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Country-Level Bio-Economic Modeling of Agricultural Technologies to Enhance Wheat-Based Systems Productivity in the Dry Areas

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Abstract

Conservation Agriculture (CA) have a large potential for enhancing cereal yields in the semi-arid areas through better management of soil moisture. The objective of the current paper is to quantify, at national level, the impact of CA adoption in wheat-based agricultural systems in Syria. A country-level bio-economic approach was used for this purpose. Different CA technical packages (TPs) were first developed and simulated through APSIM crop modeling software, in order to estimate the long-term yields of wheat under different CA TPs for the period 2015-2039. The considered CA packages are a combination of zero-tillage, mulching, raised bed, fertilizer doses, and planting dates. The simulated yields are then introduced into IMPACT model while assuming that TPs will be adopted on 35% of the wheat areas in the countries. Results show that the comparative advantages of CA TPs on overcoming the effect of climate change will only be significant after 2030. In 2039, the effect of different TPs on average wheat yields in Syria will be 4% to 12% (depending on the TP) higher than the average yields under climate change and no CA technology adoption. These yield enhancements may reduce the wheat trade deficit with 30 up to 140%, also depending on the technical package. The combination of mulching techniques, together with average nitrogen dose of 30kg/ha, and late planting date of wheat provides the best prospective for the wheat sector in Syria.

Keywords: Mulching, planting date, Foresight modeling, wheat supply, Syria

1. Introduction

In the Middle East and North Africa (MENA) region, wheat (*Triticumaestivum* L. and *Triticumturgidum* subsp. durum) is extremely important staple food crop. Wheat-based systems dominate the 250-600 mm rainfall zones across the region. It is mostly grown in rainfed conditions, except for the case of Egypt. For over half a century, the MENA region has experienced a decline of per-capita wheat production (FAOStat, 2013) because local production has grown slower than the demand of growing populations. As a consequence, MENA has become the largest food-importing region of the developing world (Solh, 2013). Much research and development efforts have been mobilized to enhance wheat yield and its domestic supply. At the same time, soil fertility losses due to erosion, declining soil organic matter and nutrient mining have further triggered burden on increasing production in the most of the agro-ecological areas of the region, where land and water resources are inherently scarce.

In the context of socioeconomic and climate changes challenges in the MENA region, complex analysis and foresights of the potential impact of relevant technologies need to be undertaken in order to guide future research investments toward most cost-effective interventions. A policy maker today needs to have more options about the social returns of public investments in research and development, especially in relation to food production and resource management. The objective of this paper is to undertake a bio-economic foresight modeling exercise in order to estimate the scope of agricultural technologies, including conservation agriculture (CA), in enhancing food security and mitigating the effects of climate change on wheat-based agricultural systems of the dry areas. The case of Syria was considered as an example for this exercise because agricultural areas of this country represent quite well the typical geography of many MENA countries. That is, semi-arid conditions with rainfall levels generally between 250 and 500 mm/year are generally found in many Arab countries where irrigation water is a constraining resource of agricultural production. Additionally, Syria was also chosen because ICARDA, operating in Syria since 1977, managed to generate substantial amount of data through many field experiments designed to test and identify wheat varieties suitable to semi-arid conditions. Such type of data is deeply required for accuracy of biophysical crop simulations. Results from this work are expected to shed light on how different improved wheat technologies can be useful in improving wheat supply and trade, and mitigating the effect of climate change through enhancement of wheat yields.

CA technologies (i.e. residue retention and zero-tillage sowing) and raised bed, which will be analyzed in this paper, have been successfully and largely adopted in semi-arid regions around the world. It is now agreed in the specialized literature that, CA practices have become a key component of cereal-based systems, and had significant impact in enhancing agricultural productivity in these semi-arid areas (Corbeels et al., 2014; Nyakudya & Stroosnijder, 2015). Benefits of conservation agriculture technologies include more efficient crop water use and increased yields through improved soil water infiltration and storage, reduced evaporative losses with residue retention, enhanced soil fertility through higher levels of soil organic matter. Similarly, raised-bed cropping is another improved technology with potential to enhance grain yield production. Complementary to these improved technologies, some appropriate management practices, including proper time of sowing the crop and optimum fertilizer applications, can substantially increase crop yield and have been modeled in our simulations. As part of the sustainability of cropping systems, such improved technologies can be highly effective as possible alternatives to the conventional soil and residue management practiced in MENA region. Research has shown that in semi-arid environments of the MENA region, wheat yield increased with zero-tillage compared to conventional tillage under relatively drier conditions as determined by site and season (Moeller et al., 2013).

