Level of Knowledge of Agricultural Science Graduate Students about Climate Change Mitigation and Adaptation Practices of Agriculture

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Received: August 27, 2021 Accepted: November 29, 2021 Online Published: December 12, 2021

doi:10.5430/wje.v11n6p50 URL: https://doi.org/10.5430/wje.v11n6p50

Abstract

Climate change (CC) is a global environmental problem and source of concern. Effective planning and implementation of CC mitigation and adaptation may arise from knowledge of its causes and effects. Therefore, dissemination of knowledge is highly important for ensuring that the knowledge grows and spreads amongst the various stakeholders and that it is turned into action. The students of today are the leaders and policy makers of tomorrow. They will effectively serve as change agents once their knowledge base has been well established. This study provides analysis of graduate students' level of knowledge of CC, its nature, causes, effects, mitigation, and adaptation. The study population was 57 agricultural science master's students in the Faculty of Agricultural Sciences in Jarash University, Jordan, and the sample consisted of 50 of those students. The study used online test as the knowledge assessment and data collection tool. Frequency distribution analysis uncovered that the sample students possess high level of general knowledge of CC, moderate level of knowledge of mitigation of CC, and high level of knowledge of adaptation to CC. As to the three investigated facets of general knowledge of CC, these students have high levels of knowledge of the nature and the effects of CC and moderate level of knowledge of its causes. These findings contribute to understanding of students' knowledge achievements and gaps and of the need for curricular reform in terms of structure and content that can be shared by agricultural science faculties around the World with similar CC graduate programs.

Keywords: climate change, knowledge, adaptation, mitigation, agricultural sciences, graduate students

1. Introduction

1.1 Climate Change: Nature, Causes, and Effects

Climate change (CC) has been defined in varying ways in the literature. The Intergovernmental Panel on Climate Change (IPCC) articulates that "*Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use*" (IPCC, 2014, p. 120). Schwirplies (2018) defined CC as *"a rise in the average global temperature over the past 150 years or in the future*" (p. 309). More recently, Fawzy et al. (2020) defined it as shift in the climate patterns that is caused mainly by greenhouse gas (GHG) emissions from human activities and natural processes. In this respect, the GHGs have been defined by Easton and Faulkner (2014) as a "*collection of human and naturally derived gases that trap heat within the atmosphere that can both regulate Earth's climate and contribute to climate change*" (p. 6). The principal GHGs emitted by human activities are methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). These gases trap the heat in the atmosphere and raise temperature of the Earth steadily above the natural levels (Easton & Faulkner, 2014). However, Lineman et al. (2015) stressed the role of fossil fuels and CO_2 in CC and defined it as "*a change in global or regional climate* *patterns, in particular a change apparent from the mid to late 20th century onwards and attributed to the increased levels of atmospheric carbon dioxide arising from the use of fossil fuels*" (p. 3).

Climate change is caused by (i) natural processes, which include natural factors and forces like volcanic eruptions and solar radiation variations; and (ii) anthropogenic factors, namely, human activities (Kakaki, 2013; Odjugo, 2010). The human activities that cause CC correspond to either (i) emitting large volumes of GHGs into the atmosphere through, for example, fossil fuel burning, gas flaring, industrialization, and agricultural – and other – waste burning; or (ii) reducing the amount of carbon that is removed from the atmosphere (Odjugo, 2010) by such activities as deforestation (Akrofi, Antwi, & Gumbo, 2019; Falaye & Okwilagwe, 2016). However, there is broad consensus among scientists currently on that the main cause of CC is human activities (Falaye & Okwilagwe, 2016; Sulistyawati, Mulasari, & Sukesi, 2018; Tobler, Visschers, & Siegrist, 2012).

