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Abstract With increasing food insecurity and climate change, conservation agriculture has emerged as a sustainable alternative to intensive conventional agriculture as a source of food supply. Yet the adoption rate of conservation agriculture is still low. Our paper analyses the factors affecting farmers' willingness to adopt conservation agriculture in Lebanon. The findings show that household characteristics—years of farming and farm size affect conservation agriculture adoption. However, household characteristics alone were insufficient to explain conservation agriculture adoption. We found that farming experience, information sources, frequency of irrigation, and severity of weed infestation in the past, participation in specific trainings, and farmers' perception about the long-term impact of conservation agriculture, were key determinants of conservation agriculture adoption. Our paper encourages policymakers to invest in conservation agriculture to overcome food insecurity and environmental changes affecting food systems in the Middle East. The paper also informs agribusiness firms to view conservation agriculture as a viable alternative to strengthen their business relationship with farmers in arid and semi-arid regions.

Keywords Food security · Conservation agriculture · Middle East · Willingness-to-adopt

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Introduction

Conservation agriculture (CA) has emerged as an environmentally sustainable alternative to intensive conventional agriculture, and hence could play a central role in ensuring global food supply. Yet the adoption rate of CA is still very low, especially in low-income countries and among small and medium farmers. The rate of adoption may vary by the benefits, costs or risks of CA, the farm's human, financial or land resources, or the farmers' risk preferences (Pannell et al. 2014). This paper investigates wheat farming households' willingness to adopt CA in Lebanon and more generally in arid and semi-arid regions of the Middle East. It aims to illustrate barriers to the adoption of improved conservation practices and shed light on context specific factors affecting farmers' conservation behavior.

CA has emerged in the seventies as an alternative to high-input-intensive conventional agriculture system. A number of studies have explored CA's benefits (Kassam et al. 2012; Pannell et al. 2014; Stevenson et al. 2014). Economically, no-till practices have been shown to be more cost-efficient than conventional farming systems since fewer inputs, such as labor and equipment, are used while yields increase (World Bank 2008). In terms of environmental performance, CA has been shown to improve soil fertility when crop residues are retained (Karlen et al. 1994), reduce soil erosion, and use less water for irrigation (Malik et al. 2005). Indeed, it has been projected that by 2050, 2500 km^3 of water could be saved by spreading CA practices (FAOSTAT 2009). Furthermore, a research conducted in the United States describes the important role that CA can play in women's empowerment (Trauger 2004), supporting women's identities as farmers while productivist rural models tend to marginalize them. In the context of climate change and the related increase in food prices, CA

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has been shown to play a central role in contributing to food supply; indeed, increased soil moisture helps increase drought resistance and reduces risks of crop failure (Ekboir et al. 2002). Thus, CA seems to be the better option for farmers as it makes better use of soil, water, and biological resources (Knowler and Bradshaw 2007).

There is some scientific evidence on the effect of CA on productivity gain in dry Mediterranean climate (Kassam et al. 2012; Mrabet 2000; Mrabet 2002). However, considering its many benefits but concomitant low adoption rate, more research is needed to understand the determinants of the household-level decisions to adopt, or not, these technologies. Against this background, research at the American University of Beirut (AUB) has tested the ecological and yield impacts of CA in the Beqaa valley, the breadbasket of Lebanon located in the east of the country, and obtained encouraging results in terms of yield, soil moisture, and economic performance, according to the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and German Technical Cooperation (GTZ) (ACSAD-GTZ 2010). Throughout this research, a number of farmers have been trained and their results have encouraged researchers. There were strong indications that CA could well be a viable alternative to the resource-intensive and environmentally harmful intensive system of agriculture in the context of the semi-arid climate prevailing in the Middle East region. Although ecological and yield impacts of CA were demonstrated in the Beqaa region by the aforementioned studies, the behavioral aspect, i.e., farming households' willingness to adopt CA, has not yet been explored; this is a necessary condition to influence policymakers and encourage ministerial investments toward a sustainable agriculture.

This paper aims to assess factors affecting the adoption of CA when farmers are being exposed to limited rainfall. By examining the relationship between individual attitudes and the propensity to adopt, the paper analyses how perceived costs and benefits of CA affect farmers' willingness to adopt. More specifically, the study aims to analyze farmers' willingness to adopt and, if so, the amount of land they are willing to enroll in CA. We expect that the farmers decisions to be conditioned by their perception about the economic benefits of CA and socio-demographic characteristic as well as the quality and sources of information.