Bio-physical systems approaches using crop simulation techniques are suitable for quantifying effect of such improved agricultural technologies. Hence it is important to carry out crop simulation exercises with these improved practices in the wheat based systems in order to address the agricultural sustainability issues which can improve food security, increase wealth in rural areas, and maintain land productivity and water resources. Keeping view of the above concerns, improved technologies, outlined in detail below, were adopted to simulate their impact on wheat productivity in Northern Syria. Crop simulations will even be more insightful when combined to a wider economic modeling approach where extrapolations of biophysical results and their economic interpretation improve the understanding of the potential of improved technologies. For this purpose, biophysical simulations have been suited, in this study, to a global partial equilibrium economic modelling approach using the IMPACT model (International Model for Policy Analysis of Agricultural Commodities and Trade).

The remaining of the paper is organized as follows: the next second section presents a generic description of the improved technologies and their potential in the MENA region, particularly for wheat. The third section provides a description of the research design in addition to the biophysical and economic methods. The fourth section presents the results of the study, while a last section concludes.

2. A Review of Conservation Agriculture and Its Potential in the MENA Region

The CA is considered as a form of sustainable agriculture, based on a set of techniques that sustain agriculture in its physical, economic, environmental and social dimensions (Lamarca, 2000; Pieri & Steiner, 1997). It aims to ensure long-term economic viability and environmental sustainability of farms, which in turn allows improving their income and livelihoods. CA also refers to various practices that allow soil management for different land uses that alter its composition, structure and natural biodiversity and prevent erosion (Mrabet, 2001). The application of CA is mainly based on the three principles: (i) minimal soil disturbance by using the technique of direct planting of crop seeds, (ii) permanent soil cover especially by crop residues and cover crops and finally (iii) crop rotations (Anderson, 2005; FAO, 2014). These principles allow combining profitable agricultural production with environmental sustainability. However, the simplest form of CA, which is also the most easily adopted form, refers only to the no-tillage technique, using no-till seeders.

No tillage techniques are mainly depending on soil preparation, where the soil cover should be opened to place the seed into a seeding slot. The effectiveness of this operation is depending on the size of the seed slot as well as the associated movement of soil that should be minimum. Furthermore, an ideal seed slot would be completely covered by mulch again after seeding and no loose soil should be visible on the surface (Seguy et al., 2001). The preparation of land for seeding or planting under no-tillage is also based on slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding directly through the mulch. The crop residues can be retained either entirely or to an adequate amount that guarantees a complete soil cover, whereas fertilizer and amendments are applied either on the soil surface or during seeding.

CA was considered in this study for many reasons, among them its capacity to enhance and sustain increased wheat yield, protection against land degradation and loss of soil fertility, its environmental services (carbon sequestration), and finally its great potential to mitigate the effect of climate change (through all the above mentioned advantages). Many reports (ICARDA 2011; IFPRI, 2012) stress the comparative advantage of this technology when compared to other wheat technologies such as breeding, supplemental irrigation, or others. This suggests that public investments in promoting CA might have higher social return compared to investing in other technologies. Our choice of CA is also due to the important potential of this technology to be adopted in the

MENA region. In fact, compared to other regions (North and Latin America, and Australia), CA techniques (even the most simple among them) have not widely been applied by MENA countries on their most strategic crops such as cereals (occupying the most important share of agricultural land). This means that the promotion of CA in these countries can create important advantages and opportunities for enhancing food security and mitigating the effect of climate change.

