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Research article

An overview of Conservation Agriculture in the dry Mediterranean environments with a special focus on Syria and Lebanon

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Abstract: Conservation Agriculture (CA), comprising minimum or no mechanical soil disturbance through no-till seeding, organic soil mulch cover, and crop diversification is now practiced on some 157 million ha worldwide, corresponding to about 11% of the global cropped land. CA adoption in the Middle-East is low compared to other regions. Lack of knowledge on CA practices and systems discourages farmers from giving up ploughing. The main reason why farmers in the Middle-East have begun to apply the no-till system has been the cost reduction in fuel, labor and machinery required for land preparation. Soil and water conservation concerns do not appear to be the main drivers in the Middle-Eastern farmers' decision to adopt or not to adopt CA. The adoption and uptake of CA by Middle Eastern farmers has been slow but it is nonetheless occurring gradually. Collection of information and research parameters related to agricultural practices are needed for designing a suitable soil and water conservation program for sustainable production intensification. Governmental policy encouraging the adoption and spread of CA systems in the Middle-East region is certainly a necessary condition for uptake. The objective of this article is to review the current status of adoption and spread of CA in the Middle-East, focusing mainly on Syria and Lebanon, and the potential beneficial consequences that can be harnessed through CA systems under rainfed conditions in both countries. The benefits include: higher factor productivity, yield and income; improved soil properties; climate change adaptation, including reduced vulnerability to the erratic rainfall distribution; and reduction in machinery, fuel and labor costs.

Keywords: no-till seeding; conventional agriculture; precipitation use efficiency; crop productivity; inputs costs; rainfed conditions; Middle-East

Abbreviations:

CWANA	Central and West Asia and North Africa
ACSAD	The Arab Center for the Studies of Arid Zones and Dry Lands
GIZ	German International Technical Cooperation
FAO	Food and Agriculture Organization
SOM	Soil Organic Matter
ZT	Zero Tillage
CA	Conservation Agriculture
CT	Conventional Tillage Agriculture
NT	No Till
RWUE	Rain Water Use Efficiency
AREC	Agricultural Research and Educational Center
LARI	Lebanese Agricultural Research Institution
AUB	American University of Beirut
US	United States of America
NGOs	Non-Governmental Organizations
ACF	Action Contre la Faim

1. Introduction

The precipitation in the dry Mediterranean environments is received as rain or snow during the autumn, winter and spring period from October to May in the northern hemisphere and from April to November in the southern hemisphere. Precipitation can range from some 200 to 600 mm annually, corresponding to a reference average length of frost-free crop growing season of 90–150 days, with relatively high precipitation variability within and between seasons [1]. The Central and West Asia and North Africa (CWANA) region in general, and the Levant region (Syria, Lebanon and Iraq) in particular, was once the breadbasket of civilizations, and food production from the region sustained the most powerful empires of the ancient world, such as the Roman empire. Yet, already during those ancient times tillage-based agriculture led to soil erosion and degradation resulting in reduced human carrying capacity of the land and to land abandonment [2]. Thus, most agricultural soils in the dry climates of the Mediterranean basin today have low organic matter (OM) status (less than 1%) with poor soil aggregate structure [3], and the predominant land use practices such as tillage, overgrazing and exposed bare soils continue to worsen the situation. In the long run, this can only lead to severe land degradation, and finally to desertification, as can be observed in many parts of the region [2]. Such consequences arise from these land use practices through a combination of factors, including: negative annual water balance, short and variable rainy season, loss of organic matter and soil structure as well as soil salinity, land degradation from wind and water erosion, and extreme temperatures [4–6].

The conventional methods of farming applied in the Middle-East consist of continuous intensive tillage [7] and removal or grazing or burning of crop residues [8], leading to decrease in soil fertility [9–10], increase in drought stress [11], and decrease in the production capacity of the agro-ecosystem [12–14]. It is well known that Conservation Agriculture (CA) is an effective method to reduce soil degradation and rehabilitate soil health [15]. CA is characterized by three linked principles [16]: (1) Continuous no or minimum mechanical soil disturbance: Soil disturbance in all operations has to be avoided as much as possible through no-till seeding; (2) Maintenance of permanent organic soil mulch cover: This refers to mulch cover on the soil surface from crop residues and cover crops; and (3) Diversification of crop species grown in sequences and/or associations: This refers to rotations and associations of annual and perennial crops, including legumes for their ability to fix nitrogen and improve soil structure and nutrient cycling. In general, these three core practices of CA, formulated within the local biophysical and socio-economic conditions, are considered to underpin the ecological sustainability of crop production systems. To achieve production intensification, these core CA practices need to be strengthened by the integration of additional best management practices applied in a timely and efficient manner, particularly: (i) use of well adapted good quality seeds; (ii) enhanced and balanced crop nutrition, based on and in support of healthy soils; (iii) integrated management of pests, diseases and weeds; (iv) efficient water management; and (v) appropriate equipment and machinery [17].

This paper provides an overview on the use of no-till CA farming in the Middle-East region and highlights the major reasons why CA has not as yet spread widely. The practice of zero tillage (ZT) has been applied by farmers and some research centers in the region for a long time [18], but the modern concept of CA (combining all three principles mentioned above) was applied for the first time in Syria and Lebanon through the joint work of AUB, ACSAD, GIZ, and FAO in 2007–2008 growing season at research stations and in farmers' fields (25 ha in Syria and 5 ha in Lebanon). CA practices were formulated to meet farmers' needs and local conditions, taking into account soil properties, prevailing environmental conditions, marketing demands and marketing value of the introduced leguminous crops in the crop rotation, livestock demands for crop residues and prices of external inputs. Due to the tremendous increase in the prices of fuel, fertilizers and herbicides in the Middle-East in general and in Syria and Lebanon in particular as a result of the ongoing conflict in the region, accompanied by the devaluation of the local currencies, CA system is becoming increasingly relevant for addressing the needs of small resource-poor farmers. Further, it is a powerful tool for enhancing farmers' income, food security, poverty alleviation, and addressing labor shortages and high energy costs. According to the FAO global data base [19], during the last 11 years CA worldwide has expanded at an average rate of about 7.5 million ha per year from 45 million ha in 1999 to some 157 million ha in 2013, about 11% of global cropland [20]. In the Mediterranean basin, the total cropland under CA is still modest in several countries (Table 1). These include Spain, Portugal, France, Greece and Italy in Europe; Morocco and Tunisia in North Africa; and Iraq, Lebanon, Syria and Turkey in West Asia [20]. In Italy, Spain, Lebanon and Syria, CA adoption has occurred in orchard crops such as olives, grape vines and apples. Applied and adaptive research work on CA has also produced promising results in several countries in Central Asia and the Caucasus where it is spreading in countries such as Azerbaijan (1,300 ha), Uzbekistan (2,450 ha), Kazakhstan (2 million ha), and Kyrgyzstan (700 ha). In Kazakhstan, CA farming extends over a significant area because there has been effective government support for CA [20].