Study Context

CA comprises of three crop management principles (Hobbs et al. 2008; Rai et al. 2011): no-till farming, residue retention, and crop rotation. This study focuses on no-till farming, partly because farmers can easily switch to this practice by simply stopping ploughing, leaving crop residues on the field after harvest, and by planting the following season's crops directly into the residue-covered field with a no-till grain drill; this type of machinery is increasingly available for purchase or rental in the Lebanese market.

No-till farming is becoming increasingly popular as a new way of farming in many developed and developing countries such as Australia, the US, Brazil, Argentina, and neighboring states like Syria and Jordan. Globally, no-till farming is expanding at a rate of approximately 6 million ha per annum (Derpsch et al. 2010), but varies across regions. For example, in South America, no-till farming is reported at 47% of the total cultivated land while only 0.3% is reported in sub Saharan Africa (Derpsch et al. 2010). Generally, there is more or less a consensus among researchers regarding the environmental benefits of no-till farming (Corsi et al. 2012; Lal 2004; Smith et al. 2008). However, its contribution to food production and food security continues to be debated. A recent (and highly cited) comprehensive study by Pittelkow et al. (2015)[1] finds a negative correlation between no-till farming and crop yields. In the United States, however, no-till farming has shown greater yield impacts for sorghum and wheat crops, particularly in warmer and more humid climates (Toliver et al. 2012). Likewise, De Vita et al. (2007) documented superior wheat yields under no-till farming in Mediterranean regions.

In summary, global evidence on the relationship between no-till farming and yield is mixed. However, pilot experiments carried out in Lebanon, which started in 2007 at AUB's Advanced Research Enabling Communities (AREC) and Lebanese Agricultural Research Institute (LARI), provide evidence that no-till farming has greater yield impacts than conventional farming (ACSAD-GTZ 2010). However, the challenge remains how to promote this practice among the Lebanese farmers, and, possibly, among farmers in other arid and semi-arid regions of the Middle East. Behavioral approaches focusing on motives, values, and attitudes have been suggested to understand individual decision-making processes governing the adoption of agri-environmental schemes similar to CA (Morris and Potter 1995). The scope and impact of CA practices depend largely on farmers' willingness to adopt CA and enroll sufficient farmland under it to bring about a meaningful economic and ecological impact.

Agricultural technology adoption theory has much to offer in terms of understanding the determinants of CA diffusion since many of the decision-making processes depend on individual characteristics, the context of adoption and the characteristics of the new technology (Ajzen 1991;

[1] This study uses 5,463 paired yield observations from 610 peer-reviewed publications across 48 crops and 63 countries.

Baumgart-Getz et al. 2012; Morris and Potter 1995). In light of this, several variables related to individual farmers (socio-demographic variables), context (information sources), and the characteristics of the technology (potential yield impacts and cost savings) have been introduced to understand the factors influencing individual farmers' willingness to adopt CA. The study uses a variant of the contingent valuation method (willingness to adopt) that gauges wheat farmers' hypothetical stated preferences with respect to CA adoption due to the limited experience of this technology in the area. The contingent valuation method has been widely used in the literature, for example, to measure consumer willingness to pay for genetically modified foods (Erenstein et al. 2012), locally grown products (Kaya et al. 2013), and to adopt CA in wheat and maize based systems (Erenstein et al. 2012).

Methods

The adoption of technology in the context of agriculture has been studied extensively in the literature (Adesina and Baidu-Forson 1995; Feder and Umali 1993; Noltze et al. 2012). Often, adoption is more than a simple dichotomous decision whereby farmers also need to decide on what proportion of their land they decide to adopt this technology (Leathers and Smale 1991). The decision process can, therefore, be conceived as a two stage one: first, the farmer decides whether or not to adopt the technology; and second, the proportion of the land on which the new technology will be used is determined; that is, the intensity of adoption. Most of the time, the two hurdles are estimated separately using a binary outcome model in which the dependent variable takes only the values 0 and 1 for the first adoption equation and a Tobit model for the second stage. The Tobit model is usually applied for fitting models with limited-dependent variables that are sometimes called "corner-solution" models (Baum 2006).

However, a key limitation of the Tobit specification is that it only allows for one type of zero observations (i.e., a corner solution) and implicitly assumes that explanatory variables as having the same effect (i.e., the same vector of parameters) on the willingness to adopt and the intensity of adoption. A more flexible alternative known as a "two-tier" or "double-hurdle" model was proposed by Cragg (1971), which allows these outcomes to be determined by separate processes. The double-hurdle model, which is a generalized Tobit specification, is able to overcome the potential restriction faced by the latter by accounting more flexibly for the two sequential decisions (Cragg 1971). The first tier adoption/participation equation is specified by a probit model, which estimates the probability that a household will adopt a given technology. A positive value implies willingness to adopt, although the possibility of enrolling no farmland is still permitted due to, for example, limited available farmland to practice CA. The second tier equation is specified as a truncated regression model estimating the intensity of adoption. The double-hurdle model has recently been used in an agricultural technology adoption context by Noltze et al. (2012) and (Langyintuo and Mungoma 2008), in CA by Uri (1997), and in environmental programs by Ma et al. (2012) and Saz-Salazar and Rausell-Köster (2008).