Conservation agriculture is applied on roughly 39,000 hectares in the West Asia region, including Iraq and Syria (ICARDA., 2011), where spontaneous adoption of CA has been catalyzed by fuel shortages and by some research projects which have resulted in increasing the availability of locally produced affordable no-till seeders - now being exported to other West Asian and North African (WANA) countries (ICARDA., 2011). According to Boulal et al. (2014), adoption of CA in the North African countries offers multiple benefits to farmers, but is still lagging behind. This paper simulates long-term effects of specific wheat improved technologies, analyzing the importance of these technologies for potential yield growth in Syria.

3. Bio-economic Modeling of Improved Wheat Technologies in Syria: a Soft Linking Approach

The combination of biophysical and economic models in foresight studies become necessary when considering long-term effects of climate and environmental factors affecting biophysical processes of crop production. Biophysical simulations can provide relevant parameters used in precise calibration of economic foresight models. In this study, we used bio-economic simulations as an approach to combine biophysical crop simulations and economic modeling.

3.1 Crop Modeling

The crop model, APSIM- Agricultural Production Systems Simulator, Version 7.5, was used to simulate crop phenological development, biomass accumulation, grain yield, nitrogen (N) and soil water balance in farming systems operating on daily time steps. APSIM has been extensively tested and evaluated against data from experimental studies, which demonstrates that the model is capable of simulating crop growth and yield for different environments, soil types and crops. It has been used across the world by various researchers for crop growth, N fertilizer treatment, simulation of conservation agriculture practices and yield simulation. The testing of APSIM performance for the conditions at Tel Hadya in Northern Syria has shown that APSIM is suitable for simulating wheat based cropping systems in Northern Syria (Dixit & Telleria, 2015). In this current paper, APSIM is only used for simulating the effect of different technical packages using the following methodology guidelines.

3.1.1 Data and Sites

An important and representative site of dry wheat growing area of Northern Syria viz., Tel Hadya (36.01 °N 36.93 °E) was selected where ICARDA and local agricultural research institutes have maintained on-farm weather stations. Long-term daily weather data, soil data and data from the wheat cultivar grown in the sites were collected in order to calibrate and apply APSIM. The rainfall in these sites predominantly occurs from November to May, for about seven months, on which the cropping seasons lie. About 90% or more of the total annual rainfall takes place in these seven months (315 mm in Tel Hadya, 243 mm in Breda).

Long-term, i.e., 50 years, daily weather data (maximum and minimum temperatures, solar radiation and rainfall) required for crop modeling studies were generated using Long Ashton Research Station Weather Generator (LARS-WG)-version 5.5. This weather generator is a semi-parametric or empirical stochastic weather generator that incorporates stochastic numerical models to produce time series of daily weather variables that aim to mimic the observed weather variables based on the statistical properties. LARS-WG requires several years of historical climate records i.e., daily observed weather data to first calibrate before embarking on long-term weather data generation, so 33 years of daily weather data was used for calibrating Tel Hadya sites. The value of LARS-WG in generation of long-term daily weather data and the quality of generated data in Northern Syria has already been studied under the purview of the Global Future Project at ICARDA.

Long-term simulations were carried out using APSIM crop simulation model that simulates the crop phenological development, biomass accumulation, grain yield, nitrogen (N) and soil water balance in a farming system and operates on daily time steps. The latest version APSIM 7.5 was used for this study. APSIM has been extensively tested and evaluated against data from experimental studies, which demonstrates that the model is capable of simulating crop growth and yield for different environments, soil types and crops. It has been used across the world by various researchers for crop growth, N fertilizer treatment, simulation of conservation agriculture practices and yield simulation. The testing of APSIM performance for the conditions at Tel Hadya in Northern Syria has shown that APSIM is suitable for simulating wheat and chickpea based cropping systems in Northern Syria (Dixit & Telleria, 2015).

3.1.2 Management Practices Simulated

The impact and benefit of 3 important technologies viz., Zero-tillage, Mulching and Raised bed cropping was seen over conventional cropping in addition to two time of planting and three fertilizer rates. Three fertilizer rates were chosen as the farmers are using varying fertilizer practices and it is good to see impact of different fertilizer rates to know the direction of our recommendations to the farmers. Also, as the impact of these technologies is more pronounced when higher rates of N are applied hence it makes sense to test the impact of these technologies using different fertilizer rates.