Table 1. Extent of adoption of Conservation Agriculture in countries of the Mediterranean basin in 2013 [20].

Country	Area under CA (thousand ha)
France	200
Greece	24
Iraq	15
Italy	380
Portugal	32
Spain	792
Syria	30
Tunisia	8
Turkey	45
Morocco	4
Lebanon	1
Total	1,531

2. Materials and Methods

2.1. Location of field trials

Field trails were conducted in the north east region of Syria (AL-Hassakha and AL-Raqa'a), as a part of a joint developmental project between ACSAD and ACF to increase the adaptive capacity of the agro-ecosystems to drought stress and improve the livelihood of the poor farmers in the region through the introduction of CA production systems. Other field trials were obtained from experiments conducted at AREC and LARI research stations in Lebanon in a collaborative work among GIZ, ACSAD and AUB.

2.2. Weather, cropping systems and soils

The climate in the targeted regions is typically Mediterranean with hot dry summers and cold wet winters, and with the amount and pattern of rainfall and temperatures fluctuating widely from year to year. The average annual air temperature is 19.5 and 18.7 ºC in the study regions in Syria and Lebanon. The average annual rainfall (1989–2013) in the AL-Hassakha and AL-Raqa'a regions of Syria is 355 mm and 400 mm, respectively; in the Lebanon region, the average annual precipitation is 550 mm. The rainfed cropping season usually begins in October–November and extends to May–June. Wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* M.) are the main rainfed crops in the region. The main soils of the targeted regions in Syria and Lebanon have been classified as vertisols, aridisols and inceptisols and are generally low in soil organic matter (SOM), nitrogen (N) and plant-available phosphorus (P), have a clay texture (50–70% clay), with a pH around 6.5–8. Soil water infiltration rates and saturated hydraulic conductivity are moderate to low when the soil is wet. The amount of plant-available water between permanent wilting point and field capacity varies between 90 and 140 mm in the upper meter of soil, with a rooting depth of about 1.4 m at Lebanon research stations (AREC and LARI), 1.30 m at AL-Raqa'a region (Syria) and 1.25 m at AL-Hassakha region (Syria).

2.3. Experimental design and management

Prior to commencement of each trial, the area had been cropped over many years with a range of cereal and legume crops under a conventional cultivation system. All the trials in Syria were conducted in the farmers' fields that were selected based on certain criteria and provided with all the required materials (improved seeds, fertilizers, herbicides and CA seeders) to apply CA system as a holistic approach. The farmers' fields were divided into two halves, one cultivated with CA and the other with the conventional/traditional farming system (CT). The aim of the trials, which commenced in 2009 in Syria, was to evaluate the effects of tillage (CA versus CT) on the performance and profitability of cultivated crops in a four-course rotation of wheat, chickpea, barley and lentil which was repeated four times so that each crop was present in the field each year. The trials followed a split plot design with tillage practice as main plots and crops as subplots (150 farmers: 90 in AL-Hassakha and 60 in AL-Raqa'a). The cultivated area for each farmer varies from 0.5 to 0.8 hectares depending on the crop and area provided by the selected farmer. Tillage treatments remained on the same plots and the crops were rotated through these each year in a wheat-chickpea, barley-lentil, or wheat-lentil or barley-chickpea sequence depending on the farmer and the marketing value of the cultivated leguminous crop in the region. There was no removal of crop residues (straw, leaves, chaff, seed pods) from wheat, chickpea or barley plots during or after the machine harvesting operation. Lentils were harvested manually in accordance with local practice to reduce pod losses, with mature plants pulled by hand at ground level and machine threshed, with crop residues not returned to plots. Generally, 30% of crop residues left on the soil surface was strictly respected for farmers who refused to leave the whole crop residues to be used for feeding of their animals during the summer. The CT treatments, in accordance with local farmer practice to "prepare a seedbed" and control weeds, involved mouldboard ploughing to about 20–25 cm after cereals or disk ploughing to about 10 cm after legumes soon after harvest in June or July, followed by one or two shallow cultivations with a tine cultivator before sowing in the autumn. There was no cultivation with CA treatments, which were sown directly into the undisturbed soil. All plots were sown with the same CA seeder each year. The seed rates for all crops were 120 kg ha^{-1} for the bread wheat (Cham6 variety), 100 kg ha^{-1} for barley (Arabi Aswad variety), 80–100 kg ha^{-1} for chickpea (Ghab4) and 100–120 kg ha^{-1} for lentil (Balady variety), for the trails conducted in Syria. All the plots of the different crop species were sown after the first germinating rains (late October-mid November); CA and CT treatments were sown at the same time for each farmer's field. Crops received a basal fertilizer of 150 kg ha^{-1} di-ammoniumphosphate (18% N, 46% P_2O_5) for cereals and 150 kg ha^{-1} triplesuperphosphate (46% P_2O_5) for legumes. Cereals received an additional 50 kg ha^{-1} N (46% N urea) around mid-tillering, 2–3 months after sowing. Post-sowing weeds were controlled with selective herbicides (pre-emergence Stomp at 2 L ha^{-1} in lentil and chickpea); (post-emergence Express at 15 g ha^{-1} for broadleaf weeds plus Ralon Super at 650 ml ha^{-1} for grass weeds in wheat and barley); (post-emergence Challenge at 500 ml ha^{-1} for broadleaf weeds plus Super Verdict at 600 ml ha^{-1} for grassweeds in lentil and chickpea). Occasional outbreaks of Ascochyta Blight in chickpea were controlled with post-emergence Bravo (chlorothalonil 500 g L^{-1}) at 2 L ha^{-1}. During the 2008–2009 growing season two trials were conducted at AREC and LARI (Lebanon) to evaluate the relevance of CA compared with CT in increasing the biomass yield, income and net revenue for barley and vetch, as individual crops, and for a vetch/barley mixture. The total area allocated for each individual trial was 10 ha in the two research stations. Thus, at AREC, a 10 ha area was divided into two halves, one for CA and the other one for CT. This whole area was cultivated with a mixture of vetch and barley (50 kg barley seed plus 50 kg vetch seeds ha^{-1} under CA and 60 kg barley seed plus 60 kg vetch seeds ha^{-1} under CT). At this same site, another area of 10 ha was also divided into two halves, one for CA and the other one for CT, with each half in turn divided into two halves, one for barley (100 kg ha^{-1} for CA and 120 kg ha^{-1} for CT) and the other one for vetch (100 kg ha^{-1} under CA and 120 kg ha^{-1} under CT) as individual crops. At LARI, a 10 ha area was divided into two equal plots (CA and CT treatments), which were cultivated with vetch alone (100 kg ha^{-1} under CA and 120 kg ha^{-1} under CT). At both research stations, all the plots were sown at the same time after the first germinating rains (mid-October), using a CA seeder for the CA treatment and the conventional method of cultivation for the CT treatment. At AREC, the trials followed a split plot design, with tillage practices as main plots and the vetch/barley mixture for the first trial, and individual barley and vetch crops for the second trial, as subplots. The trial at LARI followed a randomized complete block design with three replications. Fertilizers were not applied for barley subplots, while a small dose of 30 kg of N (46% N urea) was applied as a basal starter dose for the mixture subplots to meet the nitrogen requirements of the vetch seedlings during the initial growth till the formation of the adequate number of effective nodules.

