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Article

Climate Change Adaptation in the Delta Nile Region of Egypt: Implications for Agricultural Extension

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Abstract: This study used quantitative and qualitative methods to collect data, using questionnaires and interviews, from 792 randomly-selected farmers in two of the governorates in the Nile Delta Region, Egypt. A workshop was organized for 59 extension professionals working in the two governorates, looking at how the adaptive capacity of the agricultural sector towards climate change was being guided by policy-makers. Two focus groups were used: one with senior officials from the regional governorates and the other with central government administrators from the Ministry of Agriculture and Land Reclamation. The study findings suggested that 51.9% of the investigated farmers at the two targeted governorates had no knowledge about the climate change phenomenon. Maximizing the use of manure, changing crop patterns, and crop rotation were the adaptation measures most commonly adopted by aware respondents against climate change. Results of a probit model analysis indicated that farmers' ability to adapt to climate change was influenced by education level, farm size, diversity of production, and membership of a Water User Association. The study recommended some extension interventions to raise awareness of the anticipated effects of climate change.

Keywords: climate change; adaptation; extension; farmers; adoption; awareness; Egypt

1. Introduction

Climate change is considered a potentially serious environmental and economic issue [1]. A Report of the Intergovernmental Panel on Climate Change (IPCC) [2] indicated that risks arising from climate change could be made worse by the interactions between hazards, vulnerability, and exposure (people, assets, or ecosystems). Continued changes in the physical and bio-geochemical environment may influence variables such as sea level, sea currents, temperature, and wave action, increasing the frequency and intensity of severe weather, which, in turn, could modify the provision of ecosystem services, and thereby the well-being of people who rely on these services [3]. Worldwide, many countries could be affected by the consequences of climate change in all sectors of development [4,5].

According to IPCC reports, Egypt is particularly vulnerable to climate change, due to its geographical position and its dependence on climate-sensitive economic sectors [6]. A rise in sea level could affect the living conditions of millions of people, especially those living in the Nile Delta and the southeast, meaning that the populations of this part of the coastal zone could be exposed to economic, social, and/or health risks [7]. It has also been suggested that Egypt's precipitation may decrease due to climate change, with some modelling indicating an annual decline of up to 5.2% by 2030, 7.6% by

2050, and 13.2% by 2100 [8]. Therefore, it would be prudent for Egypt to identify adaptive strategies to manage climate risks in vulnerable areas [9].

The agricultural sector is considered to be vulnerable to climate change [10]. Nelson (2009) [11] stated that agriculture contributes about 13.5% of annual greenhouse gas (GHG) emissions, with forestry contributing an additional 19%, compared with 13.1% from transportation. The agriculture sector can also contribute to climate change mitigation, through soil and land use management, carbon sequestration, and biomass production. Several studies have produced modelling projections which have indicated the potential for adverse impacts from climate change on agricultural productivity, capital income, poverty levels, and loss of resources [12–14].

In Egypt, a large portion of arable land located in the Nile Delta is particularly sensitive to increased sea level and precipitation, and to temperature change [15]. Authors have postulated that this could affect farming activities in the Nile Delta in various ways: (i) a decline in agricultural productivity by up to 30–40%, and consequent reduction in farm net revenue [16]; (ii) increasing consumption of water for crops; (iii) soil degradation; (iv) lost agricultural lands; and (v) movement of people from vulnerable areas, especially the Northern Nile Delta, to other areas [17]. Kheir et al. (2019) [18] modeled the impact of climate change scenarios on wheat production in the Northern Nile Delta, their outputs indicated that a mean annual temperature rise of 1–4 °C decreased wheat yield by 17.6%. Moreover, areas available for wheat cultivation could be reduced by 0.07, 52.9, and 60.8%, under modeled sea level rise scenarios of 0.5, 1.5, and 2.0 m, respectively.

Another study, conducted by Fawaz and Soliman (2016) [19] indicated that a temperature increase of approximately 2 °C during the period across the 2012–13 season to the 2014–15 season caused production reductions of 18%, 18%, and 11%, for barley, maize, and rice, respectively, while there was a 17% increase in cotton production.

Agricultural researchers are working globally to mitigate and adapt to these potential effects, in order to maintain productivity within a finite natural resource basis [20]. Agricultural adaptation to climate change requires modification of agricultural systems to minimize losses or to capitalize on opportunities [21]. The effectiveness of adaptation depends on adjustments in social, economic, and ecological systems occurring across a range of micro- and macrolevels, especially in terms of farm production practices, technological developments, farm financial management, government programs, and insurance [22–24]. It has been suggested that, to sustain their livelihoods in this climate change context, farmers across the world need to continuously make adjustments to their farms' physical capital, productive capacity, and output [25]. In the Egyptian context, it has been suggested that agricultural adaptation is important for agriculture, especially in the Nile Delta, to achieve food security and sustainable water management [26].

Literature on adaptation has presented different adaptation strategy options, including minimizing tillage, changing planting dates, the development and promotion of new crop varieties, increased use of water and soil conservation techniques, crop diversification, use of subsidies and taxes, improvement in agricultural markets, changed use of capital and labor, shading and sheltering/tree planting, mixed crop–livestock farming systems, and diversification from farm to nonfarm activities [27–33]. Since 2010, the Egyptian government has provided support to facilitate change by building and managing infrastructure, allocating supplies, and coordinating with national private entities and international donors to implement adaptation measures in the Nile Delta, such as developing more heat- and salinity-resistant/tolerant crops, improving irrigation systems, and supporting crop insurance, crop diversification, and environment friendly practices, including a Good Agricultural Practices system [34].

To foster climate change adaptation, it is important to gather information on the constraints that influence the adoption of adaptation options at the microlevel [33,34]. It has been noted in previous studies that the adoption of adaptation measures was related to socioeconomic characteristics, access to formal and informal credit, access to extension services, limited access to services, poor regional infrastructure, insufficient funding, and the high cost of production [35–41]. To assist farmers address

these barriers, and to promote the employment of long-term adaptation options, Menike and Arachchi (2016) [42] offered the opinion that governments should introduce reforms that promote economic growth, technology, information and skills, infrastructure, and institutions.

There is therefore a demand for strong extension agencies, which could play key roles in addressing climate issues, to the point where they were able to bolster farmers' coping capacities. Agricultural extension has a key role to play in changing the knowledge, attitudes, and skills of the people [43]. A series of embedded communicative interventions could be planned and organized by agricultural extension personnel, to advise farmers on climate change adaptation measures [44]. Furthermore, agricultural extension is involved as a brokerage for awareness creation and knowledge sharing, among different participants in the agricultural innovation system. Such interventions, agricultural extension could build the capacity for resilience in vulnerable people, with the help of suitable government policies [45].