3.1.3 Agricultural Technologies Simulated

Conventional tillage: Conventional tillage is the normal practice that farmers adopt in the region which includes removal of residue by the tillage operation. Generally, two tillage operations are carried out before sowing. The conventional tillage was simulated by applying two tillage operations, first on 1st October and the second on 1st November with the seed bed preparation depth of 5 and 15 cm at first and second tillage operation. Ten percent of residue was incorporated in to the soil and 90% residue was removed during conventional tillage operation.

Zero-tillage: Zero-tillage was simulated by complete residue retention without any tillage operation and hence no residue was removed from the field contrary to the conventional tillage practice. This means that the grain was harvested and the entire residue was left in the field at harvest.

Mulching: Mulching was simulated by complete residue retention and 6,000 kg/ha wheat residue mulch added at sowing with C:N of 80 during wheat cultivation. C:N determines the speed of residue decomposition and mineralization. Lower the C:N, the higher the rate of decomposition and mineralization.

Raised-bed cropping: Raised-bed was simulated by allowing 12-15% moisture increased up to a depth of 0-45 cm soil layers and only 25% residue removed at harvest hence residue retention was 75%.

3.2 Economic Foresight Modeling: Assessing the Long Term Effect of CA Packages Adoption on the Wheat Sector in Syria

3.2.1 Linking Biophysical and Economic Models

The methodological approach used in this paper is based on a soft linking approach of a biophysical crop simulation model with the economic model. The “soft” nomination is due to the fact that the inputs of the biophysical model are simply formulated within few adoption scenarios, and considered as inputs of the economic model. An inputs/outputs function is specified together with an adoption function for each scenario. Adoption scenarios are discussed at the end of this section.

The IMPACT model (IFPRI, 2013) was used for simulating the long-term economic impact of varieties adoption. IMPACT is a partial equilibrium global agricultural sector model combining biophysical data about crops growth and yields (under different environmental and climate conditions) together with economic simulations of international world market and trade for 56commodities including wheat, rice and maize. Equilibrium price at the world market can be then converted into domestic prices for each country, and producers/consumers welfare can then be calculated. IMPACT is considering 159 regions (country) and 154 water basins; which combines into 320 “food production units”.

Agronomic and management factors play crucial role in enhancing the yield of improved varieties. We used the IMPACT model to test technical packages and their effects on improving yields in the frame of climate change. Because of agro-climatic conditions two Syrian sites were chosen to represent semiarid conditions of the country. In addition, long historical databases containing data from successive experiments in the same locations and for the same wheat varieties were used to facilitate the biophysical simulations.

3.2.2 Simulated Agricultural Technologies and Management Practices

Few technical packages (Table 1) have been developed for wheat crop (Sham03 variety) farming for the Syrian context. The Sham03 variety which is a high yielding wheat variety widely cropped in Syria was used in the biophysical simulation. These technologies were also combined together with two management practices related to the planting date and the dose of fertilizers (Table 1).

Table 1. Combinations of CA and management practices simulated

CA Technologies	Zero-tillage			Mulching			Raised bed		
Sowing data	Early		Late	Early		Late	Early		Late
Nitrogen doses (Kg/ha)	0	30	60	0	30	60	0	30	60

As shown by Table 2, five combinations (technical packages: TPs) of technologies and management practices have been then selected to be simulated using the IMPACT model (Table 2).