Cragg's double hurdle model can be specified as follows:
Participation/adoption equation: $y_{i1}^{*} = x_{1i}^{'}\alpha + u_i$
Proportion/intensity equation: $y_{i2}^{*} = x_{2i}^{'}\beta + v_i$
In these specifications:

- y_{i1}^{*} and y_{i2}^{*} are the two latent variables of adoption and intensity;
- x_{1i} and x_{2i} are vectors of household characteristics determining the adoption and intensity decisions, respectively;
- α and β are coefficients to be estimated;
- u_i and v_i represent the respective error terms, which are assumed to be independent and normally distributed with $u_i \sim N(0, 1)$ and $v_i \sim N(0, \sigma^2)$.

For our analysis, we estimated both Tobit and double-hurdle models for the purpose of comparison. In the double-hurdle model, the first tier and second tier are represented by the adoption and proportion equations, respectively. The dependent variable for the first tier is a dichotomous choice variable equal to 1 if the farmer is willing to adopt CA and 0 if not. As for the second tier, the dependent variable is the number of dunums that the farmer would enroll in CA, including 0 dunums. The first and second tier equations were specified by means of stepwise estimation using backward selection (Whittingham et al. 2006), mainly because this procedure allows to fit models with fewer variables having greater generality (Ginzburg and Jensen 2004). Stepwise procedure was also recently used to measure agricultural technology adoption (Yila and Thapa 2008).

In addition, the marginal effect of an independent variable x_j on the unconditional expected value of y (intensity of adoption) is estimated based on Burke (2009) according to the following equation:

$$\frac{\partial \mathrm{E}(y|x_1,x_2)}{\partial x_j} = \alpha_j \phi(x_1\alpha) \mathrm{X} \left\{ x_2\beta + \sigma \mathrm{X} \lambda\left(\frac{x_2\beta}{\sigma}\right) \right\}$$

$$+ \Phi(x_1\alpha)\mathrm{X}\beta_j \left[1 - \lambda\left(\frac{x_2\beta}{\sigma}\right) \left\{ \frac{x_2\beta}{\sigma} + \lambda\left(\frac{x_2\beta}{\sigma}\right) \right\} \right] \text{ if } x_j \epsilon\ x_1 x_2$$

Table 1 Information provided to farmers about the potential advantages and disadvantages of no-till farming

Benefits	Potential downsides
Significantly reduces costs for operating machinery and fuel	Can result in higher weed pressure and thus can require higher applications of herbicides
Increases soil moisture due to reduced evaporative losses	Crop residues must be kept on the field instead of being used as animal fodder or for some other purpose
Increases numbers of beneficial soil organisms, including earthworms	For maximum positive effects, no-till is best done in combination with well-planned crop rotations, and this can be complicated
Improves soil water infiltration	
Reduces soil compaction	
Increases the level of soil organic matter	
Reduces soil erosion	
Can lead to increased yields, especially in the long run	

Source: Knowler and Bradshaw (2007) and Powlson et al. (2014)

Whereby:

- If $x_j \in x_1$ then $\beta = 0$
- If $x_j \in x_2$ then $\alpha_j = 0$
- y is the latent variable of intensity
- x_1, x_2 are vectors of household variables determining the decisions of adoption and intensity
- x_j is an independent variable
- α_j and β_j are coefficients to be estimated
- ϕ is the standard normal probability distribution function
- Φ is the standard normal cumulative distribution function

Survey Questionnaire and Administration

A total of 151 farming households that grow wheat were randomly selected to participate in the survey in the Beqaa region. The survey was administered face-to-face with the farmers at their homes or on the land where they work. Wheat farmers were specifically sought due to the importance of the crop in ensuring the country's food supply, and Beqaa is the main wheat production region in Lebanon. The survey was conducted with farmers located in the Caza of Baalbeck, where AUB's Advancing Research Enabling Communities (AREC) is situated, and the nearby Caza of Zahle. The survey was conducted over a three months period from May to July 2013.

