفی پنج روش خاک‌ورزی (کم-خاک‌ورزی، بی‌خاک‌ورزی، خاک‌ورزی مرسوم و دو سیستم خاک‌ورزی تناوبی)، از رویکردکارایی تصادفی با توجه به تابع، برای تناوب گندم و ذرت در مرودشت با استفاده از مجموعه داده‌های مزرعه‌ای چهار ساله (۲۰۱۴-۲۰۱۰) استفاده شد. نتایج نشان داد که کشاورزان ریسک-خنثی با تکیه بر بازده خالص بالاتر تناوب گندم- ذرت، روش خاکورزی مرسوم را بر روش‌های خاکورزی حفاظتی ترجیح می‌دهند. با این حال، در درجه‌های ریسک‌گریزی بالاتر، رتبه‌بندی خاک‌ورزی مرسوم به سرعت کاهش یافته و سیستم‌های خاک‌ورزی تناوبی بر سایر گزینه‌های خاک‌ورزی ترجیح داده می‌شوند. مقایسه معادل حتیمت (CE) تیمارهای خاک‌ورزی حفاظتی نشان‌دهنده برتری کم-خاک‌ورزی بر سیستم بی-خاک‌ورزی در تمامی سطوح ریسک‌گریزی بود. نتایج برآورد غرامت پذیرش ریسک در این مطالعه نشان داد که تخصیص یارانه برای ترویج اتخاذ شیوه‌های خاک ورزی حفاظتی کافی نیست. بنابراین، حمایت از کشاورزان ریسک‌گریز از طریق افزایش دانش آنها در مورد گزینه‌های ریسک-کارا ضروری است.

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