The main cause of CC is human activities that increase release of GHGs into the atmosphere or reduce their sinks in the environment. These gases are derived both from human activities and natural processes (Crowley, 2000; Frigg, Thompson, & Wernd, 2015; Hulme et al., 2009; Olaniyi, Olutimehin, & Funmilayo, 2019). In particular, the GHGs CO_2, CH_4, and N_2O are the three largest individual contributors to CC (Lynch et al., 2021). A substantial cause of CC is fossil fuel burning, which releases CO_2 and other GHGs into the atmosphere (Baer et al., 2019; Plotnikoff, Wright, & Karunamuni, 2004). Agriculture too is a major contributor to anthropogenic CC (Jørgensen & Termansen, 2016). In effect, agriculture and food production contribute the foregoing three GHGs (Lynch et al., 2021) and others such as ammonia (NH_3). Olaniyi et al. (2019) and Parant et al. (2016) support that the main cause of global warming and CC is the ongoing increase in the concentration of CO_2 in the atmosphere due to emissions from deforestation, cement production, and fossil fuel burning, which constitute the major sources of CO_2. Deforestation reduces CO_2 sequestration whereas fossil fuel burning produces the largest volumes of the atmospheric CO_2 and cement production ranks as the third largest CO_2 producer (Olaniyi et al., 2019).

Climate change has widely-varying negative impacts on the ecosystem that include increased incidence and intensity of extreme weather conditions such as frost (Niles, Brown, & Dynes, 2016), drought, thunderstorms, windstorms, rainstorms, floods, and tsunamis (Limantol et al., 2016; Olaniyi et al., 2019; Rahman et al., 2021). The negative impacts also include heat waves (Falaye & Okwilagwe, 2016; Kakaki, 2013; Olaniyi et al., 2019; Onoja et al., 2011); wildfires (Falaye & Okwilagwe, 2016); melting of ice caps (Kakaki, 2013; Onoja et al., 2011); rising sea levels (Kakaki, 2013; La Torre et al., 2020; Marty & Yokochi, 2006; Onoja et al., 2011); coastal flooding and erosion (Agboola & Emmanuel, 2016; Olaniyi et al., 2019); and soil erosion (Onoja et al., 2011). Erosion, the heat waves, and drought contribute to desertification (Kakaki, 2013), which aggravates the negative impacts of CC. Additionally, the deleterious impacts of CC encircle changes in rainfall trends and patterns (Easton & Faulkner, 2014; Limantol et al., 2016; Marty & Yokochi, 2006) and adverse effects on human, animal, and plant health (La Torre et al., 2020; Marty & Yokochi, 2006) due, mainly, to proliferation of water-borne, vector-borne, and infectious diseases (Baer et al., 2019; Sulistyawati et al., 2018). Furthermore, climate change causes shortages of water supplies for domestic and agricultural use (Akrofi et al., 2019; Dhanya & Ramachandran, 2016; Easton & Faulkner, 2014; La Torre et al., 2020).

As far as agriculture, in specific, is concerned, the problems associated with CC encompass insect and pest infestations (Asrat & Simane, 2018; Dhanya & Ramachandran, 2016); weed proliferation (Ramesh & Negi, 2014); crop damage and failure (Dhanya & Ramachandran, 2016; Easton & Faulkner, 2014; Kakaki, 2013); biodiversity loss (Akrofi et al., 2019; Kakaki, 2013; La Torre et al., 2020); deterioration of arable lands (Odjugo, 2010) and reduction of their areas due to land degradation (Asrat & Simane, 2018); and reduction in crop yields (Agboola & Emmanuel, 2016; Akrofi et al., 2019; Apata, 2011; Easton & Faulkner, 2014; Limantol et al., 2016; Olaniyi et al., 2019). Moreover, climate change has been reported to be altering the incidence, distribution, and intensity of plant and animal pests and diseases (Ramesh & Negi, 2014), in addition to those of alien and invasive species (Barkmann, Siebert, & Lange, 2017; Ramesh & Negi, 2014). Furthermore, climate change effects extend over rangelands and include spread of non-native invasive weeds, emergence of new weeds, and decline in the desirable grasses (Yung et al., 2015). A direct consequence of the aforementioned detrimental effects of CC is that plant and animal farm production and productivity drop tangibly in parts of the World (Apata, 2011; Easton & Faulkner, 2014; Mkonda, He, & Festin, 2018; Olaniyi et al., 2014), with concomitant negative implications for food security.

Policymakers and scientists in general agree on that CC has far more adverse impacts on the production ecosystems than positive outcomes (Easton & Faulkner, 2014). It should be highlighted, however, that the net impact of CC varies qualitatively and quantitatively by climatic region (Apata, 2011; Olaniyi et al., 2019), season (Apata, 2011; Easton & Faulkner, 2014), and farming system (Niles et al., 2016). As a result of the aforementioned negative effects of CC, it has socio-cultural, economic, and political impacts on communities. However, a discussion of these impacts is out of scope of this study.