The administration of public Egyptian agricultural extension has a complex structure. At the national level, extension services involve the Central Administration of Agricultural Extension Services (CAAES), working in a close relationship with the Agricultural Research Center (ARC). Extension services are still supply driven in different scientific disciplines, lacking interdisciplinary exchanges among staff [46]. At Governorate level, there are extension departments in the agriculture directorates in (26) governorates. Subject matter specialists (SMSs) work in the extension departments at district level, to provide information and support concerning new technologies to the village extension workers (VEWs). The role of the VEWs at the village level has been to receive and simplify information received from SMSs, provide convincing information to farmers, and either resolve farmers' associated problems, or provide feedback to SMSs and ARC researchers, who will then try to find solutions [47].

Most research conducted on climate change in Egypt has followed a top-down approach, to assess the consequences of climate change on the different areas of agriculture and other sectors [15,16,48,49], or to test the efficiency of different adaptation measures applied by local farming systems [17,26]. Little research has been conducted on how farmers in the Nile Delta conceptualize climate-related risk, or how these farmers address risk through the adoption of recommended strategies (bottom-up approach). It has therefore been considered important to clearly understand both the farmers' current situation, when preparing them to address the issue of climate change, and the role of extension work in this situation. The current study has therefore tried to provide further insights, by filling the research gap on the potential role of extension institutions here, and by identifying procedures needed at the policy level to raise and convert the potential extension role into action on the ground. The objectives of the current study were as follows.

To explore awareness levels of the farmers and extension workers regarding climate change, and thereby identify their capacity to undertake appropriate climate change adaptation strategies.

To suggest procedures for addressing negative impacts from climate changes, through the collaboration of different stakeholders from all levels.

2. Methodology

2.1. Description of the Study Area

The Nile Delta Region is located in the north of Egypt where the Nile River spreads out and drains into the Mediterranean Sea. The Nile Delta Region has an area of approximately 22,000 km², and covers 240 km of the Mediterranean coastline, from Alexandria in the west to Port Said in the east. It is the richest agricultural area in the country and comprises 63% of Egypt's productive land [50]. Administratively, the Nile Delta Region includes of eight governorates—El-Beheira, Kafr-El-Sheikh, Al-Dekhalia, Damietta, Al Sharqiya, Al-Qalyubia, Al-Menufia, and Al-Gharbia—as shown in Figure 1, and lies between 31.01° E and 30.85° N. Its mean annual rainfall is estimated at 100–200 mm, mostly falling in the winter. In summer, the temperature is normally in the range of 32 to 38 °C, rarely reaching

45 °C, in July and August. In winter, the temperature is normally in the range of 9 °C at night to 19 °C in the daytime, with quite high relative humidity [51].

Most of the farms in the Nile Delta are small, with an average size of 3–4 feddan (~1.5 hectares). Cropping during the summer season includes maize, rice, cotton, cucumber, tomatoes, potato, squash, and watermelon, while in winter, the main crops grown are wheat, Egyptian clover, green pea, cabbage, carrot, barley, horsebean, sugar beet, spinach, and Tepary bean. Some vegetables and fruits grow in the study area year-round, including guava, strawberry, apple, white mulberry, sweet orange, bitter orange, pomegranate, banana, date, and peach [50]. Surface irrigation from the River Nile is used in the region. Water is distributed to different locations by a network of canals and is then drained away by separate canals [52]. The soil in the northern and central parts of the Nile Delta is clayey to silty-clay, while sandy soils are also present, with limited distribution in the eastern and western parts of the region [53].

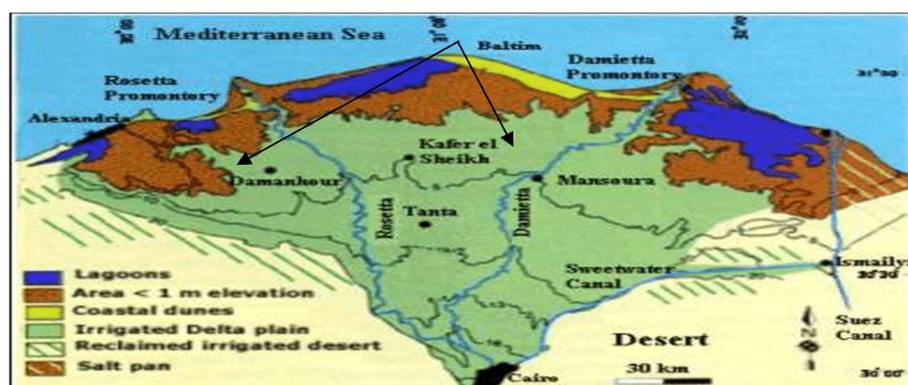


Figure 1. Location of the Kafr-El-Sheikh and El-Beheira governorates in the Nile Delta Region of Egypt. Source: adapted from Zeydan (2005) [54].

It has been reported that climate change manifestations already being experienced in the region include rising sea levels and eroding coasts, increasing soil salinity, decreased Nile flow, increasing summer temperature, changed rainfall patterns, land degradation in coastal areas, changes in weed species and distribution, pest and disease pressures, and declining crop productivity [19].

2.2. Conceptual Framework

A suggested conceptual framework to facilitate the role of extension work regarding climate change adaptation is shown in Figure 2. This framework suggests that promotion of the adaptive capacity of extension when confronting climate change can be enhanced through three cumulative factors. The first factor is the existing levels of awareness of farmers and extension workers. The second factor includes the adoption of adaptation measures recommended by extension in Egypt. The third factor focuses on the procedures required for climate change adaptation at the micro-, meso-, and macrolevels.

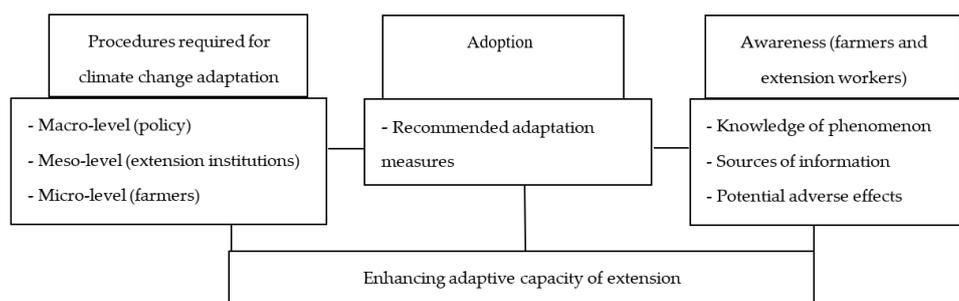


Figure 2. Conceptual framework of the study.