2.4. Recorded parameters

Grain/seed yield was measured by harvesting whole plots at harvest maturity in May/June, using a large plot harvester for wheat, barley and chickpea or hand harvesting of plants and threshing with a stationary harvester for lentil. Rainwater use efficiency (RWUE) (kg mm^{-1} ha^{-1}) was calculated according to Oweis by dividing the economic yield by growing season precipitation (October to April) [21]. The percent reduction in working hour/labor time, seeding rate and fuel consumption was computed under CA compared with CT. The biomass yield of the individual barley and vetch crops and the vetch-barley mixture (t ha^{-1}) were recorded in the middle of May in the AREC and LARI trials. Soil samples were only collected from CA fields that were adjacent to conventional fields, in order to minimize the effects of natural soil variation in fields located far away from one another. A composite sample of 16 sub-samples was collected. Paired soil samples were collected from three sites at a depth of 0–20 cm. A pair consisted of one sample from a CA field and another from a conventional field for 50% of the farmers' fields in the same location/site. Soil samples in replicates of eight (8) were then subjected to chemical characterization. The soil samples were analyzed for total nitrogen [22], available phosphorus [23], soil organic matter content [24] exchangeable (K^+) [25]. A simple gross margin and benefit-cost ratio were calculated for each treatment using input and commodity costs and prices in northern Syria during the study period, coinciding with the outbreak of civil unrest, which cause a remarkable devaluation of Syrian currency. Kirkegaard et al. used a similar "simple economics" approach to effectively compare the profitability under CA compared with CT [26]. The variable costs included all inputs and operations for tillage, sowing, fertilizer application, weed control, harvesting, transport of grain/seed and transport of lentil residues. The cost of tillage operations in the CT treatments amounted to US$37 ha^{-1}. Crop residue prices in Syria vary depending on the time of year and local availability. The lentil residues removed in the hand harvesting operation were valued at 130US$ t^{-1}; the residues of wheat, chickpea and barley returned to plots in the machine-harvesting operation were not assigned an economic value.

3. Results and Discussion

3.1. Effects of CA on rainwater use efficiency (RWUE) and crop productivity

The results of field experiments in Syria (Table 2) show that the rainwater use efficiency (RWUE) was significantly ($p < 0.05$) higher under CA compared to CT for all the crops under rainfed conditions (average of experiments in six different provinces). This can be attributed to the reduction in water loss by evaporation under no-till conditions, so more water was available to the crop, which increased the productive loss of water (transpiration) and reduced the unproductive losses (soil evaporation, surface run-off and deep drainage), enabling crop plants to produce more total dry matter and more dry matter per unit volume of water (higher water productivity). The possible improvement of soil porosity and soil moisture holding capacity as well as the lowering of evaporation due to the soil mulch cover serves to buffer the plants from dry spells that frequently occur during the rainy season in dry Mediterranean climates. In dry Mediterranean Spain, elimination of tillage and maintenance of crop residues showed two to three fold increases in precipitation storage efficiencies [27]. Protecting the soil surface from direct impact of high-energy rain-drops (splash effect) prevents surface-sealing and surface soil particle dislodgement, thus maintaining the soil's water infiltration capacity, while at the same time minimizing water evaporation from the soil surface as reported by Mrabet in Morocco [28], Akbolat et al. in Turkey [29] and Ben Moussa-Machraoui et al. in Tunisia [30]. Results also show that on average RWUE was significantly higher in small grain cereals (barley and wheat) compared to food legumes (lentil and chickpea), but barley was found to be more efficient in using water (9.04 kg mm^{-1} ha^{-1}) than wheat (6.59 kg mm^{-1} ha^{-1}), and lentil significantly more efficient (3.86 kg mm^{-1} ha^{-1}) than chickpea (1.65 kg mm^{-1} ha^{-1}) (Table 2). The differences are attributed to the variation in crop productivity, because the average grain yield was significantly higher in barley (3,397 kg ha^{-1}) followed by wheat (2,711 kg ha^{-1}), while it was significantly lower in chickpea (848 kg ha^{-1}) (Table 2).

Table 2. Productivity and rainwater use efficiency (RWUE) of four crop species under rainfed conditions in Syria during the 2008–2009 growing season as affected by Conservation Agriculture (CA) and Conventional Tillage agriculture (CT).

Parameter	Wheat		Barley		Lentil		Chickpea	
	CA	CT	CA	CT	CA	CT	CA	CT
Productivity (kg ha^{-1})	2975^{B}	2447^{C}	3788^{A}	3005^{B}	1401^{D}	1021^{E}	931^{F}	764^{G}
RWUE (kg mm^{-1} ha^{-1})	$7.36B^{C}$	5.83^{CD}	10.14^{A}	7.95^{B}	4.23^{DE}	3.49^{EF}	1.93^{FG}	1.38^{G}

* Within the same file values denoted by the same letter are not significantly different at $p < 0.05$.