Table 2. Description of the technical packages (TP) simulated by APSIM for Sham03 in Syria and considered for the economic analysis

Name	Technology simulated	Fertilizers dose (Kg N/ha)	Planting date
TP1	Zero-Till	30	Late planting
TP2	Mulching	30	Early planting
TP3	Mulching	30	Late planting
TP4	Raised bed	30	Early planting
TP5	Raised bed	30	Late planting

3.2.3 Adoption Rates to Be Considered in IMPACT Modeling

Each of the five technical packages have been simulated to achieve a maximum adoption rate of 35% of cultivated areas for the period 2015-2040. The adoption function is supposed to follow a logistic form, where the year 2028 is considered as median. The impact of these different technical packages has been simulated under the SSP3 socioeconomic scenario (OECD) and the GFDL (rcp8p5) climate change scenario. In SSP3 (or "Fragmentation''), economic growth is assumed to be much slower as a combination of multiple causes: lack of international cooperation, slow technological progress, and low education levels. This 'conservative' scenario was chosen because of the political instability of the MENA region, which would also affect future economic growth and food demand.

3.2.4 Distribution of Yield Divers of TPs Compared to the Conventional Practices

From an agronomic perspective, effects of technology adoption on yields take from 5 to 7 years to be first assessed on farms. The full effect of technologies on yields will even take up to 15 years. For this reason, we assume that the difference in yields between packages and conventional wheat farming will be distributed between three time periods (P1, P2, and P3) as shown below. As example, if a given TP will generate in average 31% higher yields of wheat (compared to conventional farming with technical change) over the APSIM simulation period, this would mean that yields will increase annually with an average of 0.0127 (31% divided by 25 years needed to the yields to be fully established). This later average percentage will be introduced in IMPACT under the following distribution:

P1: First period of 5 years: where no much difference in wheat yield is yet observed between conventional and CA technologies. From 1st year to 5th year, TP3 is assumed to only generating annual wheat yields growth of 0.42%.

P2: Second period of 7 years, where the yield gap between conventional and improved technologies starts to be more obvious. From 6th to 7th year, TP3 will be assumed to generate annual wheat yields growth of 1.27%.

P3: Third period (rest of the IMPACT simulation period) where the yield difference between enhanced technologies and conventional farming will be established and stabilized. From 8th to 25th year, TP3 will be assumed to generate annual wheat yields growth of 1.60%.

If we calculate the total of the previous average annual growth rates over the first 25 years period of our simulation, the results will be 31%. This type of distribution will be repeated for all technical packages.

4. Results

4.1 Results of the Biophysical Model

The results reported here are the averages from 50 years of continuous yield simulations. Results show that in almost all the cases, zero-tillage, mulching, or raised-bed at different fertilizer rates and sowing dates gave higher yields compared to conventional tillage (Table 3). Late sowing tends to provide more yield than early sowing. This can be attributed to the favorable conditions of crop growth when sowing takes place in December, especially in relation to the available water to the crops. At Tel Hadya, higher percentage change in yield was obtained for mulching treatment with 0 kg N/ha fertilizer application when the crop was sown early. The negative effects of early sowing are more pronounced when no fertilizer is applied. It can be concluded that planting in the month of December is the most optimum bet.

Table 3. Percentage change in wheat yield in relation to different planting time, fertilizer rates and cropping technologies at Tel Hadya in Northern Syria

	Planting time					
	Early			Late		
	Fertilizer rates (kg N/ha)			*Fertilizer rates (kg N/ha)*		
Tel Hadya	0	30	60	0	30	60
Zero-tillage	-19.6	-2.6	24.7	-13.0	11.3	49.8
Mulching	20.3	17.8	38.8	3.1	31.9	65.3
Raised-bed	-4.6	5.9	28.3	5.3	26.4	51.0

Note. GrayCelles design the selected technical packages for the economic simulation.

Fertilizer treatment also had bearing on the results of different technologies. In case of no tillage zero fertilizer application affected negatively the yield crop, even with improved seed variety. This can be due to the fact that when there is residue in the field (zero till) and not sufficient moisture available for decomposition because there is no nitrogen application, and therefore low rate of residue decomposition known as 'immobilization effect'. This suggests that the system requires more nitrogen for the residues to decompose and hence to produce more nutrients to the soil and plant. The combination of favorable temperatures, sufficient moisture and nitrogen determines the extent of mineralization and hence the crop growth and yield.

