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Towards Sustainable Production of Potato under Climate Change Conditions

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Abstract

Nile delta of Egypt is one of the most vulnerable areas subjected to climate change impacts. A large portion of our agricultural cultivation is mainly accumulated in the Nile delta. As a result the agricultural cultivation is facing several challenges due to climate change impacts especially extreme climatic events. This leads to a significant drop in potato production consequently negative socio-economic impacts all over the country. The aim of this paper was to investigate the climate change impacts on one of Egypt's top strategic crops, potato. It was found that assessing climate change impacts on potato cultivation at local level is required. Increasing losses in crop production and quality have been taking place due to climate change in Egypt. It is very useful to identify proper adaptation practices for mitigating climate change impacts in potato production. Decision makers in developing adaptation strategies for potato production in Egypt should be assisted.

Keywords: Adaptation, Climate change, Economic analysis, Egypt, Potatoes

1. Introduction

Potato is one of the most important export vegetable crops in Egypt and the second most important vegetable crop after tomato in economic value. Egypt is one of the top 20 producers of potato worldwide and the top largest producer in Africa [1]. It reached a total production of 4.8 million tons/ year, including 637,434 ton for exportation with a market value of 250 million USD. About 19% of total area devoted for vegetable production is cultivated with potato [2]. Nowadays, potato cultivation is facing several challenges to maintain and improve production, from the point of view of both quality and quantity. In fact, there are many factors that can negatively affect this cultivation such as environmental factors, mainly linked to climate change. This demands a better comprehension of the relationship between climate (specially the extreme climatic events) and critical stages of the potato cultivation. Moreover, socio-economic factors have affected potato production as well [3]. Where, the last decade was increasingly characterized by a strong

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competition for land between urbanization and extensive crop systems, such as potato cultivation. All these factors can bring a significant drop in potato production and have negative socio-economic and environmental impacts all over the country. Few studies investigated the potential impacts of climate change on potato production in USA, some areas in Europe [4-6] and South Africa [7, 8]. As for Egypt, although studies agreed that the Nile Delta is one of the vulnerability areas subjected to climate change impacts and expanding urbanization; to date no similar studies were conducted addressing this issue in Egypt [9].

As a result, there is an increasing necessity to study the vulnerability of potato cultivation to climate change impacts and to identify the main driving factors that can influence the cultivation processes and finally to promote conservation and adaptation strategies specific for different targeted areas. The aim to study is to highlight the importance of investigating climate change impacts on potato production in Egypt to provide sustainable productivity.

2. Materials and Methods

Descriptive analysis was applied to characterize the problem in addition to the quantitative analysis method using some of the various measurements such as simple linear regression. Related data was based on annual data during the period (2000- 2016) obtained from the Central Agency for Public Mobilization and Statistics (CAPMAS), Ministry of Agricultural and Land Reclamation (MALR), the Egyptian Central Department of Agricultural Economics & statistics, the United Nations food and Agriculture Organization statistical database (FAOSTAT), etc.

3. Results and Discussion

3.1 Global potato production

The cultivation of potato is one of the main agricultural activities worldwide for both economic and social reasons. Potatoes were mainly produced and consumed in Europe, North America and the former Soviet Union till early 1990s. After that, potato production and demands increased in developing countries such as Asia, Africa and Latin America [10]. In 2014, the total world potato production was estimated at 381.7 million tons. China is the biggest potato producer with 96 million tons, followed by India with 45.3 million tons. The third of worldwide potatoes is harvested in China and India [11].

As for Africa, since the beginning of 20th century, potato production has been exponentially expanding in the continent reaching 30 million tons in 2013. The adaptation of potato production under wide range of climatic conditions was assisted in its expansion. Nowadays, potatoes are grown by irrigated commercial farms in Egypt and South Africa, and intensively cultivated in a tropical highland such as small farms in Eastern and Central Africa [12].

3.2 Production indicators of Egyptian potatoes

At the national level in Egypt, potato is the most important vegetable crop after tomato in terms of cash and production. It is the most important exportation vegetable crop. More than 105,000 ha are devoted for potato production [13]. Commercial production of potatoes in Egypt is focused in the Nile Delta (72% of total production) and Middle Egypt (16% of total production). El- Behera, Dakahlia, Gharbia and Menoufia governorates are the leading producers of potatoes with 27.4%,

9.17%, 8.3% and 8.29% of total production in the Nile Delta while production in Middle Egypt is concentrated in Minia and Giza governorates (7.5% and 4.3% of total production in the Middle Egypt) [2].

Most of the exported potato production in Egypt is centered in the governorates of El-Behera, Menoufia and Gharbia, where yields range between 20 and 36 tons/ha [2]. El-Behera Governorate came in the first place in terms of total production with 1.1 million tons, while cultivated area in El-Behera Governorate was 105.4 thousand tons [2].