According to Lahmar and Triomphe, CA is perceived as a powerful tool of land management in the dry Mediterranean areas of the CWANA region [31]. CA allows farmers to improve the productivity of their crops and profitability, especially in dry areas, while conserving and even improving the natural resource base and the environment. Adoption of no-till systems permits farmers to plant directly after the onset of rains, or even dry planting, thus exploiting the entire rainy season. Timely weeding is important, as weeds compete for water. Results of three consecutive growing seasons (2011–2014) in Syria (joint development project between ACSAD and ACF-Spain) showed that the productivity of barley, wheat and lentil crops was significantly higher under CA (1,433 kg ha^{-1}) compared with CT (1,113 kg ha^{-1}) (Table 3). Results also show that the average increase in yield of barley, wheat and lentil under CA compared with CT was 31.3, 27.0 and 27.7%, respectively (Table 3). CA is not a low output agriculture but delivers sustainable yields that are greater than those obtained with modern tillage-based intensive agriculture. Yields tend to improve over the years with a simultaneous decrease in yield variations from one season to another, even under variable rainfall rates. Piggin et al. reported from results of trials conducted in Iraq that the average grain yield increases with no-till systems and early sowing when compared to CT and late sowing, were significant, namely 332 kg ha^{-1} (18%) for wheat, 127 kg ha^{-1} (20%) for chickpea and 135 kg ha^{-1} (15%) for lentil, but non-significant, 295 kg ha^{-1} (12%), for barley [32].

Table 3. Average crop yields under rainfed conditions over three consecutive growing seasons in Syria as affected by Conservation Agriculture (CA) and Conventional Tillage agriculture (CT).

Crop species	Productivity (kg ha^{-1})		Yield increase (%)
	CA	CT	
Barley	1,557^{A}	1,186^{D}	31.3
Wheat	1,489^{B}	1,172^{D}	27.0
Lentil	1,252^{C}	980^{E}	27.7

*Within the same file values denoted by the same letter are not significantly different at $p < 0.05$.

Results from Lebanon showed that the vetch yield was significantly ($p < 0.05$) higher under CA compared to CT in two different sites at the Beka'a plain, the Agricultural Research and Educational Center (AREC), which belongs to the American University of Beirut (AUB) and the Lebanese Agricultural Research Institute (LARI), which belongs to the Ministry of Agriculture. The yield of vetch and barley mixture at AREC was much higher than the yield of vetch as an individual crop under both CA and CT, keeping in mind that the yield of mixture was 32% higher under CA compared to CT (Table 4).

Table 4. Vetch and vetch/barley yield under Conservation Agriculture (CA) and Conventional Tillage agriculture (CT) at two sites in Lebanon during the 2008–2009 growing season.

Farming system	Vetch/barley yield (t hay ha^{-1})	Vetch yield (t hay ha^{-1})	
	AREC	AREC	LARI
CA	45.0^{A}	25.3^{A}	28.5^{A}
CT	34.0^{B}	17.5^{B}	24.0^{B}
Yield increase (%)	32.4	44.6	18.7

* Within the same column values denoted by the same letter are not significantly different at $p < 0.05$.

3.2. Effects of CA on soil properties

CA has been shown to be an effective management technique which can improve soil quality and fertility as well as yield and yield stability in the dry Mediterranean climate of Morocco [33–35], Spain [36–38], Tunisia [30], Iraq [32], Uzbekistan [39], Australia [40] and Syria [41]. Implementation of CA in the North East region of Syria at two sites (AL-Hassakha and AL-Raqa'a) over three consecutive growing seasons improved soil quality by increasing soil organic matter (SOM) content and soil fertility (NPK) (Table 5), thereby converting soils from being a source of CO_2 emission into an effective sink by increasing its capacity to sequester CO_2 [42]. Long-term research and practice has shown that after several years of CA, the soil has a higher amount of biological nitrogen than a tilled soil [43]. Overall, CA systems have a higher adaptability to climate change because of the higher effective rainfall and a better fit between the available growing period and crop growth cycle, so that crops under CA systems can continue towards maturity for longer periods than those under CT [6].

Table 5. Changes in soil chemical properties at two different locations in Syria (AL-Hassakha and AL-Raqa'a provinces) over three consecutive growing seasons (2011–2014) under Conservation Agriculture (CA).

Soil property	AL-Hassakha		AL-Raqa'a		Average	
	2011	2014	2011	2014	2011	2014
SOM (%)	0.45^{D}	0.60^{C}	1.38^{B}	1.55^{A}	0.91^{B}	1.07^{A}
N (%)	0.053^{C}	0.072^{B}	0.046^{C}	0.090^{A}	0.050^{B}	0.081^{A}
P (μg g^{-1})	2.70^{D}	4.23^{C}	4.40^{B}	6.23^{A}	3.46^{B}	5.31^{A}
K (μg g^{-1})	155^{D}	178^{C}	684^{B}	713.3^{A}	419.5^{B}	445.7^{A}

* Within the same file values denoted by the same letter are not significantly different at $p < 0.05$.

3.3. Effects of CA on fuel consumption

CA systems require much less input of energy per unit area, and per unit output, and lower depreciation rates for equipment and machinery. In a three-year experiment conducted in Syria at two sites to assess the relevance of CA as an alternative farming system to conventional tillage, there was a remarkable reduction in fuel consumption in the farmers' fields during the three growing seasons under CA compared with the CT system in both AL-Hassakha and AL-Raqa'a sites, the two targeted environments in the North East of Syria. The average reduction in fuel consumption was 45.9% for barley, 43.7% for wheat and 37.3% for lentil (Table 6). This reduction is caused by the reduction in the number of agricultural operations, since seeding and fertilizer application can be done in a single operation. The quantity of fuel consumption was significantly higher for lentils compared with barley and wheat (Table 6).

Table 6. Influence of Conservation Agriculture (CA) and Conventional Tillage agriculture (CT) on fuel consumption for different crop species in the North East of Syria.

Crop species	Fuel consumption (L ha^{-1})		Reduction under CA (%)
	CA	CT	
Barley	24.7^{E}	45.6^{B}	45.9
Wheat	24.6^{E}	43.8^{C}	43.7
Lentil	31.5^{D}	50.3^{A}	37.3

* Within the same file values denoted by the same letter are not significantly different at $p < 0.05$.

3.4. Effects of CA on seeding rate

Over time, less mineral fertilizers and seeds are required for the same output in CA systems. Production costs are thus lower, thereby increasing profit margins as well as reducing greenhouse gas emissions from tractor fuel [44,45]. In the experiment conducted in the North East region of Syria already referred, there was a gradual increase in the reduction percentage of seeding rate under CA compared with CT over three consecutive growing seasons, with average reductions of 35.2, 37.5 and 33.8% for barley, wheat and lentils, respectively (Table 7). This reduction in seeding rate under CA is mainly attributed to the use of direct drilling, where all seeds are placed at a suitable and uniform depth, so that all the viable seeds germinate and emerge (100% germination) compared with conventional tillage, where many seeds do not germinate due to uneven depth, and there is a tendency to use a higher seed rate as a compensation mechanism. Also, in the conventional system, some seeds remain on the soil surface, which may be eaten by birds, and some other seeds are placed into deeper soil layers, thus exceeding the potential length of the coleoptile.