Using this model as the basis, addressing the potential effects of climate change occurs through a two-stage process: (1) perceiving the effects of climate change on agricultural production and (2) making a decision whether to adopt a particular measure or not [55]. Ajala et al. (2018) [56] pointed out that analyzing awareness is a key way to understand how farmers sustainably respond to climate change impacts. Consequently, extension institutions utilize the empirical evidence of farmers' awareness to design programs and campaigns designed to enable farmers to make informed decision on adaptation and mitigation strategy application [57]. In a similar vein, the knowledge and skills of extension personnel form the competencies needed to facilitate action in a wide variety of situations [58].

The need for competency in agricultural extension is a fundamental prerequisite for climate change oriented extension services [59]. Accordingly, Afful (2016) [60] stated that the low level of awareness and lack of climate change-related competencies among extension workers had a negative effect on supporting farmers to cope with the risks of climate change. Conceptually, the overall adaptive capacity of extension is a function of extension workers' and farmers' perceptions of climate change.

Other studies have found that adoption of climate change measures was conceptualized by the extent to which the farmers effectively and continuously use them in farming [61], and that decisions on selection and implementation of specific measures were influenced by various cognitive, behavioral, financial, physical, and institutional barriers [62]. To foster adoption of climate change adaptation strategies, Fagariba et al. (2018) [63] indicated the importance of investigating adaptation strategies implemented by farmers, the constraints impeding farmers' efforts to cope, attempts to determine the implementation gap to be covered by extension institutions, and efforts or policies needed from other stakeholders.

To promote timely and appropriate adaptation, the government has formulated microlevel procedures, which take into consideration regular assessments of climate change and its impacts. The procedures also support identification of suitable measures to be implemented at the microlevel, based on the latest scientific findings, and take account of the capacity of extension at the mesolevel to provide services that are more accessible for small-scale farmers [64].

By analyzing these three factors, this paper can contribute to the dialogue on developing extension institutions, on identifying potential interventions needed to meet adaptation needs, and on establishing procedures required to reduce vulnerability to climate change effects.

2.3. Research Design

A descriptive research methodology, using a survey approach, was designed to illustrate the roles of the different stakeholders in adaptation to climate change. Structured interviews (n = 792) were conducted between January and March 2017 to collect quantitative data. In addition, a mixture of qualitative methods was used, including two focus group discussions (n = 19), and a workshop (n = 59).

2.4. Study Sample

The survey was completed at four levels of representation:

- At the local (village) level, involving farmers in the Kafr-El-Sheikh and El-Beheira governorates in the North Delta region.
- At the district level, involving extension agents in the two governorates.
- At the governorate level, involving directors general of extension in the Nile Delta Region governorates.
- At the national level, involving chief administrators at the CAAES, and at the Ministry of Agriculture and Land Reclamation (MALR).

At the local level, farmers were selected using a multistage procedure. In the first stage, two governorates (Kafr-El-Sheikh and El-Beheira) were selected from the eight in the study area, on the

basis that they have been reported as those most vulnerable to climate change effects [13,15]. Four villages were then randomly-selected from each of the two selected governorates: Nekla, Arimoon, Sunhor, and Bsentsway from the El-Beheira governorate and El-Khadmia, Arimoon, El-Mothalth, and El-Qarn from the Kafr-El-Sheikh governorate. In the third stage, 792 farmers from the two governorates, representing approximately 10% of the target population, were selected, by employing a stratified, random sample technique.

2.5. Data Collection Methods

A questionnaire, whose content validity was assessed by a team of experts at the Department of Agricultural Extension and Rural Society, King Saud University, Saudi Arabia, was used as the main instrument for primary data collection. The questionnaire was divided into three sections; socioeconomic attributes; farmers' awareness of climate change; and farmers' adoption of adaptation measures. The index of adaptation measures consisted of 15 strategies included in Egypt's national plan for climate change adaptation (UNDP, 2011). According to this report, the strategies are long-term and have been practiced over an extended period. A farmer's awareness of climate change reflected his/her perception about changing temperature and/or rainfall, and was assigned one point for aware and zero for unaware. In the case of awareness, the farmer was asked about information sources, observed adverse effects, and adoption of adaptation measures.

The authors listed adaptation measures in the questionnaire, and farmers were able to select any options they had adopted to counter perceived climate change effects, with a value of one assigned for adopters, and zero for nonadopters. The questionnaire's content validity was assessed by a team of experts at the Department of Agricultural Extension and Rural Society, King Saud University, Saudi Arabia. Prior to this, a pilot study was conducted in the study area with the collaboration of 30 farmers. The aim of the pilot study had been to ensure that each question was appropriate and understandable by the farmers.

The questionnaire's reliability was assessed using Cronbach's alpha. A value of 0.89 indicated high reliability and internal consistency in the varied domains for the questionnaire. After testing the questionnaire for validity and reliability, data were collected by conducting personal interviews. The data from the completed questionnaires were coded, and then entered for analysis with SPSS program version 22.

At the district level, all extension workers in the governorates of Kafr-El-Sheikh and El-Beheira were invited to attend a workshop. Fifty-nine extension workers attended, representing 71.6% of the total available from the two governorates (30 from Kafr-El-Sheikh and 29 from El-Beheira). The workshop aimed to explore their level of knowledge about the adverse effects of climate change, and services currently provided on the subject, and to explore the climate change challenges faced by the farmers. The authors have summarized the main results from the workshop in this paper, to facilitate discussion of the data and to help verify the preliminary results from the farmers' interviews. Feedback at the workshop was used to increase research validity.

At the governorate level, one focus group discussion (FGD), whose aim was to identify the procedures and plans suggested to deal with climate change, was conducted. All 13 directors of extension working at the Delta Nile governorates were invited, with eight accepting the invitation and attending the FGD. At the national level, one FGD was designed and implemented, with all 11 chiefs of administrations at CAAES, to discuss the vulnerability of the agricultural sector to climate change effects, and the plans suggested for adaptation. The duration of each FGD was around one hour, on average, and then data reduction methods and thematic analyses were used to summarize the key findings [65].

2.6. Data Analysis

Statistical tools were applied to analyze the data, and the results have been developed in the form of frequencies, means, and standard deviations. We also used inferential analysis to explore factors

affecting awareness and adoption, and a chi-square test (Pearson's chi-squared test) to determine the relationship between farmers' awareness of climate change and their socioeconomic characteristics. A probit model was employed to investigate the determinants of farmers' adoption of on-farm adaptation strategies.

A binary logistics regression model was employed, and the allocated independent variables included those hypothesized to influence the adoption of adaptation measures. The list of explanatory variables used in the model was obtained from previous studies, and from the authors' knowledge of the aspects studied, described in Table 1.

Table 1. Definitions of variables in farmers' adoption model.