The survey questionnaire was composed of four sections. The first aimed at screening out respondents who did not meet the following criteria: being aged 18 or above, being a tenant or owner of the land, growing wheat on all or part of the land, and having not applied any form of CA. The second section included questions related to farming practices and knowledge. Farmers were asked about their farming experience; the sources of information such as extension services (through governmental and/or non-governmental organizations, agrochemical companies, radio, internet, other farmers, trial plots, etc.), trainings, their contact with extension agents and quality of the information received; various costs of wheat production (seeds, irrigation, herbicides, fertilizers, tillage); trends in their wheat yields; access to finance; and whether they had any prior knowledge of CA. The variable "farming experience" is treated as categorical rather than as continuous. This is because past studies have shown that the direction of the relationship between experience and CA adoption has not always been clear (Kurkalova et al. 2006; Soule et al. 2000; Uri 1998). The survey was thus designed to capture any potential non-linear relationship between experience and CA adoption decision. Accordingly, this variable was subdivided into three categories: <15 years (loosely representing younger farmers), 16–24 (loosely representing middle age farmers), and >25 years (loosely representing older farmers). Such classification is particularly important to understand the effect of experience/age toward CA because the potential yield benefits are likely to be attained in the long-term, and farmers may experience reduced yield up to 15 years if implemented in degraded soil conditions (Giller et al. 2011). We expect the relatively younger farmers to be more willing to adopt CA compared to older farmers because the former expect to live longer to witness the fruits of CA.

Before proceeding to the third section the interviewer provided each farmer with an informative brochure detailing potential advantages and disadvantages of CA (Table 1), which we developed based on Knowler and Bradshaw (2007) and Powlson et al. (2014). In addition, the brochure explains how to apply CA, where it is applied in the world and in the Middle East region, and results from trials conducted in Lebanon and Middle East region showcasing the resulting reduction in farming costs and increase in yields.

Table 2 Variable definition

Category	Variable	Measurement	Definition
Source of information	Contact with extension agent over the last 10 years	Dummy	1, if yes; 0, otherwise
	Access to farm practice information through public extension services	Dummy	1, if yes; 0, otherwise
	Access to farm practice information from agrochemical companies	Dummy	1, if yes; 0, otherwise
	Access to CA training in the last 10 years	Dummy	1, if yes; 0, otherwise
Farming and land characteristics	Experience in wheat farming (15 or less years)	Dummy	1, if yes; 0, otherwise
	Experience in wheat farming (16–24 years)	Dummy	1, if yes; 0, otherwise
	Experience in wheat farming (25 or more years)	Dummy	1, if yes; 0, otherwise
	Weed problem in wheat farming	Dummy	1, if yes; 0, otherwise
	Soil fertility decline in the last 10 years	Dummy	1, if yes; 0, otherwise
	Frequency of wheat field irrigation	Continuous	Number of irrigations per season
	Quantity of fertilizer used for wheat growing	Continuous	Fertilizer used in Kg per dunum per season
	Additional laborers required in wheat growing	Continuous	Number of days additional laborers participated in wheat growing per season
	Continuous use of a rented in land for wheat growing	Continuous	Number of years a rented in land was continuously used
	Size of arable land rented in	Continuous	Land size in dunum
Perception about CA	Positive perceptions on the effect of CA on wheat yields	Dummy	1, if yes; 0, otherwise
	Positive perceptions on the effect of CA on cost savings	Dummy	1, if yes; 0, otherwise

The interviewer went over the brochure with the farmer to ensure that the information was well received and that the farmer would be able to provide informed answers in the third section of the survey related to the willingness to adopt CA.

In the third section, farmers were asked about their perceptions on CA and their intention to adopt it, whether they believe that CA can lead to lower costs and higher yields, whether they would adopt CA without any external support and over what proportion of their land. Farmers were asked their perceptions on CA mainly to verify the validity of the model against the hypothesis that farmers who think CA is useful are more likely to adopt CA on larger tracts of their land; that is, the expectation that the coefficients for perceived CA usefulness are positive in both the adoption and proportion equations. In addition, the survey questionnaire included a question on the potential sources of information such as extension services through governmental or non-governmental organizations, agrochemical companies, radio, internet, other farmers, and trial plots.

Finally, section four included socio-demographic questions related to farmers and their households including gender, marital status, age, educational level, farming experience, sources of income, average household income, number of workers employed, dunums of land rented in and/or owned and household size. The definition for the variables is provided in Table 2.

Of the 151 completed survey questionnaires three were dropped from the estimation sample as the respondents had already applied CA on their land and thus could not be included.

Model Specification

The double-hurdle model used in this paper nests the Tobit specification. Accordingly, a likelihood-ratio (LR) test was conducted to select the best model. Based on the results it was found that the LR statistic is significant at the 1 percent significance level leading us to adopt the double-hurdle model as our preferred model.