Table 7. Average seeding rate for different rainfed crops under Conservation Agriculture (CA) and Conventional Tillage agriculture (CT) in Syria.

Crop species	Seeding rate (kg ha^{-1})		Seeding rate reduction under CA (%)
	CA	CT	
Barley	103^{CD}	159^{B}	35.2
Wheat	115^{C}	184^{A}	37.5
Lentils	98^{D}	148^{B}	33.8

* Within the same file values denoted by the same letter are not significantly different at $p < 0.05$.

3.5. Effect of CA on labor time

The positive impact of CA on the distribution of labor during the production cycle and, even more important, the reduction in labor requirements are the main reasons for farmers to adopt CA, especially for farmers who rely mainly or entirely on family manual labor. The reduction in on-farm labor requirements allows farmers in Syria and Lebanon to extend their cultivated areas, hire themselves out in off-farm employment, or diversify their activities. In the study conducted in the North East of Syria (AL-Hassakha and AL-Raqa'a) on 90 farm fields, the average reduction in the number of working hours observed under CA compared with CT, was 50.6% for barley, 55.2% for wheat and 52% for lentils (Table 8).

Table 8. Labor time under Conservation Agriculture (CA) and Conventional Tillage agriculture (CT) for different crops in the North East of Syria.

Crop species	No. of working hours (h ha^{-1})		Time saving under CA (%)
	CA	CT	
Barley	2.00^{E}	4.05^{C}	50.6
Wheat	1.98^{E}	4.44^{B}	55.4
Lentil	2.69^{D}	5.61^{A}	52.0

* Within the same file values denoted by the same letter are not significantly different at $p < 0.05$.

3.6. Effects of CA on production costs

Results from Syria (Table 9) revealed that during three consecutive growing seasons, the production costs for the three investigated crops (barley, wheat and lentil) were lower under CA than under CT. The average decrease in production costs under CA was 21.6% for barley, 23.3% for wheat and 17.5% for lentils, for all farmers' fields in the North East region of Syria (AL-Hassakha and AL-

Raqa'a). The reasons for lower production costs under CA were mainly due to savings in fuel and labor costs, i.e. cost of ploughing and land preparation. There was also observed an increase in the production returns (outputs) under CA compared with CT, which on average was of 31.3% for barley, 28.0% for wheat and 27.7% for lentils under CA compared with CT (Table 9). This increase could be attributed to the increase in the productivity per unit land area. It was also found that the average values of the outputs to inputs ratio were higher under CA (3.05, 3.11 and 7.85 for barley, wheat and lentil respectively) compared with CT (1.82, 1.86 and 5.07 respectively) (Table 9), indicating the importance of CA in increasing farm productivity, income and life quality of farmers. In general, a farmer who is planting CA-barley may get a net return of US$209.3 ha^{-1} compared to US$106.9 ha^{-1} under CT. Similarly, a farmer who is planting CA-wheat may get a net return of US$229.2 ha^{-1} compared with US$122.5 ha^{-1} under CT, and a farmer who is planting CA-lentil may get a net return of US$819.6 ha^{-1} compared with US$590.3 ha^{-1} under CT. Based on these results, it can be concluded that CA is a farming system more profitable than CT, with an average percent increase in the net return of 48.9% for barley, 46.6% for wheat and 28.0% for lentils for both AL-Hassakha and AL-Raqa'a. Piggin et al. showed that the increases in gross margins for wheat, chickpea, barley and lentils under CA were 162, 147, 89 and 176US$ ha^{-1}, respectively [32]. In chickpea, the most profitable treatment was ZT sown late, producing an extra 281 kg ha^{-1} and US$271 ha^{-1} compared with CT sown late.

Table 9. Average costs and economic returns under Conservation Agriculture (CA) and Conventional Tillage agriculture (CT) for different rainfed crop species in Syria over three consecutive growing seasons.

Crop species	Production costs (US ($ ha^{-1})		Production return (US$ ha^{-1})		Outputs/inputs ratio	
	CA	CT	CA	CT	CA	CT
Barley	102.1^{F}	130.3^{C}	311.4^{D}	237.5^{F}	3.05^{C}	1.82^{D}
Wheat	108.4^{E}	141.4^{B}	337.7^{C}	263.8^{E}	3.11^{C}	1.86^{D}
Lentils	119.5^{D}	144.9^{A}	939.1^{A}	735.3^{B}	7.85^{A}	5.07^{B}

* Within the same file values denoted by the same letter are not significantly different at $p < 0.05$.

Results from Lebanon (Table 10) agree with those obtained in Syria and showed that farmers may obtain higher net revenues when applying CA namely about US$400 per ha for barley and US$560 per ha for barley-vetch mixture.

Table 10. Average net revenue for barley and barley/vetch mixture under Conservation Agriculture (CA) and conventional Tillage agriculture (CT) in Lebanon (AREC) during 2008–2009 growing season.

Variable	Barley		Vetch/barley mixture	
	CA	CT	CA	CT
Production costs (US$ ha^{-1})	850	1200	800	1150
Income (US$ ha^{-1})	1940	1890	2250	2040
Net revenue (US$ ha^{-1})	1090	690	1450	890

4. Factors Limiting the Spread of CA in Syria and Lebanon

Although CA has been shown to save water, fuel and labor, and reduce the production costs, in addition to increasing net profit, the rate of adoption of CA in Syria, Lebanon and other Middle-East countries has been very slow and this may be due to the following constraints.

4.1. Unavailability of CA seeders

Lack of availability of proper machinery, mainly CA seeders, in addition to high prices of imported seeders, constitutes a major limitation. This problem was almost solved in Syria by promoting the local manufacturing of CA seeders. By the end of 2011 there were more than 10 local manufacturers in the North East region of Syria (Aleppo, Qamishli, Hassakha and AL-Raqa'a) who could produce CA seeders as good as the imported ones but at 50% of the price. The locally manufactured machines were also exported to many other Arab countries, such as Jordan, Iraq, Morocco, Lebanon and Tunisia.