Variables	Description	Measurement
Dependent variable		
Adoption	Adoption of adaptation measure	1 = adoption, 0 = otherwise
Explanatory variables		
Age	Age of respondent	Age of the farmer in years
Education	Level of education obtained (dummy)	1 = elementary education at least, 0 = otherwise
Farming experience	Farming experience of respondent	Years of farming experience
Farm size	cultivated areas (owned, rented, or shared)	Number of cultivated areas (unit = Feddans *)
The diversity of farming activities	Type of agricultural activities (crops, vegetables, fruits, animal production)	1 if the farmer has different farming activity besides cultivating crops, 0 otherwise
On-farm demonstrations attended	Participating in on-farm demonstrations organized by extension in the last three seasons	Number of on-farm demonstrations attended
Extension meetings or training sessions attended	Participating in an extension meeting organized by extension in the last three seasons	Number of extension meetings or training sessions attended
Extension visit	Extension visits received from extension at the last three seasons	Number of extension visits received
Water User Association (WUA) membership	Membership of a WUA	1 = member, 0 = otherwise

* 1 Feddan = 4200 m² (0.42 Hectare).

The model for the probit regression is specified as shown in Equation (1):

$$P\left(y = \frac{1}{x}\right) = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_nX_n + \mu \quad (1)$$

where 0 refers to an individual not adopting adaptation measures and y is the 0–1 outcome, with 1 corresponding to an individual adopting the particular adaptation measure; X_1 and X_n correspond to sets of independent factors, β_0 = the intercept of the function and β_1 – β_n are its coefficients, μ is the error term, which is assumed to follow a standard normal distribution with a mean of zero and variance of one.

The regression equation can be stated as shown in Equation (2):

$$\gamma = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 \quad (2)$$

where: X_1 = age; X_2 = education; X_3 = farming experience; X_4 = farm size; X_5 = diversity of farming activities; X_6 = on-farm demonstrations attended; X_7 = extension meetings attended; X_8 = extension visits; and X_9 = WUA membership.

3. Results and Discussion

3.1. Socioeconomic Profile of the Farmers

The findings listed in Table 2 revealed that 46% of the farmers were in the 36–50 years age category, 31.7% were illiterate, while 32.3% of the farmers could read and write but had no further education. The results of the socioeconomic profile also showed that the majority of the farmers (70.3%) were small-scale farmers, operating 10 Feddan or less, while 54.5% had 16–30 years of experience practicing

farming. More than half of the farmers (56.3%) cultivated or managed 1–2 farming activities. More than half of the farmers had received limited contact (three times or less) from extension workers in the last three farming seasons, in terms of either attending on-farm demonstrations (64%), participating in extension meetings or training sessions (56%), or receiving extension visits (50.4%). Finally, 15.4% of the respondents were members of WUAs.

Table 2. Distribution of farmers based on socioeconomic characteristics.

Variable (n = 792)	Frequency	Percentage
	Age (years)	
≤ 35	119	15
36–50	364	46
> 50	309	39
	Education	
Illiterate	251	31.7
Read and write	256	32.3
Elementary school	215	27.2
Secondary school	70	8.8
	Farming experience (years)	
≤ 15	77	9.7
16–30	431	54.5
> 30	284	35.8
	Farm size (Feddans *)	
≤ 5	309	39
6–10	327	41.3
> 11	156	19.7
	The diversity of production (agricultural activities)	
1–2	445	56.3
3–4	260	32.8
More than 4	87	10.9
	Number of on-farm demonstrations attended (last 3 farming seasons)	
≤ 3	507	64
4–6	237	29.9
7–9	42	5.3
10 or more	6	0.8
	Number of extension meetings or training sessions attended (last 3 farming seasons)	
≤ 3	444	56
4–6	306	38.6
7–9	24	3.1
10 or more	18	2.3
	Number of extension visits received (last 3 farming seasons)	
≤ 3	399	50.4
4–6	311	39.3
7–9	82	10.3
10 or more	-	-
	Membership of WUAs	
Yes	122	15.4
No	670	84.6

Field survey, 2017; (*) 1 Feddan = 4200 m² (0.42 Hectare).

3.2. Awareness of Climate Change

The farmers' awareness of climate change and its associated effects as a newly emerged concept in Egyptian agriculture was measured, and the findings are displayed in Table 3. These findings indicate that 48.1% of the investigated farmers from both the targeted governorates were aware of the climate change phenomenon, findings which are in line with the study by Raghuvanshi et al. (2017) [66], where the awareness level of climate change was measured to be 50% among farmers in India. Of

interest, is a study conducted in South Africa [67], which found awareness levels among cabbage and potato farmers of 94.67% and 90.67%, respectively.

Table 3. Distribution of farmers' climate change information sources.

Variables	Awareness (n = 792)	
	Frequency	Percentage
Aware	381	48.1
Not aware	411	51.9
	Source of information (*)	
Extension agent	33	7.1
Meeting/Seminar	30	6.4
Radio	5	1.1
TV	157	33.7
Agricultural researchers	3	0.6
Sons	278	59.6

Field survey, 2017. (*) Farmers who had awareness of climate change were asked to select from a list of possible sources of information (more than one selection was possible).

It was found that the majority of the farmers (59.6%) who indicated knowledge of climate change in both governorates depended on their sons as information sources. Other information sources included TV (33.7%) and knowledge from the extension system (extension agent and/or extension meetings, 13.5%), while just 0.6% of the farmers in the study obtained their knowledge about climate change from agricultural researchers. Adebisi-Adelani and Oyesola (2014) [68] also found that family members were the main sources of climate change, for 91.9% of a sample of citrus farmers in Nigeria. However, our results are inconsistent with those reported by Idrisa et al. (2012) [69], who reported that extension agents were the main source of technical information about climate change among farmers in a different part of Nigeria.

Findings reported in Table 4 showed that the reported effects of climate change, mentioned by more than half of the respondents, included decreased crop productivity (84.5%), increased infestations of pests and diseases (81.4%), and increased soil salinity (57.2%). The other issues reported by the respondents as likely effects of climate change were decreased incomes for farmers (35.7%), increased prices of production supplies (33.3%), increased ground water levels (29.4%), increased consumption of fertilizers (29.4%), and increased water requirements (25.7%).

Table 4. Distribution of the farmers according to their awareness of the impacts of climate change.

Adverse Effects (n = 381)	Aware		Not aware	
	Frequency	Percentage	Frequency	Percentage
Increased pests and diseases	310	81.4	71	18.6
Decreased crop productivity	322	84.5	59	15.5
Increased ground water levels	112	29.4	269	70.6
Increased soil salinity	218	57.2	163	42.8
Decreased farmer income	136	35.7	245	64.3
Increased operational cost due to increased expenditure on inputs	127	33.3	254	66.7
Increased consumption of fertilizers	112	29.4	269	70.6
Increased water requirements	98	25.7	283	74.3

Field survey, 2017.