Zero-tillage appears to have a positive impact on yield in most cases when more fertilizer is applied, because more nitrogen is needed to avoid immobilization process. The zero-tillage technology can provide 37% more yield than the conventional tillage practice when 60 kg N/ha is applied (when results from early sowing and late sowing combined, Figure 1). This practice is not suitable at the study area when no fertilizer is applied and only little gains are observed when 30 kg N/ha is applied. If the crop is sown in December and 60 kg N/ha is applied, almost 50% more yield can be obtained (Table 2) which is highly promising.

Mulching on the other hand provides the highest yield gains whether early planting or late planting compared to all other technologies. The benefits are higher when 60 kg of nitrogen are applied. Mulching provides more residue, reduces runoff and drainage and stores water which can be used by the crops. More water also helps in decomposition of the residue. The yield gains from mulching can be about 52% (when results from early sowing and late sowing combined, Figure 1) and about 65% (Table 3) yield gains can be obtained when crop is sown in December and 60 kg N/ha is applied compared to the conventional tillage practice.

Yield gains from raised-bed technology fall in between the benefits of zero-tillage and mulching. However, as raised-bed is more suitable when there is irrigation, in cases of no irrigation mulching or zero-tillage can provide more yields depending on fertilizer application and planting time. When no fertilizer is applied there is almost no impact of raised-bed technology at Tel Hadya compared to the conventional tillage. The benefits kick-in only when there are higher rates of fertilizer application. Generally higher fertilizer rates have been always associated with substantially higher yields.

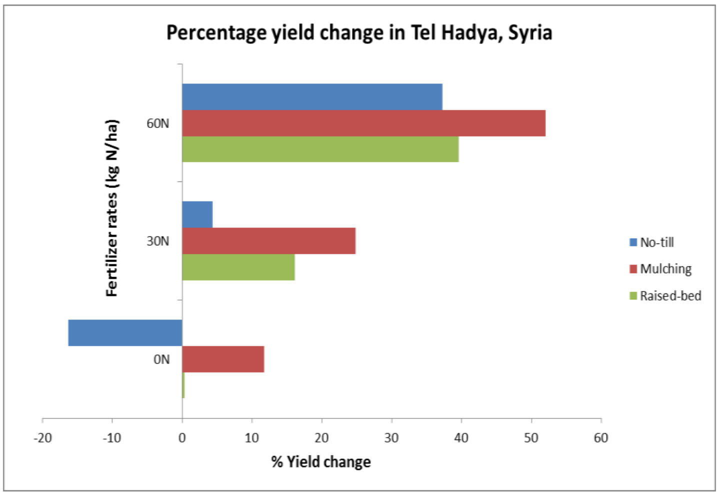

Figure 1. Average percentage yield change in wheat for different technologies based on different fertilizer application rates (combining early and late planting) at Tel Hadya, Syria

4.2 Results of the Foresight Modeling

This section presents the results of simulating the adoption of different technical packages for wheat production in Syria, assuming a progressive adoption of these TPs on a maximum of 35% of the total wheat area. Results concerns the trend of the average wheat yield in Syria after the adoption of these TPs, the trend of the total wheat supply, and the net trade of wheat.

4.2.1 Effect of Different CA Packages Adoption on Average Wheat Yield and Supply in Syria

Table 4 shows that the comparative advantages of TPs on overcoming the effect of climate change (compared to baseline scenarios without climate change) will be only significant after 2030. In 2039, TP3 will allow an increase of more than 12% of average wheat yield in Syria compared to the average yield of wheat under ‘climate change and no technology adoption scenario’. Second-best technical package will be the TP5, which will also allow an increase of average wheat yields of about 9.8% compared to the latter scenario. We remind that the considered packages will be only adopted on 35% of the total wheat areas of Syria by 2039. This means that if more efforts will be made to promote the adoption of these TPs, an even higher average wheat yield in Syria can be reached.