4.2. Crop residue management

Some farmers burn crop residues to reduce seeding and crop establishment problems and weed infestation. This practice should be banned. In addition, crop residue is a major source of biomass for feeding and/or grazing animals. Thus, it is very important to get the balance right between the crop residue requirements of CA as an essential component of the system and the feed demand by livestock, especially during the summer time, after harvesting wheat and barley, which coincides with a shortage in fodder and forage resources for livestock. It is very important to conduct research work to define available options for allocating, over time, enough biomass to meet competing demands. This would involve the determination of the optimum quantity of crop residues to be left on the soil surface to establish conditions to achieve over time the socio-economic and environmental benefits of CA while ensuring the availability of some amount of biomass for livestock. The adaptation of CA in drylands faces critical challenges linked to water scarcity and drought hazard, low biomass production and acute competition between conflicting uses including soil cover, animal fodder, cooking/heating fuel, raw material for habitat, etc. Poverty and vulnerability of many smallholders that rely more on livestock than on grain production are other key factors.

4.3. Weed infestation

There is a perception that CA is "chemically-dependent" for weed control but in reality CA promotes integrated cultural weed management strategy. CA systems with minimum soil disturbance and effective residue management and crop rotations involving cover crops or green manure crops can be effective in suppressing weeds [40–46]. Weed control is often highlighted as a special challenge for CA, but it is a challenge in all production systems. More research is necessary to provide local solutions based on integrated weed management in CA systems that can keep the use of herbicides to a minimum or avoid it altogether where necessary or where possible.

4.4. Education

Farmers, scientists, and decision makers should be educated about the new technique to become convinced about its benefits through experimentation, because it is an entirely new farming system approach, and not just a shift from ploughing to direct planting. The whole production system under CA functions differently and all aspects have to be managed in line with the new biophysical and economic conditions that become manifest over time and space as the farmland is transformed from a degrading tillage-based system to a sustainable and more productive system. This has serious implications for education and training institutions that must become equipped to deliver CA-based theoretical and practical education and training.

4.5. Governmental support

Most of the governments in the Middle-East do not have policies to support farmers with CA mechanization or any subsidy system to encourage them to adopt the no-till CA system of production. This situation needs to be changed to reduce financial risks to the farmers and encourage them to engage in the transformation of their conventional agriculture.

4.6. Research

The amount of research that has been conducted on CA in the Middle-East is relatively limited and so is the information based on long-term experiments. The information about the use of herbicides to control weeds and research on crop residue management are scant and most farmers do not have enough knowledge about the proper methods for weed control, residue management, suitable varieties, optimum seeding rates, nutrient management and crop rotation, etc. Similarly, research is needed to formulate options for community-based livestock management systems that are compatible with the needs of managing CA-based crop-livestock integration as a win-win strategy.

5. Farmers Participation

Agricultural research is considered successful once the new technology is adopted by farmers and, in turn, generates positive impact on their livelihood. Farmers are similar to other groups of people; they become convinced once they see the results on their fields because "*seeing and doing is believing*". Farmers in Brazil and Argentina recognized that "soil erosion and degradation" is a major problem that needed resolution. They formed no-till farming associations and collaborated with the private sector trying to find solutions. The participation of farmers from the beginning, in the experimentation of no-till-based agriculture in Brazil, Argentina, Australia, US and Canada was very important and helped the development and spread of CA technology worldwide. In Lebanon and Syria, most of the CA field trials, during the past six years, have been conducted on farmers' lands and this arrangement helped their acceptance of the new method at a relatively faster pace than in the neighboring countries (Table 11).

Table 11. Development of no-till cultivation in Lebanon and Syria [47].

Year	Lebanon (ha)	Syria (ha)
2007/2008	4	25
2008/2009	560	250
2009/2010	1,100	800
2010/2011	1,500	5,000
2011/2012	1,700	10,000
2012/2013	1,300	18,000
2013/2014	1,100	35,000

Shifting agricultural practices from "traditional animal based subsistence" to "intensive chemical and machinery based agriculture" led to the declining of the organic carbon level in the soil [48]. The soil organic carbon level in most cultivated soils in Lebanon and Syria is less than 0.5 % compared to 1–2% or more in uncultivated virgin lands. The low concentration of soil organic carbon is due to the removal of crop residues, loss of soil carbon into the atmosphere due increased organic matter decomposition rate by ploughing and other form of mechanical tillage, and mining of soil organic form nutrients by mineralization. In many intensively farmed areas, deficiency of N, P and some micro-nutrients is common. Unfortunately, in Lebanon and Syria, many farmers still believe that summer-fallow/ ploughing is a good practice to improve land productivity, but it was proved by field trials [41] that zero tillage is more beneficial and economically more feasible. At AREC-AUB, in Beqaa, several cereal crops were planted following both CA and CT systems. The average yield for four years of trial in both systems was almost the same (no significant difference), but there was a saving in production cost of US\$160 ha^{-1} under no-till CA (Table 12). Knowing that the Lebanese farmers' net profit in wheat is about US\$400 ha^{-1}, this would increase the total net profit under CA to US\$560 ha^{-1}.

Table 12. Average production costs under Conventional Tillage agriculture (CT) and Conservation Agriculture (CA) for a cereal crop in Beqa'a plain, Lebanon.

Operation	Costs (US\$ ha^{-1})	
	CT	CA
Ploughing	100	0
Seed bed preparation	100	0
Planting	120	120
Seeds	200	200
Fertilization	250	250
Herbicide	60	100
Harvest	120	120
Others	100	100
Total	1050	890

According to the figures in Table 12, once 30% of agricultural land in Lebanon adopts CA system, there will be a saving of 1.3 million US\$ in production costs. This is in addition to the environmental benefits whose value may be greater than this number. In Syria, the increase in wheat yield after six growing seasons of CA implementation in the same farmers' fields was 21.4% (Table 13). What does that mean from the economic point of view? In an area that receives 300 mm of rainfall per cropping season, most productive farmers can harvest 2–3 tons of wheat grain per hectare. Adopting CA increased the wheat grain yield by 21%, corresponding to an additional amount of grain yield equal to 420 kg ha^{-1}. Keeping in mind that the total area cultivated with wheat (bread and durum) under rainfed conditions in Syria is 817,362 ha, the total additional wheat grain yield would be 817,362 × 0.420 = 343,292.04 tons. Since in Syria a tone of wheat grain sells for US\$400, the total gain would be about 1.4 billion US\$ if the whole rainfed wheat area is cultivated under CA. The same estimation can be made for barley and lentils under CA system.

Table 13. Yield increase over time for different rainfed crops in Syria under Conservation Agriculture (CA) with respect to Conventional Tillage agriculture (CT).