A classification of the respondents based on overall impact of climate change on agriculture is shown in Table 5, in which it can be seen that 43% of the respondents had a medium level of awareness, 37.5% showed a high level, and 19.2% exhibiting a low level. The farmers might have gathered as much information as possible from various channels, particularly their educated sons, the mass media, and

extension. Their awareness of potential impacts of climate change on agriculture was good, overall, and this finding accords with other reports [66,70].

Table 5. Farmers' awareness categories of the impacts of climate change.

Awareness categories	Frequency	Percentage	Mean	SD
Low (< 3.16)	73	19.2		
Medium (3.16–5.72)	165	43.3	4.44	2.56
High (> 5.72)	143	37.5		

Field survey, 2017.

Data presented in Table 6 shows that a chi-square test revealed significant differences across respondent education groups regarding their reports of observed changes in climate ($\chi^2 = 16.41$, $df = 3$, $P = 0.005$), indicating that as the farmers' levels of education increased and that their interest in seeking new information about climate change increased. However, the educational status of farmers in the two governorates was substantially good, with only 31.7% of the farmers being illiterate, and the more educated farmers were more aware of climate change. This result can be compared to a study by Mustafa et al. (2018) [71] who found that the education level of farmers was a significant determinant of farmers' awareness of climate change.

Table 6. Relationship between farmers' awareness and selected socioeconomic characteristics.

Variables (n = 792)	χ^2	p-value
Governorate	4.7	0.16
Age	2.19	0.58
Education	16.41	0.005 **
Farming experience	9.61	0.02 *
Farm size	1.1	0.73
Diversity of production	1.72	0.79
Number of on-farm demonstrations attended	12.1	0.01 **
Number of extension meetings or training sessions attended	12.5	0.01 **
Number of extension visits received	0.9	0.84
Membership of WUAs	0.6	0.89

Field survey, 2017. * Significant at the 0.05 level, ** significant at the 0.01 level.

It was observed that awareness of the respondents on changes in climate differed significantly according to their farming experience groups ($\chi^2 = 9.61$, $df = 2$, $P = 0.02$), with more experienced farmers being more aware of climate change than those who were less experienced. Farming experience apparently helped develop a sensitivity to the effects of climate change on their activities among farmers. This supports the work of Matsalabi et al. (2018) [70], who reported that farming experience significantly affected farmers' awareness of climate change.

Significant differences were observed across the indicators of extension contact, on awareness of climate change, in terms of the number of on-farm demonstrations attended ($\chi^2 = 12.1$, $df = 3$, $P = 0.01$) and the number of extension meetings or training sessions attended ($\chi^2 = 12.5$, $df = 3$, $P = 0.01$). In contrast, our findings suggested that the number of extension visits received appeared to be unrelated to the level of awareness ($\chi^2 = 0.9$, $df = 2$, $P = 0.84$). Farmers who attended on-farm demonstrations or extension meetings had a greater awareness of climate change compared to those who did not attend. Participation in on-farm demonstrations or attendance at extension meetings increased the ability of the farmers to see adaptation measures in the field, or to hear about new topics in agriculture, especially those related to climate change. This result is in line with the findings of other work [71,72].

Results also revealed that the difference in awareness of climate change between the two governorates was not significant ($\chi^2 = 4.7$, $df = 1$, $P = 0.16$). There was also no significant effect detected in relation to difference in age ($\chi^2 = 2.19$, $df = 1$, $P = 0.58$), farm size ($\chi^2 = 1.1$, $df = 2$, $P = 0.73$), diversity of production ($\chi^2 = 1.72$, $df = 2$, $P = 0.79$), or membership of WUAs ($\chi^2 = 0.6$, $df = 1$, $P = 0.89$).

Data obtained from the workshop organized for the extension agents revealed that they had adequate awareness of climate change and its adverse effects. The findings revealed that their perceptions were that the main climate change indicators were increased water consumption in summer (88.1%), increased spread of insects like flies and mosquitoes (76.3%), increased soil salinity (66.1%), irregular irrigation applications (37.2%), reduced soil properties (37.2%), decreased crop productivity (28.8%), changed crop cultivation dates (20.3%), and an increase in livestock diseases (15.3%). Moreover, the predominant effects of climate change on health and environment identified by the respondents were comprehensive changes in the rural environment (47.4%), increased disease frequency (especially among the elderly) (44%), increased pesticide residues in soil (33.8%), increased spreading of pests (33.8%), increased temperature (30.5%), increased relative humidity (30.5%), increased respiratory diseases (18.6%), decreased availability of food to feed people (18.6%), and a decline in the demand for agricultural workers (6.7%). These findings confirmed that the extension workers still needed to enhance their competencies on anticipated climate change issues.

According to Belay and Abebaw (2004) [73], the effectiveness of extension systems depends highly on the availability of extension agents who are qualified, committed, motivated, and responsive. Hence, lack of competencies such as knowledge, and skills, and the attitudes that they have, will affect their job performance. The results of the workshop were in line with other published work [60], where it was found that 94% of the investigated extension agents in South Africa expressed their needs for training in climate variability, to enable them to support farmers better. In another study, conducted in Ethiopia, the study indicated that only 20.7% of the extension workers believed they had adequate access to scientific materials or policies and strategies about climate change and adaptation [74].

3.3. Adoption of Recommended Climate Change Adaptation Measures

Findings of adaptation measures adopted by the respondents against climate change (Table 7) indicated that the majority (91.6%) maximized use of manure in their farms, to add organic matter to the soil. Changing crop patterns and rotation was practiced by 76.3%, while 52.2% took measures to avoid exhausting the soil, and to control weeds, pests, and diseases. Approximately two-thirds (66.1%) of the respondents reported that they rationalized use of mineral fertilizers by use of organic fertilizers as supplements, to reduce water pollution and GHG emissions. Over half (51.9%) of the respondents planted drought-resistant varieties to cope with shorter rainfall regimes, while 38.1% cultivated salinity-resistant varieties, to reduce the soil salinization risk from climate change, especially in the coastal areas. Of all farmers surveyed, 45.4% adopted making and using compost to reduce the problem of air pollution (black cloud) that stemmed from burning crop residues. Other adaptation measures used by the respondents included changing planting dates, mixed cropping, applying modern irrigation systems, and mulching, as reported by 37.2%, 25.4%, 25.4%, and 23.3%, respectively.