Table 4. Impact of different TPs on the average wheat yield in Syria (% of change against baseline scenario: climate change without any technology adoption)

		2025		2030		2039	
		Average Yield T/ha	% change*	Average Yield T/ha	% change*	Average Yield T/ha	% change*
No CC scenario	air	5.94	2.45	6.29	3.20	6.77	4.29
	arf	1.51	3.44	1.58	4.54	1.65	6.45
With CC scenario	air	5.79	--	6.10	--	6.50	--
	arf	1.46	--	1.51	--	1.55	--
TP1	air	5.82	0.38	6.17	1.26	6.75	3.91
	arf	1.47	0.38	1.53	1.25	1.61	3.90
TP2	air	5.83	0.61	6.22	2.03	6.91	6.38
	arf	1.47	0.61	1.55	2.01	1.65	6.36
TP3	air	5.86	1.11	6.33	3.74	7.28	12.15
	arf	1.48	1.10	1.57	3.71	1.73	12.09
TP4	air	5.81	0.20	6.14	0.64	6.62	1.95
	arf	1.47	0.19	1.52	0.63	1.58	1.94
TP5	air	5.85	0.92	6.28	3.07	7.13	9.85
	arf	1.48	0.91	1.56	3.05	1.70	9.80

Note. Air: irrigated areas; arf: rainfall areas; (*), average change compared to CC scenario without technical change.

Based on these average yields, the IMPACT model calculates the total annual wheat supply in Syria for each TP over the simulation period. Results of this calculation are shown in Table 5 and Figure 2 below.

For the given adoption scenarios, the effect of TPs on maintaining reliable wheat supply in Syria will only be significant after we reach the maximum adoption in 2039. Table 5 and Figure 2 show that not all simulated TPs will allow mitigating the effect of climate change by this date.

Table 5. Impact of different TPs on the total wheat supply in Syria (% of change against baseline scenario)

	2025		2030		2039	
	Tot Supply (000 mt)	% change* compared to CC scenario	Tot Supply (000 mt)	% change* compared to CC scenario	Tot Supply (000 mt)	% change* compared to CC scenario
No CC	6194.78	3.16	6624.67	4.15	7185.70	5.81
GFDL	6004.88	0.00	6360.67	0.00	6790.88	0.00
TP1	6027.82	0.38	6440.81	1.26	7055.89	3.90
TP2	6041.44	0.61	6489.31	2.02	7222.96	6.36
TP3	6071.17	1.10	6597.69	3.73	7613.31	12.11
TP4	6016.54	0.19	6401.16	0.64	6922.97	1.95
TP5	6059.67	0.91	6555.29	3.06	7457.59	9.82

Note. mt: Metric tons. (*) change against baseline scenario: climate change (GFDL) without any technology adoption.

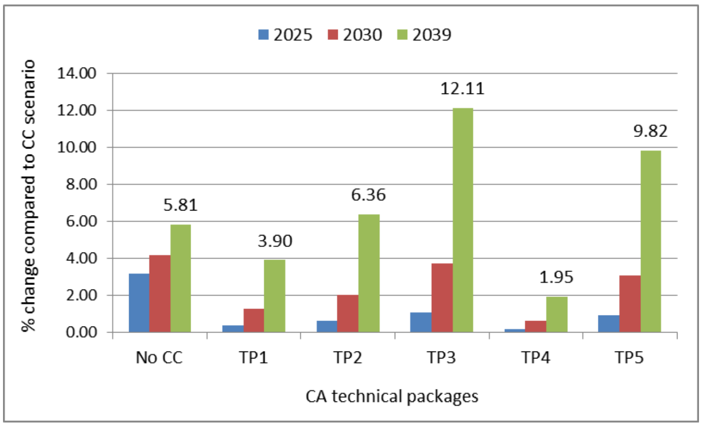

Figure 2. Impact of different CA TPs on the total wheat supply in Syria (% change compared to the baseline scenario of CC without any technology change)

Adoption scenario of the TP2 (mulching + 30 Kg N/ha + early planting) provides similar results to the no CC scenario in terms of total wheat supply in Syria. The fertilizers dose and early planting techniques simulated in TP2 are already common practices in Syria. A simple adoption of the mulching technique will then provide very good results in terms of mitigating the effect of climate change in the wheat sector.