3.2.1 Total cultivated area of potato in Egypt

Table 1 showed that the total cultivated area of potatoes during the period of 2000-2016 reached 305.9 thousand feddan, while the cultivated area of potatoes was 178.7 thousand feddan in 2000, compared to about 437.4 thousand feddan in 2015. The equation 1 in Table 2 shows that the potatoes total area in Egypt had increased at annual statistically significant rate reached 16.6 thousand feddan during the period of 2000-2016.

3.2.2 Potato total production in Egypt

The results in Table 1 showed that the production of potatoes during the period of 2000-2016 reached 3,317.4 thousand tons. the total production was 1,769.9 thousand tons in 2000, reached the maximum production to 4,955.4 thousand tons in 2015 because of the increasing in cultivated area.

Table 1. Evaluation of total cultivation area, total production and yield of potatoes in Egypt during the period of 2000-2016

Years	Total area (Thousand feddan)	Potatoes Production (Thousand ton)	Potatoes yield (Ton/feddan)
2000	178.7	1769.9	9.9
2001	189.9	1903.1	10.0
2002	196.7	1985.3	10.1
2003	197.3	2039.4	10.3
2004	248.2	2546.6	10.3
2005	300.8	3167.4	10.5
2006	220.3	2312.8	10.5
2007	257.1	2760.5	10.7
2008	327.6	3567.1	10.9
2009	329.9	3659.3	11.1
2010	334.8	3643.2	10.9
2011	391.0	4338.4	11.1
2012	422.1	4758.0	11.3
2013	382.0	4265.0	11.2
2014	410.0	4611.0	11.3
2015	437.4	4955.4	11.3
2016	376.6	4113.4	11.4
Average	305.9	3317.4	10.8
Min	178.7	1769.9	9.9
Max	437.4	4955.4	11.3

Source: Compiled and calculated from: MALR and FAOSTAT

The equation 2 in Table 2 showed that the total production of potatoes in Egypt had increased annually at significant rate and reached 203.2 thousand tons during the period of 2000-2016, which means that the annual production increased basically attributed to increasing in cultivated area.

Table 2. General trend equations of total area and total production of potatoes in Egypt during the period of 2000- 2016

	Items	Equation	R^2	F-test	t-test	no
1.	Total area of potato cultivation (thousand feddan)	$\hat{Y}_i = 156.19 + 16.6X_i$	0.88	112	10.6	1
2.	Total production of potato (thousand tons)	$\hat{Y}_i = 1488.4 + 203.2X_i$	0.88	116	10.8	2

Where:
$\hat{Y}_i$ = the estimated value for the dependent variable in the year i.
X_i = reflect time variable in the year i.
i = 1, 2, 3……17
Source*:* Calculated using the data from Table 1.

3.3 Economic analysis of potato cultivation in Egypt

3.3.1. Domestic prices for potatoes in Egypt

The results in Table 3 showed that the growth of domestic prices of potatoes was about 426 LE/ ton in 2000, reaching 1332 LE/ ton in 2013 with annual average of 750 LE/ ton during 2000-2013. The equation 1 in Table 4 showed that the annual domestic prices of potatoes in Egypt had increased at significant rate and reached 72.3 LE/ ton during the period of 2000-2013.

3.3.2 International prices for potatoes in Egypt

Table 3 showed that the growth of international prices of potatoes was about 175 USD/ ton in 2000, reached 479 USD / ton in 2013 with annual average of 311 USD / ton during 2000-2013. The international prices of potatoes were minimum in 2003 with 148 USD/ ton, and maximum in 2009 with 676 USD/ ton. The equation 2 in Table 4 showed that the annual international prices of potatoes in Egypt had increased at significant rate and reached 31 US$ / ton during the period of 2000-2013.

Table 3. Evaluation of domestic prices, international prices and potatoes exports of Egypt's potatoes during the period 2000 -2013

Years	Domestic prices (LE/ Ton)	International prices (USD/ Ton)	Quantity of Potatoes Exports (Thousand ton)	% of Potatoes Exports
2000	426	175	156.6	8.8
2001	428	160	185.5	9.7
2002	443	186	229.4	11.6
2003	505	148	296.3	14.5
2004	499	176	381.5	15.0
2005	483	197	392.2	12.4
2006	635	178	367.1	15.9
2007	706	277	389.7	14.1
2008	828	443	397.9	11.2
2009	913	676	215.1	5.9
2010	979	434	298.6	8.2
2011	1107	393	637.4	14.7
2012	1216	431	699.2	14.7
2013	1332	479	705.4	16.5
Average	750	311	382.3	12.2
Min	426	148	156.6	5.9
Max	1332	676	705.4	15.9