Growing season	Yield increase (%)		
	Wheat	Barley	Lentil
2008–2007	7.1	15.2	3.5
2009–2008	12.2	8.56	14.1
2010–2009	15.3	18.6	7.4
2010–2011	18.9	20	9.6
2011–2012	20.1	21.3	11.1
2013–2012	21.4	23.8	12.9

CA has been accepted by many agricultural scientists as a methodology for enhancing soil productivity, improving environmental quality and preserving natural resources. Adoption of CA is considered as a major step to prevent soil degradation and to rehabilitate fragile land to combat desertification. CA in Lebanon and Syria is still at its initial stage and it is expected to increase steadily, especially after the substantial increase in the price of fuel and external agricultural inputs (fertilizers and herbicides).

6. Conclusion

In Middle Eastern countries, about 40% of the people are involved in agricultural activities. Conventional farming has led to stagnant or declining agricultural production, land degradation, land abandonment, improper use of natural resources and high use of chemicals and fertilizers, causing damage to the environment and creating sub-optimal development conditions for agricultural economic growth. These countries are also experiencing high population increase, and their agriculture production sectors must cope with the impact of climate change. Decision makers should realize that conventional tillage-based cropping practices are no longer sustainable and cannot be relied upon to satisfy the ever-growing need for food security and ecosystem services. Another approach to sustainable agriculture intensification is needed. CA which is "a concept for resource management that strives to achieve acceptable profits" seems to be an appropriate climate-smart option.

In the Middle East there is a need to promote CA-based agriculture as both a short- and a long-term goal, and governments should include CA curriculum in extension training and formal education, support the transfer of this technology to farmers, facilitate access to the needed CA equipment and machinery, and allocate sufficient funds for research and extension programs to help farmers learn and apply this new approach and technology for sustainable intensification. The encouraging news is that in recent years, CA adoption and spread is beginning to move forward rapidly in the Middle East region and at a slow pace in the dry Mediterranean environments of CWANA region. Whereas a decade ago only a handful of countries in the CWANA region were actively promoting CA, today the situation has changed completely. Just about all the countries in the region are now promoting the adoption and spread of CA, with the involvement of national governments, NGOs, international and national research bodies and funding agencies. This effort must be encouraged and supported.

Conflict of Interest

All authors declare no conflicts of interest in this paper.

References

1. Kassam AH (1988) Some agro-climatic characteristics of high-elevation areas in North Africa, West Asia and Southeast Asia, In: Srivastava, J.P., Saxena, M.C., Varma, S., Tahir, M. (Eds.), *Winter Cereals and Food Legumes in Mountainous Areas,* ICARDA, Aleppo, Syria:1–32.
2. Montgomery D (2007) Dirt: *The Erosion of Civilizations*. University California Press, Berkeley, Los Angeles.
3. Lahmar R, Ruellan A (2007) Dégradation des sols et stratégies coopératives en Méditerranée La pression sur les ressources naturelles et les stratégies de développement durable. *Cahiers Agric* 16: 318–323.
4. Kassam AH (1981) Climate, soil and land resources in North Africa and West Asia, In: Monteith, J., Webb, C. (Eds.), *Soil Water and Nitrogen*. Martinus Nijhoff/Dr. W. Junk, The Hague: 1–29.
5. Ryan J, de Pauw E, Gomez H, et al. (2006) Drylands of the Mediterranean Zone: Biophysical Resources and Cropping Systems, in: Peterson, G.A., Unger, P.W., Payne, W.A. (Eds.), *Dryland Agriculture*, 2 Eds., *American Society of Agronomy* Monograph 23: 577–624.
6. Stewart BA (2007) Water conservation and water use efficiency in drylands. In: Stewart, B., Fares Asfary, A., Belloum, A., Steiner, K., Friedrich, T., Eds., *Proceedings of the International Workshop on Conservation Agriculture for Sustainable Land Management to Improve the Livelihood of People in Dry Areas*, 7–9 May 2007. ACSAD and GTZ, Damascus, Syria: 57–66.
7. Lal R, Reicosky DC, Hanson JD (2007) Evolution of the plow over 10,000 years and the rationale for no-till farming. *Soil Till Res* 93: 1–12.
8. Busari MA, Kukal SS, Kaur A, et al. (2015) Conservation tillage impacts on soil, crop and the environment. *Int Soil Water Conserv Res* 3: 119–129.
9. During RA, Thorsten H, Stefan G (2002) Depth distribution and bioavailability of pollutants in long-term differently tilled soils. *Soil Till Res* 66: 183–195.
10. Ali A, Ayuba SA, Ojeniyi SO (2006) Effect of tillage and fertilizer on soil chemical properties, leaf nutrient content and yield of soybean in the Guinea savanna zone of Nigeria. *Niger J Soil Sci* 16: 126–130.
11. Busari MA, Salako FK (2013) Effect of tillage, poultry manure and NPK fertilizer on soil chemical properties and maize yield on an Alfisol at Abeokuta, south-western Nigeria. *Niger J Soil Sci* 23: 206–218.
12. Corsi S, Friedrich T, Kassam A, et al. (2012) Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: A literature review, Integrated Crop Management (101pp.). Vol.16. Rome: AGP/FAO.
13. Busari MA, Salako FK (2015) Soil hydraulic properties and maize root growth after application of poultry manure under different tillage systems in Abeokuta, south western Nigeria. *Arch Agron Soil Sci* 61: 223–237.
14. FAO, Advancement and impact of conservation agriculture/no-till technology adoption in Kazakhstan. Information note. 2012. Available from: ftp://ftp.fao.org/ag/agp/ca/CA_CoP_March13/FAO_Info_note_on_CA_in_Kazakhstan.pdf
15. Miura F, Nakamoto T, Kaneda S, et al. (2008) Dynamics of soil biota at different depths under two contrasting tillage practices. *Soil Biol Biochem* 40: 406–414.
16. FAO, "Resources." *ESS Website ESS:* Web, 2013. Available from: http://www.fao.org/economic/ess/ess-publications/ess-yearbook/ess-yearbook2010/yearbook 2010-reources/en/