Results and Discussion

Descriptive Statistics

Only 1.35% of respondents were women, and over 80% of the respondents were aged 40 and above reflecting

Table 3 Descriptive statistic of factors that affect farmers' willingness to adopt CA ($n = 148$)

Variable	Percentage/mean
Information source related factors	
Contact with extension agent over the last 10 years (% yes)	49.3
Access to farming practice information through public extension services (% yes)	46.6
Access to farming practice information from agrochemical companies (% yes)	24.3
Access to CA training in the last 10 years (% yes)	32.5
Farming and land characteristics	
Experience in wheat farming (15 or less years, % yes)	31.1
Experience in wheat farming (16–24 years, % yes)	20.3
Experience in wheat farming (25 or more years, % yes)	48.6
Weed problem in wheat farming (% yes)	88.5
Soil fertility decline in the last 10 years (% yes)	45.3
Frequency of wheat field irrigation (irrigations per season)	3.45
Quantity of fertilizer used for wheat growing (Kg/dunum)	46.1
Additional laborers required in wheat growing (days/season)	72.3
Continuous use of a rented in land for wheat growing (years)	4.3
Size of arable land rented in (dunums)	333.2
Perception about CA	
Positive perceptions on the effect of CA on wheat yields (% yes)	37.2
Positive perceptions on the effect of CA on cost savings (% yes)	56.8

the diminishing interest of the new generation in the Beqaa region in agriculture, probably due to its low and unstable economic returns. This is confirmed by the fact that 66.25% of respondents who agreed to provide us with their monthly income mentioned that it did not exceed 1000 USD per month which is considered insufficient, according to Lebanese standards of living, to fully provide for a whole family. Since all farmers were concentrated in the same age span, farming experience was observed as a variable that would affect their decision. Farmers with over 25 years of experience constituted the biggest portion of the sample (47%).

Although education was used to separately capture the effect of formal education from other type of trainings such as participation in extension programs, it did not play a major role in affecting farmers' willingness to adopt CA as only 24.78% of those who mentioned they were ready to adopt CA had tertiary level education. In fact, education as well as other socio-demographic variables (including age, household size, income and number of dunums planted with wheat) turned out not to be significant in determining farmers' willingness to adopt CA. Table 3 displays the variables that were included in our model.

Adoption Status of CA and its Intensity at the Household Level

The estimation results on the adoption status of CA and its intensity are presented in Tables 4 and 5, respectively. The estimation coefficients and their corresponding test statistics are presented as well as the unconditional average partial effects (UAPE), which are the combined effects of both decision stages, namely the decision to adopt and the conditional average partial effect if the initial adoption decision is positive (Fernández 2010). Tables 4 and 5 present the estimation results of the adoption equation (Tier 1) and the proportion equation (Tier 2), respectively. In the latter, the coefficients measure the effect of the independent variables on the amount of land farmers are willing to enroll in CA, unconditional on expressing their willingness to adopt CA.

The determinants of adoption and intensity were selected through a stepwise regression performed in both first and second stage equations using backward stepwise selection as described in section 2. Demographic indicators such age, gender (since most respondents were male), income and education turned out to have no significant effect both on the decision to adopt and the intensity of adoption.[2] Age was proxied by farming experience in the aim of finding a correlation with adoption and showed that farmers with greater farming experience were less likely to adopt CA than their younger counterparts and in lower intensities. The interpretation of UAPE should, therefore, take into account the results of Tier 1 and Tier 2. For example, the result shows farmers with 16–24 and 25 or more years of experience were less likely to adopt CA than the farmers with <15 years of experience. The UAPE indicates that, in

[2] For this study, intensity of adoption is defined as the amount of farm area (dunums) that farmers are willing to enroll in CA (no-till farming)

Table 4 Probit estimation results for farmers' willingness to adopt CA (Tier 1)

Variables	Model		Marginal effect	
	Coefficient	*p*-value	Coefficient	*p*-value
Information source related factors				
Presence of contact with extension agent over the last 10 years ($y = 1$))	−0.680	0.034	−5.015	0.147
Access to farming practice related information from public extension services ($y = 1$)	0.623	0.072	4.592	0.008
Access to farming practice related information from agrochemical companies ($y = 1$))	−0.740	0.032	−5.451	0.133
Farming and land characteristics				
Experience in wheat farming, 16–24 years, ($y = 1$)	−0.825	0.041	−6.080	0.123
Experience in wheat farming, 25 or more years, ($y = 1$)	−0.537	0.096	−3.955	0.213
Presence of weed problem in wheat farming ($y = 0$)	1.060	0.064	7.813	0.008
Frequency of wheat field irrigation (per season)	0.189	0.110	1.390	0.264
Dummy variable including all missing values of frequency of wheat field irrigation	−0.215	0.771	−1.585	0.705
Quantity of fertilizer used for wheat growing (Kg/dunum)	−0.013	0.078	−.095	0.952
Additional laborers required in wheat growing (days/season)	0.041	0.096	0.301	0.834
Perceptions about CA				
Presence of positive perception on CA in improving wheat yields ($y = 1$)	0.566	0.067	4.174	0.007
Presence of positive perception on CA in cost savings ($y = 1$)	0.390	0.144	2.874	0.050
Constant	0.752	0.159		
Observation	148			