1.2 Response to Climate Change: Mitigation and Adaptation

1.2.1 Mitigation

Climate change adaptation and mitigation are the primary responses of the human community to CC in order to reduce its incidence and minimize its negative impacts on humans and the ecosystems. Mitigation of CC has been defined by IPCC (2014) as "*A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)*" (p. 125). In the context of agriculture, these two facets of mitigation, that is, reducing the sources and enhancing the sinks, have been affirmed recently by Pareek (2017), who stated that mitigation of CC is realized through farm management actions that lower GHG emissions and improve carbon sequestration by soil. Very recently, Marangoni et al. (2021) defined mitigation strategies as rules that prescribe reductions in the global CO_2 gas emissions from the industry and fossil fuel burning. According to Schwirplies (2018), climate change mitigation encircles all the measures that help in reducing the GHG emissions like generation of energy from renewable resources and improving the energy use efficiency. In harmony with this, we tend to re-organize the various mitigation strategies in this paper in two categories: (i) energy conservation, which includes energy use efficiency, and (ii) energy substitution, that is, replacing the energy generated from non-renewable resources with energy that is produced from renewable resources. We maintain that all CC mitigation efforts revolve around these two strategies.

Examples of mitigation practices that focus on reduction of GHG emission include the use of energy-efficient equipment (e.g., light-emitting diode (LED) lights), devices, and vehicles; and the use of alternative fuels, e.g., solar energy (Mukhopadhyay, 2020; Niles et al., 2016; Sanneh et al., 2013), biofuel or biodiesel (Haden et al., 2012; Niles et al., 2016; Smith & Olesen, 2010), and wind energy (Haden et al., 2012; Mukhopadhyay, 2020). Emissions of CO_2 can be lowered via efficient energy use and reduced biomass burning (Pareek, 2017). Since, according to Tobler et al. (2012), the diesel-engine vehicle releases more CO_2 per kilometer and person than a similar petrol-engine vehicle, then replacement of diesel-engine agricultural machinery and equipment with comparable petrol-engine machinery and equipment is a CC mitigation practice because this reduces GHG emissions.

Examples of mitigation practices that focus on enhancement of GHG sinks include tree planting (Atube et al., 2021; Duguma, Minang, & van Noordwijk, 2014); afforestation (Atube et al. 2021; Duguma et al., 2014; Liu, Liu, & Gao, 2020); reforestation (Duguma et al., 2014; Liu et al., 2020), and agroforestry (Pareek, 2017). In effect, agroforestry improves carbon sequestration and lowers GHG emissions from the terrestrial ecosystems, thus mitigating CC (Shrestha et al., 2018). Climate change can also be mitigated by increasing the concentration of soil organic matter (Jørgensen & Termansen, 2016; Pareek, 2017). Many practices contribute to this, including use of organic fertilizers such as green or dry manure and plant residues (Jørgensen & Termansen, 2016; Pareek, 2017; Shrestha et al., 2018), mulch (Esham & Garforth, 2013; Limantol et al., 2016), compost (Pareek, 2017; Shrestha et al., 2018), boiochar (Shrestha et al., 2018), sludge (Pareek, 2017), and cover crops (Jørgensen & Termansen, 2016; Limantol et al., 2016). Interestingly, while these practices increase the carbon sinks in soil, they contribute to adaptation to CC by, for example, increasing the soil moisture content and reducing susceptibility of soil to erosion.

Moreover, the agricultural CC mitigation measures encircle use of fuel-efficient farm equipment and reducing use of electricity in the farm operations (Haden et al., 2012). Additionally, mitigation practices include reducing use of nitrogen fertilizers and improving their use efficiency (Haden et al., 2012; Niles et al., 2016; Pareek, 2017). Further, organic farming is advocated by a number of researchers as a CC mitigation activity (e.g., Goh, 2011; Niles, 2008) since this agricultural production method has the highest potential for combating CC by (i) lowering the GHG emissions (Goh, 2011; Niles, 2008) and (ii) sequestering high amounts of carbon (Niles, 2008). Lastly, while conservation tillage, i.e., no (or zero) tillage or low (i.e., reduced) tillage, has both CC mitigation and adaptation effects (Pareek, 2017), many researchers advocate that it is a mitigation practice (e.g., Easton & Faulkner (2014), Haden et al. (2012), and Shrestha et al. (2018)).