17. Kassam AH, Friedrich T, Derpsch R (2010) Conservation Agriculture in the 21st century: A paradigm of sustainable agriculture, *Proceedings of the European Congress on Conservation Agriculture*, Madrid, Spain, October 2010.
18. Derpsch R (2004) History of crop production, with and without tillage. *Lead Edge* 3: 150–154.
19. FAO, What is Conservation Agriculture? FAO Conservation Agriculture, 2011. Available from: http://www.fao.org/ag/ca/1a.html
20. Kassam AH, Friedrich T, Derpsch R, et al. (2015) Overview of the worldwide spread of conservation agriculture. *Field Actions Sci Rep* 8.
21. Oweis T (1997) Supplemental irrigation: a highly efficient water-use practice. ICARDA, Aleppo, Syria, pp. 16.
22. Bremner JM, Mulvaney CS (1982) Nitrogen total. In A. L. Page, R. H. Miller and D. R. Keeney (Eds.), *Methods of Soil Analysis*, Part 2: Chemical and Microbiological Properties (2nd ed.). *Agronomy, 9,* 595-624.
23. Olsen SR, Sommers LE (1982) Phosphorus. In A. L. Page, R. H. Miller, and D. R. Keeney (Eds.), *Methods of soil analysis: Part 2- Chemical and microbiological properties* (2nd ed.) (pp. 403-430). Madison, WI: American Society of Agronomy.
24. Mocek A, Drzymala S (2010) Genesis, analysis and classification of soils. Ed. UP in Poznan. 418.
25. Egner H, Riehm H, Domingo WR (1960) Studies concerning the chemical analysis of soil as background for soil nutrient assessment. II. *Chemical extracting methods to determine the phosphorous and potassium content of soil*. Kungliga Lantbrukshögskolans Annaler 26; 199.
26. Kirkegaard JA, Conyers MK, Hunt JR, et al. (2014) Sense and nonsense in conservation agriculture: Principles, pragmatism and productivity in Australian mixed farming systems. *Agric Ecosyst Environ* 79: 107–122.
27. Cantero-Martinez C, Gabina D, Arrue JL (2007) Evaluation of conservation agriculture technology in Mediterranean agriculture systems. In: Stewart, B., Fares Asfary, A., Belloum, A., Steiner, K., Friedrich, T., Eds., *Proceedings of the International Workshop on Conservation Agriculture for Sustainable Land Management to Improve the Livelihood of People in Dry Areas*, 7–9 May. ACSAD and GTZ, Damascus, Syria: 157–164.
28. Mrabet R (2002) Wheat yield and water use efficiency under contrasting residue and tillage management systems in a semiarid area of Morocco. *Exp Agric* 38: 237–248.
29. Akbolat D, Evrendilek F, Coskan A, et al. (2009) Quantifying soil respiration in response to short-term tillage practices: a case study in southern Turkey. *Acta Agri Scand Sect B Plant Soil Sci* 59: 50–56.
30. Ben Moussa-Machraoui S, Errouissi F, Ben-Hammouda M, et al. (2010) Comparative effects of conventional and no-tillage management on some soil properties under Mediterranean semi-arid conditions in north-western Tunisia. *Soil Till Res* 106: 247–253.
31. Lahmar R, Triomphe B (2007) Key lessons from international experiences about conservation agriculture and considerations for its implementation in dry areas. In: *Proceedings of the International Workshop on Conservation Agriculture for Sustainable Land Management to Improve the Livelihood of People in Dry Areas*, 7–9 May, ACSAD and GTZ, Damascus, Syria:123–141.
32. Piggin C, Haddad A, Khalil Y, et al. (2015) Effects of tillage and time of sowing on bread wheat, chickpea, barley and lentil grown in rotation in rainfed systems in Syria. *Field Crop Res* 173: 57–67.

33. Mrabet R (2000) Differential response of wheat to tillage management systems under continuous cropping in a semiarid area of Morocco. *Field Crop Res* 66: 165–174.
34. Lahlou S, Ouadia M, Malam Issa O, et al. (2005) Modification de la porosité du sol sous les techniques culturales de conservation en zone semi-aride Marocaine. *Etude et Gestion des Sols* 12: 69–76.
35. Magnan N, Lybbert TJ, Mrabet R, et al. (2011) The quasi-option value of delayed input use under catastrophic drought risk: the case of no-till in Morocco. *Am J Agric Econ* 93: 498–504.
36. López-Fando C, Almendros G (2000) Interactive effects of tillage and crop rotations on yield and chemical properties of soils in semi-arid central Spain. *Soil Till Res* 36: 45–57.
37. Fernández-Ugalde O, Virto I, Bescansa P, et al. (2009) No-tillage improvement of soil physical quality in calcareous, degradation-prone, semiarid soils. *Soil Till Res* 106: 29–35.
38. Moreno F, Arrúe JL, Cantero-Martínez C, et al. (2010) Conservation agriculture under Mediterranean conditions in Spain. *Sust Agric Rev* 5: 175–193.
39. FAO (2009) Conservation Agriculture in Uzbekistan. Crop and Grassland Service Working Paper 2. FAO, Rome.
40. Crabtree B (2010) Search for sustainability with no-till bill in dryland agriculture. Crabtree Agricultural Consulting, Australia.
41. AL-Ouda SA (2013) Effect of tillage systems on wheat productivity and precipitation use efficiency under dry farming system in the North East of Syria. *Arab J Arid Environ* 6: 3-11.
42. Bashour I (2007) Impact of conservation agriculture on soil fertility in dry regions. *Proceedings International Workshop on Conservation Land Management to Improve the Livelihood of People in Dry Regions*. 7–9 May 2007, Damascus, Syria: 111-119.
43. Lafond GP, Walley H, Schoenau J, et al. (2008) Long-term vs. short-term conservation tillage. In: *Proceedings of the 20th Annual Meeting and Conference of the Saaskatchewan Soil Conservation Association*, 12–13 February, Regina, Saaskatchewan: 28–43.
44. Blank D (2008) A fresh look at life beneath the surface. In: Goddard, T., Zoebisch, M., Gan, Y., Ellis, W., Watson, A., Sombatpanit, S., Eds., No-Till Farming Systems, Special Publication No. 3. *World Association of Soil and Water Conservation*, WASWC, Bangkok: 73–81.
45. Wolfarth F, Schrader S, Oldenburg E, et al. (2011) Earthworms promote the reduction of Fusarium biomass and deoxynivalenol content in wheat straw under field conditions. *Soil Biol Biochem* 43: 1858–1865.
46. Upadhyaya MK, Blackshaw RE (2007) Non-chemical weed management: principles, concepts and technology. CABI International, Wallingford.
47. ACSAD (2014) The Annual Report of Conservation Agriculture Program, Damascus, Syria.
48. Sayre KD (2011) Global overview of conservation agriculture-principles and focus. *Proceedings Workshop on Conservation Agriculture and its Impact on Water Productivity*. September, 2011, Karaj, Iran: 6-11.

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