the absence of *ex ante* knowledge of the willingness to adopt status, farmers with 16–24 and 25 years or more experience in wheat farming are expected to enroll 14 and 34 dunums less in CA than the farmers with 15 years or less experience in wheat farming, respectively. This, however, has little to do with the farmers negative or positive learning experience related to CA. Rather the result implies difference in risk preferences between younger and older farmers with the latter likely to be more risk averse and stay away from CA. Generally, we find evidence of non-linearity in the adoption equation, with the probability of adoption decreasing between the <15 year and 16–24 year categories, increasing slightly between the latter and 25 year or more category but remaining negative. This suggests that younger or less experienced farmers might be more open to innovation. This result is not surprising given the limited level of experience on CA in the region. It is likely that older farmers may lack confidence about the performance of CA and may shy away from greater levels of adoption.

Technology adoption theory more clearly suggests that farm size positively correlates with adoption, since larger farmers have a greater capacity to undertake additional investments that entail technological changes (Haghjou et al. 2014). Furthermore, greater endowment with land tends to reduce risk aversion and enhance openness for innovation (Just and Zilberman 1983). In our model, farm size was approximated by rented in land due to the high correlation between rent and ownership. We opted for the former as wheat farming in the region is largely practiced on a rented land. Indeed, farm size was a significant determinant of intensity of adoption as farmers with larger rented in lands mentioned their willingness to adopt CA on larger portions than the ones with smaller rented in lands. The UAPE shows that for each additional dunum of land rented in, the area for CA adoption increases by 0.02 dunum. As noted earlier, this result requires a careful interpretation as this relationship may be picking up some of the effects of land ownership. With regards to farming practices, farmers who have not had weed infestation for over 10 years were more likely to mention that they would adopt CA compared to those farmers with high weed problems in the past. Although the latter have more experience on weed management and thus more likely to adopt CA, the result shows otherwise. Perhaps, farmers with existing weed infestation are concerned of having more weed problems as they were informed of the possibility of higher weed pressure with the adoption of CA and thus a consequent use of higher level of herbicides. Also, frequency of irrigation is positively (but marginally) correlated with the likelihood of adoption. This implies the farmers' tendency toward a sustainable water use system in food production as CA improves soil water infiltration and soil moisture (due to reduced evaporative

Table 5 Cragg estimation results for the amount of farm area farmers are willing to enroll in CA (Tier 2)

Variables	Model		UAPE	
	Coefficient	*p*-value	Coefficient	*p*-value
Information source related factors				
Access to CA training in the last 10 years (y1)	157.075	0.176	10.692	0.000
Farming and land characteristics				
Experience in wheat farming, 16–24 years, ($y=1$)	−117.420	0.419	−14.073	0.003
Experience in wheat farming, 25 years or more, ($y=1$)	−447.534	0.046	−34.420	0.000
Presence of weed problem in wheat farming ($y=0$)	319.638	0.054	29.571	0.000
Presence of weeds negatively affecting wheat yields ($y=1$)	−539.954	0.074	−36.756	0.000
Presence of soil fertility decline in the last 10 years ($y=0$))	−190.461	0.069	−12.965	0.000
Additional laborers required in wheat growing (days/season)	14.081	0.125	1.259	0.000
Continuous use of a rented in land for wheat growing (years)	0.625	0.911	.043	0.651
Dummy variable including missing values of continuous use of rented in land	363.272	0.033	24.729	0.000
Size of arable land rented in (dunum)	0.231	0.053	0.016	0.000
Dummy variable including missing values of size of arable land rented in	−609.860	0.048	−41.514	0.000
Perception about CA				
Presence of positive perception on CA in improving wheat yields ($y=1$)	662.713	0.015	49.286	0.000
Constant	−898.216	0.034	—	—
Sigma	126.515	0.000	—	—
Observation	148			
LR χ^2	−530.403	0.040		
LR test against tobit specification	278.5	0.000		

losses) and thereby reduces the need to frequently irrigate the land. The UAPE shows that for each additional time farmers mention they irrigate their lands, the CA adoption area is increased by 1.4 dunums.