Classification of the respondents based on the number of adaptation measures adopted, as shown in Table 8, revealed that 9.4% of the respondents did not adopt any adaptation practices. Moreover, 49.6% of the respondents had a low level of adoption, followed by medium (25.4%) and high (15.6%), which showed that most farmers had adopted one or more climate change adaptation measures (Mean 4.11, SD 1.73). The findings were consistent with the findings of Taruvinga et al. (2016) [75] in South Africa, who indicated that 62.5% of farmers were classified in the low adopter category, regarding adaptation measures.

Table 7. The distribution of investigated farmers according to the number of climate change adaptation practices adopted.

Measures (n = 381)	Number of Farmers Adopting	Adopters (%)
Changed cropping pattern	291	76.3
Mixed cropping	97	25.4
Crop rotation	199	52.2
Shading/tree planting	64	16.8
Changed planting dates	142	37.2
Cultivation of drought-resistant varieties	198	51.9
Cultivation of salinity-resistant varieties	145	38.1
Applying modern irrigation systems	97	25.4
Adjusting irrigation scheduling	126	33.1
Night irrigation (in summer)	142	37.3
Making and using compost	173	45.4
Rationalizing mineral fertilizers usage	252	66.1
Mulching	89	23.3
Maximizing the use of manure	349	91.6
Conservation tillage	59	15.5

Source: Field survey, 2017.

Table 8. Adoption categories of climate change adaptation practices.

Adoption categories (n=381)	Frequency	Percentage	Mean	SD
Non-adopters	36	9.4		
Low (< 3.25)	189	49.6		
Medium (3.25–5)	97	25.4	4.11	1.73
High (> 5)	59	15.6		

Field survey, 2017.

The probit model was used to determine the factors influencing farmers' adoption of adaptation measures (Table 9). Personal attributes (age, education, farming experience, farm size, diversity of production, and membership of WUAs) and extension contact variables (attending on-farm demonstrations, participating in extension meetings or training sessions, and extension visits received) were analyzed for their correlation with farmers' adoption behavior.

Table 9. The influence of various factors on farmers' adoption of adaptation measures.

Variable	Marginal Effects	Std. Err.	p-value
Age	−0.074	0.04	0.71
Education	0.392 **	0.016	0.006
Farming experience	0.088	0.028	0.23
Farm size	0.171 *	−0.08	0.022
Diversity of production	0.36 **	0.089	0.00
Number of on-farm demonstrations attended	0.084	0.017	0.5
Number of extension meetings or training sessions attended	0.033	0.023	0.33
Number of extension visits received	0.051	0.024	0.41
Membership of WUAs	0.195 *	−0.072	0.04

Wald $\chi^2 = 80.11$, Sig. = 0.01, Log pseudo likelihood = 73.47, Pseudo $R^2 = 0.32$

Field survey, 2017. * Significant at the 0.05 level; ** Significant at the 0.01 level.

The results presented in Table 9 indicated that four out of eight variables used in the adoption model were statistically significant at either the 0.05 or 0.01 levels. The Wald χ^2 value of 80.11 showed that the likelihood ratio statistics were highly significant ($p < 0.01$), suggesting that the adoption model had a strong explanatory power. The Pseudo R² value was 0.31, indicating that the explanatory variables explained ~32% of the variation in farmers' adoption of adaptation measures.

The education level of the respondents significantly influenced the likelihood of adoption of adaptation measures in the study area. Specifically, the marginal effect of 0.392 indicated that farmers having secondary education and above increased the probability of adoption by 39%. A probable explanation for this is that educated farmers are more able to seek new information, and process and evaluate its use for reducing the adverse effects of climate change.

Responding to climate change actions and farmers' education level can work together in three ways; education fills knowledge gaps on causes and impacts of climate change, challenges apathy and creates a desire for adaptation measures to mitigate the effects of climate change, and furnishes the technical knowledge to adopt the innovations within the constraints of local farming systems [76]. These results were consistent with those from several previous studies [48,63,69,75,77–79].

It could be concluded that education has a productive value for people in gaining productivity and increasing adapting capacity. The impact of education classified into cognitive by achieving literacy and numeracy. This aspect of education enables people to read, understand, and calculation of the different issues. Another type of effect is noncognitive, where a change occurs in an individual's attitudes in terms of punctuality, cooperative work, timeliness, conflict management, and so on [80]. Accordingly, the government of Egypt should pay attention and invest in enhancing the quality of formal schooling and supporting nonformal education by strengthening extension services and adult literacy classes. Furthermore, encouraging social platforms and forming groups whereby people share ideas among each other as a form of informal education.

The results also showed that, in relation to farm size, farmers with larger farms had a higher probability of adopting adaptation measures, by 0.171. A possible explanation for this might be that an increase in the area cultivated minimized the risk, allowing farmers to gain a higher yield. Moreover, farmers could take advantage of market opportunities and increase their incomes. These results were similar to those of previous studies [48,81].

One of the key determinants to adoption was diversity in production. In this context, the findings presented in Table 9 indicated that an increase of types of agricultural activities managed by individual farmers was associated with a 36% probability of adoption of adaptation strategies. Diversification of agricultural production has been suggested as playing a key role in reducing risk in agriculture. Farmers who pursued different farming activities (vegetables, fruits, animal production, crops, food processing enterprises, etc.) are thought to be less vulnerable to climate change. Consequently, farmers are trying to seek information about adaptation measures for maximizing profit, reducing risk from climate change, and leading a sustainable livelihood. This result supported the previous findings of Ali and Erenstein (2017) [48].

WUA membership and the adoption of adaptation strategies were significantly positively correlated. Enhancing social capital among farmers by cooperative operation and maintenance of irrigation systems has been reported as playing an important role in encouraging users to adopt sustainable technologies for more efficient water use and increased crop production [82,83]. This is consistent with the findings of Chuchird et al. (2017) [84], who reported that WUA membership was a significant factor in the adoption of irrigation technologies.

Variables related to extension contact (number of on-farm demonstrations attended, number of extension meetings or training sessions attended, and number of extension visits received) were found to have a nonsignificant influence on adoption. This result was similar to that from the study by Taruvinga et al. (2016) [75], who found that access to extension services was not a determinant of adaptation to climate change. It has also been noted, however, that many previous studies have found that farmers with access to extension services had a higher probability of adopting adaptation

strategies [48,63,69,77–79]. The result in our study reflects the low effect of extension services on motivating farmers to adopt adaptation strategies.

According to Leeuwis (2006) [85], agricultural extension is a series of embedded communicative interventions that aims to facilitate farmers' and other rural stakeholders' knowledge sharing, problem-solving, and skills development, in order to improve their livelihoods. Such interventions include creating awareness on climate change issues, encouragement of wide participation of all stakeholders in addressing climate change issues, building resilience capacity among vulnerable individuals, and brokerage among stakeholders on the issues of climate change.