Source: Compiled and calculated from: MALR and FAOSTAT

Table 4. General trend equations of domestic prices, international prices and exports quantity of Egyptian potatoes during the period of 2000 -2013

Items	Equation	R^2	F-test	t-test	no
1. Domestic prices (LE/ ton)	$\hat{Y}_i = 207.4 + 72.3X_i$	0.93	158	12.5	1
2. International prices (US/ ton)	$\hat{Y}_i = 77.9 + 31X_i$	0.63	20.4	4.5	2
3. Export quantity (thousand ton)	$\hat{Y}_i = 123.8 + 34.5X_i$	0.63	20.8	4.5	3

Where:
$\hat{Y}_i$ = the estimated value for the dependent variable in the year i.
X_i = reflect time variable in the year i.
i = 1, 2, 3……14
Source*:* Calculated using the data from Table 3.

3.3.3 Quantity of Egyptian potato exports

The results in Table 3 showed that the average of potato exports quantity during the period of 2000-2013 was 382.3 thousand tons. The quantity of potato exports was 156.6 thousand tons in 2000 and reached the maximum of 705.4 thousand tons in 2013. The equation 3 in Table 4 showed that the quantity of potato exports in Egypt had increased annually at significant rate and reached 34.5 thousand tons during the period of 2000- 2013.

3.4 The effect of climate change on potato production and potato quality

Several studies have addressed the influence of climate change and extreme climate events on potato culture and agro-technical improvements. For instance, Tubiello *et al.*[4] investigated the role of simple adaptation techniques in minimizing negative climate impacts on US crop production and Hijmans [5] studied the same on potato production in Peru. Haverkort *et al*. [7] reviewed the repercussions of climate change on potato supply chain on North European and Mediterranean climates. These studies agreed that potato yields were highly sensitive to the projected climate changes. Tubiello *et al* [4] and Hijmans [5] declared that early planting fully counterbalanced negative impacts of climate change, yield reductions ranges were 18% to 32% in case of no adaptation practices and 9% to 18% in case of adaptation practices. Mohamed *et al.* [14] found that climatic factors played an important role in the determination of the yield of potatoes, directly or indirectly, where they affected growth, production quality and quantity. The increasing of temperature by one degree Celsius during March at the Northern Delta caused the yield decreased by 0.67 ton per acre in summer potatoes crop.

As for potato quality, even though the potato plant has a wide range of adaptability, it requires sufficient cumulative temperature during the cultivation period. It was noted that during the cultivation time: a) a linear correlation exists between seeding days to emergence, flowering to harvest and mean temperature, b) insufficient cumulative temperature causes decrease in accumulation of dry matter, weight of tuber fresh, and final yield [15]. According to Haverkort *et al.* [7] potato quality in South Africa may be affected by climate change in form of larger tubers with higher dry matter concentration. At the same time, water efficiency is very important due to the reduction in rainfall worldwide, food shortages in Africa is expected [9]. A recent study by Haverkort *et al*. [7] found that climate change had an impact on potato production in South Africa

Regarding the impact of climate change on potato diseases and pests, few studies were conducted in this matter. It was reported that at higher temperatures and longer growing season, pests and diseases were expected to increase. Moreover, milder winters will lead to an increase in tubers survival, thereby acting as a source of inoculum and multiplication [16]. Van der Waals *et al*. [8] calculated past and future trends of pest and disease pressure in potato cropping. Their results helped in prioritizing research and breeding management strategies for diseases and pests reduction.

3.5 Research deficits and demands of future studies

Some general adaptation techniques for potato production under climate change conditions such as expanding rainwater harvesting, water conservation techniques, improve irrigation efficiency, adjust planting dates and relocate crops are suggested [9]. However, more in-depth analysis must be taken into consideration and especially on the study area and practices by local producers. In spite of potato production importance in Egypt and increasing demand for ensuring its production sustainability, no up-to-date investigations have been conducted assessing climate change impact on potato production in Egypt.

There is an increasing need to assess the potential impacts of climate change on potato production in Egypt and identify the proper practices for sustainable conservation and production.

These practices can be propagated to stakeholders and decision makers to assist in developing adaptation strategies for potato production in Egypt.

4. Conclusions

Potato cultivation is one of the most important agricultural cultivations in Egypt. Assessing climate change impacts on potato cultivation at local level is necessary in order to avoid related losses in crop production and quality. Identifying the best practices for mitigating climate change impacts in potato production can be very useful for local farmers. Moreover, these results will also help decision makers in developing adaptation strategies for potato production in Egypt as well as in similar climatic areas.

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