1.2.2 Adaptation

Adaptation to CC has been defined by IPCC as "*The process of adjustment to actual or expected climate and its effects*" (IPCC, 2014, p. 118). However, Easton and Faulkner (2014) defined adaptation to CC as a response that aims at reducing vulnerability of the biological systems to the CC effects. Examples of agricultural adaptation measures include the use of drought-resistant (drought-tolerant) crop varieties and species (Atube et al., 2021; Easton & Faulkner, 2014; Haden et al., 2012; Hussain et al., 2020); cultivation of salt-tolerant crops (Dhanya & Ramachandran, 2016; Liu et al., 2020); use of improved seeds and crop varieties (Asrat & Simane, 2018; Atube et al., 2021); and cultivation of plants that have low water requirement (Haden et al., 2012). Agricultural diversification practices are too categorized as adaptation practices (Asrat & Simane, 2018; Pareek, 2017; Sanneh et al., 2013). They include crop rotation (Asrat & Simane, 2018; Esham & Garforth, 2013; Smith & Olesen, 2010), intercropping (Asrat & Simane, 2018), and integrated (plant and animal) farming. Genetic improvement of the crops in order to develop varieties with high tolerance to high temperatures, drought, and salinity and with enhanced responsiveness to the growing CO_2 concentrations in the atmosphere is another noteworthy adaptation practice (Ramesh & Negi, 2014). Search for substitute and/or additional (new) water sources is too categorized as an adaptation practice (Haden et al., 2012; Niles et al., 2016). This can be achieved by such operations as water harvesting (Esham & Garforth, 2013; Sanneh et al., 2013) and exploration of new water wells (Niles et al., 2016). In other respects, adaptation practices extend to irrigation and include water-conserving irrigation methods such as micro-sprinkler irrigation and drip irrigation (Haden et al., 2012; Hussain et al., 2020; Liu et al., 2020). Additionally, climate forecasting and projection (Hussain et al., 2020) and provision of early warning systems are CC adaptation measures (Dhanya & Ramachandran, 2016; Hussain et al., 2020). Lastly, expansion of the protected areas has been pinpointed by a number of researchers (e.g., Sanneh et al. (2013)) as an adaptation measure.

1.3 Climate Change Education

Global climate change is considered by 97.0% of CC scientists as a man-made problem. This problem requires action on two critical tracks: mitigation and adaptation. However, implementation of mitigation and adaptation actions calls for capable policymakers and informed public. In general, the educated people are more knowledgeable of the risks which the CC poses and are well equipped with appropriate knowledge and skills to take informed decisions about CC responses on the local, national, regional, and international scales (Molthan-Hill et al., 2019). Indeed, higher education has critical role to play in educating the students about CC and linking it with social dimensions, including access to food and drinkable water and a shift to increased use of sustainable energy (Rees, 2003). Role of university in climate change education (CCE), from the perspective of Molthan-Hill et al. (2019), is of paramount importance if the scientific, environmental, social, and political challenges which the World is facing are to be met. The future leaders should make informed decisions and the public needs to embed the CC mitigation and adaptation tools and practices into everyday activities.

Various definitions of CCE have so far been formulated. However, what they all share in common is a stress on knowledge and on behavioral and attitudinal change. In effect, climate change education concerns helping the learners to understand global warming and CC and their current and future impacts while encouraging the change in people’s attitudes and behaviors that is needed to put the World on a more sustainable track in the future (Boakye, 2015). According to Anderson (2012), climate change education should be integral part of Education for Sustainable Development (ESD), which is a critical tool for sustainable development and integral constituent of quality education (Filho et al., 2021). Anderson (2012) defined ESD as approach to teaching and learning that is based on the principles and ideals that underlie sustainability and which are applicable to all sorts, levels, and settings of education. Consequently, it is an education approach that promotes multi-stakeholder social learning; emphasizes empowerment of the citizens and societies; involves fundamental social and economic issues (e.g., human rights, gender equality, sustainable livelihoods, poverty reduction, and environmental education) in integrated manner; and encourages and promotes changes in behavior in such a way as to ensure that human behavior will contribute to more sustainable future. It empowers the people to change their thinking and actions towards sustainable future (Filho et al., 2021). In this respect, Dalelo (2011) maintains that “*The environmentally literate person is described as a person who possesses the values, attitudes and skills that enable knowledge to be converted into action*” (p. 85). Consequently, climate change education for sustainable education should equip the learners with the values and skills that enable them to convert the CC knowledge they acquire and accumulate into action.