Previous studies in Egypt have given rise to a myth about the parlous state of agricultural extension [47,86]. According to these studies, constraints such as lack of extension staff, lack of responsiveness to farmers' needs, focusing on supply-driven approach (push technology), lack of funding, and inadequate utilization of information communication technologies (ICTs) affect the efficiency and effectiveness of agricultural extension. Despite these challenges, however, agricultural extension is a pillar for agricultural development in Egypt, and governments still need it in terms of implementing agricultural policies, collection of field data and statistics by extension workers, working on environmental sustainability (due to the lack of interest from the private sector on such issues), and dealing with emergency situations in any area [86].

To develop the role of extension, our research has suggested that government should lead and implement extension reforms by suggesting new regulations for providing efficient extension services, conducting partnerships with different stakeholders, appointing and training new extension personnel, applying a demand-led, participatory and market-oriented approach, and strengthening research-extension linkages [87]. These suggested roles embody the concept that the different levels of government should support extension, as an objective source of scientific information, and as a resource whose reputation its constituents can rely on in addressing the consequences of a variable climate on natural resources [88].

3.4. Procedures for Addressing Climate Change and Adaptation Needs

Addressing the issue of climate change requires collaboration between all stakeholders in order to devise an appropriate strategy. The following section discusses the perspectives of different organizations working to help farmers address the issue of climate change.

A. Macrolevel:

The procedures to address negative impacts from climate change have been discussed with personnel from the MALR, CAAES, and the agricultural directorates. Discussions with a focus group consisting of the CAAES administration and chiefs recommended many measures to respond of climate change, such as planning and implementing awareness programs on climate change for the farmers, the production of extension publications, making climate data available on a regular basis, broadcasting radio and TV programs on climate change, creating a specific unit at CAAES to monitor climate change, and conducting training programs on climate change. The respondents recommended an action plan to address issues associated with climate change, and to disseminate adaptation options further at the national and local levels, to achieve a sustainable agriculture sector. The respondents identified the following pivots.

- I. Infrastructure, by establishing a specific unit on climate change monitoring at CAAES.
- II. Research, through provision of resistant varieties and improving farm irrigation systems.
- III. Extension, by conducting awareness programs and field schools for farmers, producing extension publications and organizing training programs for extension workers.
- IV. Information, by making data on climate available on a regular basis and launching radio and TV programs on climate change.

Discussions held with a focus group comprising the directors of extension working at the Nile Delta Region governorates enabled the researchers to offer recommendations on combating climate change, and to include such recommendations in the future executive plan. The steps of this plan included changing the frequency of irrigation, changing fertilizer quantities, suggesting new methods for pest/disease control, considering new planting dates for summer and winter crops, organizing extension meetings to raise awareness of climate change, providing resistant varieties, improving farm irrigation systems, refurbishing irrigation canals, and training extension workers on climate change issues.

B. Mesolevel (agricultural extension institutions)

The analysis presented here regarding the role of extension work in addressing climate change at the mesolevel is based on two main indicators: (1) the current role of agricultural extension towards climate changes adaptation and (2) meeting farmers' needs to address climate change through extension services. Data which illustrate that the role that extension activities play in raising awareness among the farmers and reducing climate change risks remains weak are shown in Figure 3, where it can be seen that the relative weight of using extension activities for that purpose was 28.2% (27.1% in Kafr-El-Sheikh and 29.2% in El-Beheira). The most extensively undertaken extension activities to raise farmers' awareness and reduce climate change risks in Kafr-El-Sheikh were extension seminars (55.5%), followed by farm visits (37.7%), whereas the farm visits ranked first (59.4%) in El-Beheira, followed by agricultural TV programs (55.1%).

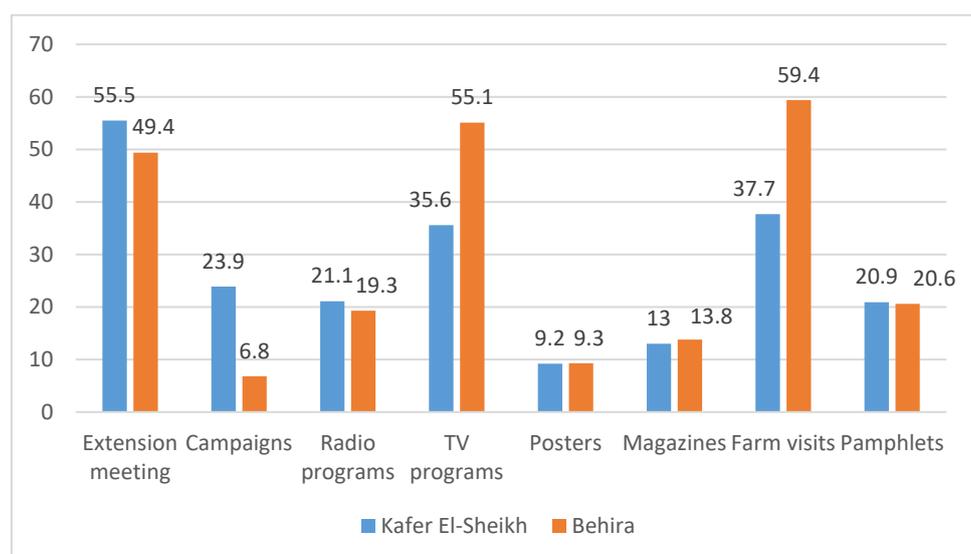


Figure 3. Participation in agricultural extension activities to raise awareness and reduce climate change risks among farmers (attendance as percent) from the two governorates.

The extension service was shown to play a weak role in creating awareness and alleviating the impacts caused by climate change among the farmers in the study governorates, as revealed in Figure 4. The relative score on farmers needs from the extension services was 16.6% (26.1% in Kafr-El-Sheikh and 7.1% in El-Beheira). The most prominent extension service activities undertaken to meet the needs of the farmers to reduce the risks from climate change in the governorate of Kafr-El-Sheikh were providing extension pamphlets and holding seminars to raise awareness on climate change. Similarly, the extension activities to address climate change in the El-Beheira governorate included holding seminars to raise awareness, providing extension pamphlets on climate change, and selecting crop patterns to offset negative impacts stemming from climate change.