On the other hand, TPs 3 and 5 provide the best results in terms of enhanced total wheat supply compared to the climate change scenario. In fact, IMPACT results show that TP3 generate a total wheat supply 12% higher than the total wheat supply which will be obtained with CC and no technology adoption scenario. This percentage will be around 10% for the TP5. A common feature of the TPs 3 and 5 are the late planting technique (combined with either mulching or raised bed: enhanced soil/water management techniques).

4.2.2 Long-Term Net Trade of Wheat in Syria under Different CA Scenarios

Based on the annual average wheat yields and total wheat supply, we also calculated the net trade of wheat in Syria under different CA scenarios. The calculation of Net trade is based on both the total wheat supply (which is supposed to be affected by our TPs scenarios) and demand (which will be affected by the socioeconomic scenarios considered in IMPACT simulations).

Table 6. Effect of different CA TPs on the long term trade balance of wheat in Syria

	2025		2030		2039	
	Net trade balance (000 mt)	% change* compared to CC scenario	Net trade balance (000 mt)	% change* compared to CC scenario	Net trade balance (000 mt)	% change* compared to CC scenario
GFDL	-124.02	0.00	-425.00	0.00	-1133.60	0.00
TP1	-101.14	-22.63	-345.07	-23.16	-869.39	-30.39
TP2	-87.55	-41.65	-296.71	-43.23	-702.82	-61.29
TP3	-57.91	-114.18	-188.63	-125.30	-313.66	-261.40
TP4	-112.39	-10.35	-384.62	-10.50	-1001.90	-13.14
TP5	-69.37	-78.77	-230.91	-84.05	-468.91	-141.75

Note. Negative value indicates that the net trade will be reduced with this value; mt: Metric tons; (*)change against baseline scenario: climate change (GFDL) without any technology adoption.

The dominance of TPs 3 and 5 is once again confirmed through the net trade values. In fact, even though Syria was considered from the rare MENA countries with positive wheat net trade in the past decade; its situation is expected to change in the coming decades, especially under the current (and expected) unfavorable socioeconomic (demographic and economic growth) scenarios. Results show that in 2025, the net trade imbalance under all CA TPs scenarios will be lower than the net trade imbalance under CC/no-technology improvement scenario. By 2025 TPs 3 and 5 will help to reduce the net trade imbalances with 114% and 78% respectively. In 2039 (where the gap between supply and demand is expected to be 9 times higher than 2025), these values are expected to be respectively 261% and 141%.

5. Concluding Remarks and Policy Implications

The objective of the current study is to estimate the long term effect of different improved wheat practices on mitigating the effect of CC in the MENA region for wheat-based systems. The research methodology was based on country-level bio-economic modeling of a set of conservation agriculture scenarios. Results of this study were very insightful and can be used to generate many policy implications.

First, from the biophysical perspective, it seems again that water is the most limiting factor in the region for wheat production. Mulching techniques and raised bed, which are supposed to be two enhanced techniques allowing for a better management of the soil moisture and fertility, gave the best results in terms of long term wheat yields.

Second, from an economic perspective, the results of the current paper proves the high potential and wide scope of CA to enhance agricultural yields and food security in the arid areas of MENA region. As an example, the 12% increase in wheat supply in Syria due to TP3, is equivalent to two times the annual wheat imports of Jordan (neighboring MENA country). If such productive technologies can be generalized in appropriate agro-ecological areas of the most wheat productive countries of the region, the impact on overall food imports of the region can decrease significantly. Note that we assumed these techniques to be only adopted at 35% of the total wheat areas in Syria. For these reasons and many others, it is time for policy makers in the region to consider CA in their adaptation strategies and to intensively promote it.

For a durable continuous shift from conventional agriculture to CA in MENA, the change in paradigms needs commitment and behavior of all concerned stakeholders (ICARDA, 2011). In fact, CA researchers, extension agents and farmers need to learn how to motivate policy-makers, institutional leaders, politicians, private sector, donors and international agencies to influence policy makers creating an environment in which CA systems can flourish (ICARDA, 2011). In many cases it is not a case of creating subsidies to promote CA, but rather to remove policies that hinder the adoption of sustainable practices – for instance subsidies on tillage equipment.

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