Farmers who mentioned that they apply more fertilizers than others are less likely to adopt CA. This can be explained by the fact that the higher the farmers' reliance on fertilizers, the less their inclination to change farming practices. The UAPE shows that for each additional Kg of fertilizer applied per dunum per growing season, the CA adoption decreases by 0.1 dunum. This result could be explained by a lack of knowledge on CA. In fact, there is little evidence supporting the view that adoption of CA reduces the use of fertilizer (Gowing and Palmer 2008). Rather, a recent study by Vanlauwe et al. (2014) suggests "appropriate use of fertilizer" as a fourth principle of CA to enhance crop productivity and organic residue availability.

As is the case in our model, a number of studies show that a farmer's perception of the usefulness of a given technology is one of the most crucial factors affecting its adoption (Adesina and Baidu-Forson 1995; Morris and Potter 1995). Particularly, farm households' perceived economic benefits of a given technology are expected to have a positive impact on adoption (Baumgart-Getz et al. 2012). This was further confirmed in our study, whereby farmers who considered that CA would increase their yields had significantly higher propensity to adopt CA over a significantly larger portion of their land. The UAPE shows that farmers who believed that CA would increase their yields tend to adopt CA on 49 additional dunums compared to those who did not believe that their yields would increase. Although we did not directly ask for their attitude, farmers were also presented with the potential environmental benefits of CA in addition to its economic incentives (Table 1). Thus, their decision to adopt CA could also be influenced by its potential environmental benefits, and this is supported by past studies (Morris and Potter 1995; Wilson and Hart 2000).

Finally, we find the sources of information having a significant effect in the farmers' willingness to adopt CA (Table 4). Public extension services and agrochemical companies turned out to be the most important sources of information for the farmers. Farmers who had access to farming practice related information though the public

Table 6 Reasons for not willing to adopt CA ($N = 35$)

Why are not you willing to adopt CA?	Percentage (Yes)
I am skeptical about the facts which you have provided	54
I cannot afford the initial capital investment needed for conservation agriculture	43
I prefer to wait and see other farmers nearby try it out to make sure it works	40
I worry that reducing or eliminating tillage would reduce my wheat yields	31
I need more information and technical support to make a decision	17
The problems I face on my farm would not be addressed by conservation agriculture	14
I think that conservation agriculture would be more expensive than my current operations because I would need to spray more herbicides and/or use more hand labor for weeding	14
Conservation agriculture will increase the yield on my land only in the long-run, and I cannot afford to make this change without support in the short-run	11
Even if conservation agriculture works well in other places I do not think it would work well in this area	11
Conservation agriculture sounds too complicated	9
Soil erosion and water retention are not major problems for me	3
I currently use crop residues for other purposes such as feeding livestock, so I cannot leave a third of them or more on the ground	0
Other	17

extension services are more likely to adopt CA. This is in keeping with the existing literature; access to specific sources of information is strongly correlated with the adoption of agricultural technologies (Adesina and Baidu-Forson 1995; Khatoonabadi 2011). On the other hand, farmers who mentioned that they depended on agrochemical companies to receive extension services have a lower probability of adopting CA. This can be explained by a lack of knowledge about CA both by farmers who depended on agrochemical companies for extension services and providers of those services. Agrochemical companies may think that adoption of CA would allow farmers to stay away from the use of external inputs. CA is not a "green technology" that does not require the use of external inputs, as highlighted by Vanlauwe et al. (2014), but rather should be viewed as a complementary to agro-chemicals, such as fertilizer and herbicides. However, having contact with extension agents may not induce farmers to adopt CA or may affect CA adoption negatively. One explanation may relate to the quality of information (Baumgart-Getz et al. 2012). General purpose extension services may not be sufficient to promote the adoption of CA by farming households. This might particularly be the case when a large number of farmers seek extension services and when extension workers involve in non-knowledge transfer activities (Anderson and Feder 2004). Our findings show that farmers who mentioned that they obtained farming practice related information from public extension agents have a higher probability of adopting CA than those farmers who simply mentioned that they had contact with extension workers (public or private).

In addition, farmers who reported their intention not to adopt CA were asked a follow-up question regarding the reasons for their choice (Table 6). Accordingly, the majority of the farmers (54%) mentioned that they are skeptical about the anticipated benefits of CA. The second most important reason relates to a lack of finance; 43% of the farmers considered that the initial capital needed to implement CA is unaffordable. Also, 40% of the farmers expressed that they would need more time to evaluate the potential benefits of CA. Obviously, the decision (not) to adopt CA can be linked to a number of factors, which we have attempted to address through the econometric analysis discussed above. The agricultural technology adoption theory attributes such decisions to individual characteristics, the context of adoption and the characteristics of the technology (Morris and Potter 1995).