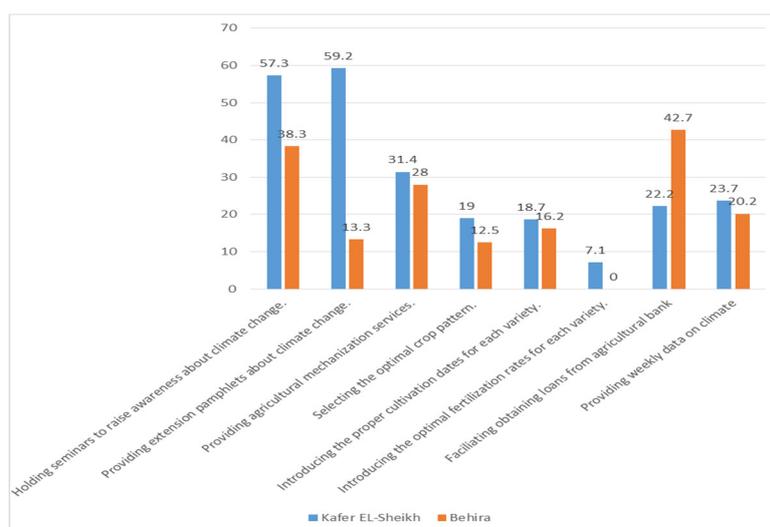


Figure 4. Distribution of the extension services to tackle climate change and their associated impacts.

C. Microlevel (Farmers)

Farmers remain at the frontline of those who are directly affected by the effects of climate change and are the leading stakeholders in the adaptation process. The perceived roles of farmers in adaptation to climate change are presented in Table 10, where the data indicated that the most well-known adaptation processes among the farmers of Kafer-El-Sheikh included changing planting dates (either early or delayed) (82%), shortening the time between irrigation periods to offset higher temperatures (64.8%), cultivating suitable varieties (30.2%), and using pesticides (23.5%). Similarly, the data indicated that adaptation strategies adopted by the El-Beheira farmers included cultivating suitable varieties (74%), changing planting dates (66.7%), shortening the time between irrigation periods, and covering plants with plastic covers (26.3%).

Table 10. Strategies suggested by the farmers to address climate change impacts.

Strategies* (n = 972)	Frequency	Percentage
Changing planting dates (either earlier or later)	588	74.2
Shortening irrigation periods in high temperatures	432	54.5
Using biopesticides	92	11.6
Changing to greenhouses system	69	8.7
Changing fertilization rates	44	5.6
Cultivating suitable varieties	414	52.3
Diversifying farming methods to cope with climate conditions	28	3.5
Covering plants with plastic covers	146	18.4

Source: field survey. (*) Strategies suggested by the farmers in case of the increasing impact of climate change.

Data on which sources for obtaining information on climate change were preferred by the farmers in the two targeted governorates are shown in Figure 5. The analysis showed that the most popular was (1) extension meetings and seminars (52.4%), followed by (2) farm and home visits (48.6%), (3) agricultural TV programs (45.4%), (4) extension pamphlets (20.7%), (5) agricultural radio programs (20.2%), (6) a national campaign (15.3%), (7) an extension magazine (13.4%), and (8) extension posters (9.2%).

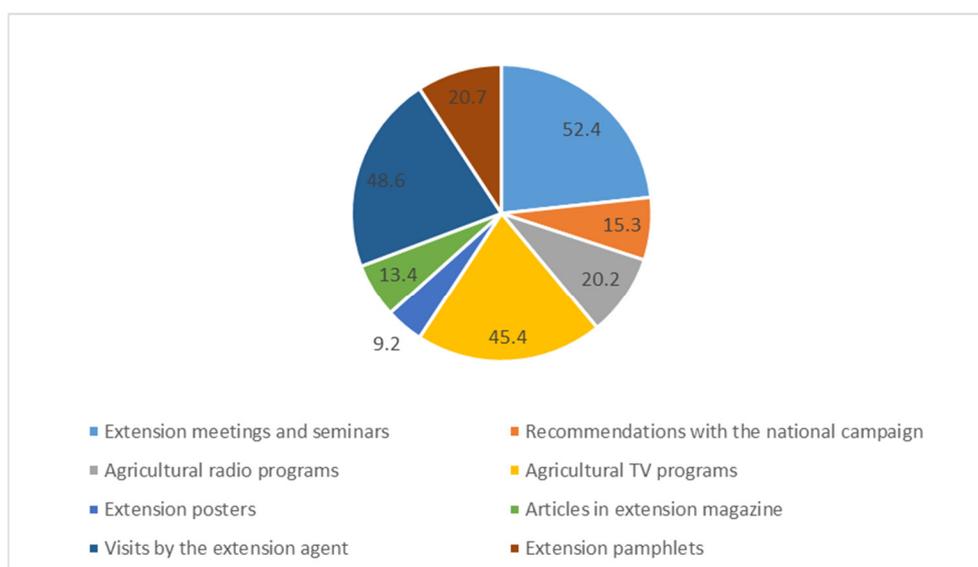


Figure 5. Farmers' preferred sources of information on climate change.

4. Conclusions

According to literature, climate change is seen as undermining agricultural production in Egypt. The current study has tried to give insights about the current situation regarding farmers' awareness of climate change issues. Results indicated that 48.1% of the respondents had awareness of climate change. This means that extension workers should still discuss climate change with unaware farmers, and influence farmers' abilities to observe and perceive the climate change effects.

Data on farmers' adoption of adaptation strategies to cope with the effects of climate change in the study area indicated that 49.6% of the respondents had a low level of adoption.

Data suggested that the farmers' education levels had a significant effect on how they perceived the issue and were able to adopt innovative adaptation practices. Promoting knowledge and skills development in the farmers was seen as important, as education could be a catalyst for the perception of risks and responding effectively to changes.

The impact of extension services on adoption of climate change adaptation was neither effective nor sufficient, even though the extension workers are quite aware of the issue of climate change and its associated impacts. Effectiveness could be strengthened if the extension focused on demonstrations and farmer field schools instead of on print media and extension meetings. The probit model also indicated that determinants of the use of adaptation measures included education level, farm size, diversity of production, and membership of a WUA. This implied that improved adoption of adaptation practices would need physical, social, and knowledge interventions.

As the government is a major stakeholder in environmental sustainability issues, climate change adaptation strategies could be improved significantly if extension was supported to train farmers on recommended adaptable strategies in the study area. These findings have tried to fill the gap concerning required procedures to be implemented to strengthen the role of extension. In this context, the study recommends the action plan suggested by the chiefs of administrations at CAAES. The action plan concluded that climate change was an issue threatening multiple negative impacts on farmers and required an integrated approach. At the microlevel, the emphasis should be on enhancing farmer capacity through mitigating and adaptive practices. At the mesolevel, strengthened capacity of extension institutions and further investment in research and development was also seen as being required. At the national level, policies should support sustainable productivity growth, in combination with adaptation and mitigation efforts.

Addressing the impacts of climate change is not only an existential issue but is also an opportunity to move toward sustainable agriculture in the study area, to achieve the goal of having sustainable communities.

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