Anderson (2012) argues that CCE has been defined narrowly in particular contexts as concentrating on environmental education and climate literacy within science classes. However, climate change education for sustainable development (CCESD) must be multidisciplinary and comprehensive; it should not only include appropriate content knowledge on CC, disaster risk reduction, social and environmental concerns, and sustainable lifestyles and consumption, but should also concentrate on the institutional environment in which that content is delivered to assure that the education systems and institutions themselves are climate-proofed and resilient, in addition to being green and sustainable. Evidence uncovers that the educational interventions are successful the most when they concentrate on tangible, local, and actionable facets of environmental education, CC, and sustainable development, particularly the aspects that relate to individual behavior. Within this context, and in an investigation of the role of pre-tertiary science curricula in Ghana in CCE, Boakye (2015) recommended that the methods of CC teaching and learning should be improved for effective behavioral and attitudinal changes so that they can help in mitigation and adaptation efforts and activities.

Review of the literature revealed lack of any earlier investigations of graduate students' knowledge of CC and mitigation and adaptation practices, both the agricultural science and other graduate students, and both in Jordan and elsewhere. This implies that the exact level of knowledge of those students about CC and how agriculture can respond to it is not known. Consequently, gaps in knowledge of those students about CC and adaptation and mitigation practices are not known and, hence, the CC knowledge needs of this population are unclear. This study fills this knowledge gap. It aims at (i) assessing the level of knowledge of agricultural science master's students about CC and about how agriculture can mitigate it and adapt to it and (ii) identifying need for curricular reform, if any. Since the population of this study is agricultural science students, then emphasis in this investigation is paid to the mitigation and adaptation practices of agriculture, which they are supposed to know well.

2 Method

2.1 Population

This study is a quantitative cross-sectional survey of graduate students' knowledge of CC. The population of the study was agricultural science graduate students enrolled in the master's program of Climate Change, Sustainable Agriculture, and Food Security (CCSAFS), which is a program that is offered by the Faculty of Agricultural Sciences (FASs) in Jarash University, Jordan. This population was chosen because the majority of the master's students in this program are actually agriculture practitioners. Moreover, this program offers two directly-related compulsory CC courses: (i) Climate Change, Sustainable Agriculture, and Food Security (CCSAFS) and (ii) Climate Change and its Mitigation and Adaptation (CCMA). All program students join these two courses and are, consequently, anticipated to acquire advanced knowledge of CC, its nature, causes, effects, mitigation, and adaptation. Additionally, this study took into account potential influence of those students on present and future climate mitigation and adaptation programs and activities in Jordan, particularly in the agricultural sector, bearing in mind that almost all of them are agricultural practitioners. The others are government officials working in agriculture-related organizations (e.g., the Ministry of Agriculture; the Ministry of Environment; and the Food and Drug Administration, Jordan).

2.2 Sample

In the time being, the total number of students enrolled in the CCSAFS master's program in the FASs is 57 students. The optimum sample size for this study was 50 students. It was computed according to the formula (Krejcie & Morgan, 1970):

$$n = \frac{\chi^2 * N * P\,(1 - P)}{d^{\,2} * (N - 1) + \chi^2 \; * P\,(1 - P)} \tag{1}$$

where

n: the sample size requirement.

χ^2: the square of the tabulated value of the Chi statistic (χ) for one degree of freedom at the desired level of confidence (α). In the present study, the desired value of α is 0.05, corresponding to an error margin of 5.0%. Accordingly, the χ^2 statistic value is 3.8416 since $\chi = 1.96$.

The degrees of freedom (df) are equal to the number of groups (k) in the study minus 1 (Turhan, 2020):

$$df = k - 1 \tag{2}$$

The number of groups in this study is two because the sample students categorize into two groups: 'Non-knowledgeable Students' and 'Knowledgeable Students'. Accordingly, k is equal to 2, and, hence, the df equal 1.

N: population size (57 agricultural science graduate students).

P: proportion of successes in the population (usually, 0.50).