Conclusions

Our paper has analyzed the factors affecting farmers' willingness to adopt CA in Lebanon. The findings show that household characteristics alone were insufficient to explain CA adoption. Farming practices, such as frequency of irrigation and severity of weed infestation in the past, participation in specific trainings, experience in wheat farming, information sources, and farmers' perception about the long-term impact of CA, were key determinants of CA adoption. Based these findings, our paper provides several contributions relevant for the development of CA schemes in Lebanon and more generally the Middle East region.

First, studies on CA related to the Middle East are scant, and in some cases generalizations are made based on the findings elsewhere such as Sub Saharan Africa and Asian (Andersson and D'Souza 2014; Pircher et al. 2013; Stevenson et al. 2014). Nonetheless, context-specific factors are critical in applying new agricultural technologies, especially in regions prone to erratic rainfall, for effective adaptation and mitigation policy responses (Knowler and Bradshaw 2007; Lybbert and Sumner 2012). Building on this gap, this paper presents empirical evidence on context-specific variables related to the adoption of CA. Our findings show that farmers in the study area are more willing to invest in CA with the aim of attaining long-term benefits compared to the findings from Sub Saharan Africa, where CA (zero-tillage farming) approximately covers 0.3% of the total cultivated land (Derpsch et al. 2010). Other studies have also documented a very low level of CA in Africa (Giller et al. 2011; Giller et al. 2009). This is despite the encouraging results from on-farm farmer- and research-managed experiments that established increased yields and improved water productivity of CA in semi-arid and dry sub-humid areas of sub-Saharan Africa, such as in Ethiopia, Kenya, Tanzania, and Zambia (Rockström et al. 2009). This differing perception could be explained by the fact that water is scarcer in the Middle East than elsewhere and thus farmers in Lebanon and the region are likely to seek a more sustainable solution to the problem.

Second, FAO has put a renewed interest in CA and the factors affecting adoption decision (Knowler and Bradshaw 2007). Due to its wider implications for food availability, our study focuses on wheat crop to understand farmers' decisions to adopt CA. Wheat is widely considered a strategic crop for food security in Lebanon and the Middle East. Based on a 25-year long experiments, Zwart and Bastiaanssen (2004) claim wheat as one of the few crops capable of producing more food with a limited amount of water by increasing water productivity. In regions where the amount of water is limited combining CA practices with crops that use lower irrigation water will have important policy impaction for ensuring food supply. Our study contributes to this discussion by showing the willingness of wheat farmers to adopt CA, which would further encourage policymakers to promote wheat crop production as a viable form of sustainable agriculture in the region.

Third, several studies report the positive contribution of extension services in promoting CA. Indeed, our findings show that access to extension services having a significant correlation with the farmers' willingness (not) to adopt CA. However, the direction of the relationship appears to vary and differs depending on the type of institution providing extension services. We find that extension services being strongly associated with the willingness to adopt CA. Farmers who had access to information through public extension services (government or non-governmental organizations) are more likely to adopt CA. In fact, the government sponsored extension is reported to be weak and is only re-structured recently, according to the Lebanese Ministry of Agriculture (MOA 2014). However, there are several NGOs providing extension services in Lebanon (Moses 2011), and this appears to have a positive contribution toward CA adoption. However, the failure in the public extension delivery system in the past has created high dependency on private input providers, and even some argue, to excessive use of pesticides and chemical fertilizers by farmers (Qamar 2010). In our study, farmers who had received agricultural information from agrochemical companies expressed their willingness not to adopt CA. Perhaps these farmers may have a presumption that adopting CA means low crop yields because of low use of inputs such as fertilizer. Indeed, there is little evidence supporting this view and, in fact, CA can induce the use of fertilizer to enhance crop productivity and organic residue availability (Gowing and Palmer 2008; Vanlauwe et al. 2014). In view of this, our paper would inform policymakers to promote CA as a sustainable food production system by educating farmers and stakeholders about the principles of CA, and its potential costs and benefits. Furthermore, with an increasing pressure by consumers and public agencies toward a sustainable food supply system, this paper informs agribusiness firms to promote CA as a viable alternative to strengthen business relationships with farmers in arid and semi-arid regions.

Our study provides some insights into the factors contributing to wheat farmers' willingness to adopt CA in Lebanon and policy implications toward sustainable agriculture in the region. Future research can extend this by exploring more context-specific variables in the region. Further research may also use different techniques, such as random control trials, and longitudinal survey to evaluate the impact of adopting CA on yield, cost-reduction, and environment in the Middle East region.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

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