It is common practice to replace P, which is usually unknown, with 0.5 since this is the value which maximizes (P – 1), that is, the value that produces the most conservative (i.e., largest) sample size (Hajian-Tilaki, 2011; Ramos et al., 2019). Therefore,

$$n = \frac{(1.96)^2 * 57 * 0.50 * (0.50)}{(0.05)^2 * 56 + (1.96)^2 * 0.50 * (0.50)} = 49.75 \cong 50$$

The 50 sample students were selected following the simple random sampling approach. The data collection process took about two weeks, extending from 4 July 2021 to 18 July 2021.

2.3 Research Tool

This study employed a test as the tool of choice for assessment of knowledge. The test was particularly designed by the researchers for the purpose of this study. It was designed and developed to serve as a comprehensive CC knowledge scale. To this end, it was composed of two major sections: (i) a demographic information section and (ii) a test section. The test section consisted of three sub-sections, each defining a construct (or sub-scale) of CC knowledge, that is, the (i) general knowledge of CC, which covers the nature, causes, and impacts of CC; (ii) agricultural practices of mitigation of CC, and (iii) agricultural practices of adaptation to CC. Each of these three sub-sections consisted of 15 true-false statements as will be shown in three tables later in the ‘Results and Discussion’ section. The general knowledge sub-scale probes factual (i.e., declarative) knowledge while the latter two sub-scales measure procedural (i.e., action-related) knowledge. They were particularly tailored to agriculture. This test can be described as a Climate Change Mitigation and Adaptation Knowledge Scale (CCMAKS). It was, then, made available to the target population online through the 'Google Docs' platform (https://docs.google.com/forms/d/e/1FAIpQLSeePyFNiPzEtQaK_ftXNZ8B2rrxVpe3eRZVXf_0RioCxPXC-w/viewform). All in all, this knowledge assessment test (CCMAKS) included statements of varying degrees of difficulty, ranging from knowledge that is covered by mass media and social communication networks to specialist's knowledge.

Content validity of the CCMAKS was examined. This type of validity evaluates the extent to which the items of the research tool adequately and representatively sample content of the field knowledge that is due to be measured. Development of a content-valid tool is typically made by rational analysis of it by experts who are quite knowledgeable about the construct and sub-constructs of interest or experts in the research theme (Bolarinwa, 2015; DeVon et al., 2013). In this respect, Boateng et al. (2018) underlined that content validity of the research tool is mainly evaluated through assessment by a panel of experts. Thereupon, the CCMAKS was subjected to content validation by three professors who are experts in assessment and evaluation and in CC teaching and research. The three judges assessed the test statements in terms of readability, relevance, clarity, accuracy, and interpretability. Based on the evaluation, the various test statements were modified to reasonably good survey design. There was high consensus among the three expert judges on that the CCMAKS corresponds to adequate and representative measurement of knowledge of CC. Merely few slight modifications to the first copy of the test were suggested.

2.4 Statistical Analysis

The research data were subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS, v24.0). The demographic data of the respondents were analyzed using cross tabulation so as to obtain a description of the study sample. Frequency distribution analysis (FDA) was applied to the sentences of each sub-construct in an effort to assess the respondents' levels of knowledge of CC and of possible ways of CC mitigation and adaptation. Thereafter, the counts and percentages of the respondents relating to the individual statements of each of the three sub-constructs were averaged for the corresponding sub-construct so as to evaluate respondents' overall level of knowledge of that sub-construct.

2.5 Knowledge Categorization

To simplify interpretation of the FDA outcomes, the CC knowledge has been classified into three levels: low, moderate, and high, using the following equation (Paternoster & Bachman, 2018):

$$Interval\ Width = \frac{Highest\ Score - Lowest\ Score}{Number\ of\ Classes} \tag{3}$$

$$= \frac{100\% - 0.0\%}{3} \cong 33.3\%$$

Accordingly, the three levels of knowledge can be defined based on percentages of knowledgeable students as shown in Table 1.

Table 1. Intervals Defining Levels of Knowledge

Knowledge level	Percentage of knowledgeable students
Low	< 33.3
Moderate	33.3 – 66.6
High	> 66.7

3. Results and Discussion

3.1 Demographic Characteristics

Cross tabulation (Table 2) shows that the study sample consisted of 14 female and 36 male agricultural science master’s students. These counts correspond to 28.0% and 72.0% of the study sample, respectively. In terms of age, it is found that students ranging in age from 21 to 25 years were the highest in number (*n* = 13, % = 26.0% (Table 1)), followed by students belonging to the age group of 26-30 years (11, 22.0%). With the exception of students older than 50 years, who were the lowest in number (2, 4.0%), all other age groups have nearly equal representations in the study sample (5-7 students, 10.0-14.0%). These results mean that the majority of the sample students were male students who are 30 years old or younger.

Table 2. Demographic Characteristics of the Sample Agricultural Science Graduate Students

		Gender		
Age group	Descriptor	Woman	Man	Total
21 – 25 Years	Count	3	10	13
	% of Total	6.0%	20.0%	26.0%
26 – 30 Years	Count	4	7	11
	% of Total	8.0%	14.0%	22.0%
31 – 35 Years	Count	1	4	5
	% of Total	2.0%	8.0%	10.0%
36 – 40 Years	Count	2	4	6
	% of Total	4.0%	8.0%	12.0%
41 – 45 Years	Count	2	5	7
	% of Total	4.0%	10.0%	14.0%
41 – 45 Years	Count	0	6	6
	% of Total	0.0%	12.0%	12.0%
> 50 Years	Count	2	0	2
	% of Total	4.0%	0.0%	4.0%
Total	Count	14	36	50
	% of Total	28.0%	72.0%	100.0%

3.2 Knowledge Assessment

The research tool (CCMAKS) consists of three main constructs: general knowledge of CC, knowledge of mitigation of CC, and knowledge of adaptation to CC. The general knowledge construct comprises three sub-constructs, namely, knowledge of the nature of CC (Statements 1-5), knowledge of causes of CC (Statements 6-10), and knowledge of effects of CC (Statements 11-15). As the FDA outcomes (Table 3) show, the sample master's students demonstrate a high level of knowledge of nature of CC since, on the average, almost 78.7% of them correctly answered all five statements of this sub-construct. The facets of nature of CC which the majority of the students know are that manifestations of CC vary from a climatic region to another (98.0%) and that CC is overall bad (90.0%). Meanwhile, the aspect of general knowledge of CC which is known by the least number of the students (18, 36.0%) is that CC is more of man made than natural, which is a result that is against our expectations as faculty members in this master's program. Either these students did not read the statement well (Statement 1) or they hold the belief that there is no CC.

Table 3. Graduate Students' General Knowledge of CC [a]

			Responses			
			Correct answer		Wrong answer	
No.	Statement	Answer	Freq.	% [b]	Freq.	% [b]
1.	Climate change is nothing but a natural fluctuation in temperatures of the Earth	False	32	64.0	18	36.0
2.	Manifestations of climate change vary from one climatic region to another	True	49	98.0	1	2.0
3.	It is very late for the human community to do anything to stop climate change or control it	False	36	72.0	14	28.0
4.	Agricultural activities like plant and animal production contribute to climate change	True	34	69.4	15	30.6
5.	Overall, climate change is bad; it is more harmful than beneficial	True	45	90.0	5	10.0
Nature of CC: Sub-construct average			**39**	**78.7**	**11**	**21.3**
6.	Human activities do not tangibly affect temperatures of the surface of the Earth	False	49	98.0	1	2.0
7.	Climate change primarily resulted from the ozone hole	False	35	70.0	15	30.0
8.	The cause of climate change is the global warming associated with the rise in concentrations of green house gases in the atmosphere	True	47	94.0	3	6.0
9.	The sector with the highest contribution to climate change is the transportation sector	False	26	52.0	24	48.0
10.	Environmental pollution resulting from the industry is the principal cause of climate change	False	8	16.0	42	84.0
Causes of CC: Sub-construct average			**33**	**66.0**	**17**	**34.0**
11.	Climate change contributes to increased water and wind erosion of soil	True	47	95.9	2	4.1
12.	Decline in animal and plant food production, and, thus, deterioration of food security, may result from climate change	True	47	94.0	3	6.0
13.	Climate change can result in shortage of water that is suitable for household use and for irrigation of animals and plants	True	48	96.0	2	4.0
14.	Climate change reduces incidence of infectious and contagious animal, plant, and human diseases	False	43	86.0	7	14.0
15.	Manifestations of climate change include temporal displacement of seasons, prolongation of some, and shortening of others	True	49	98.0	1	2.0
Effects of CC: Sub-construct average			**47**	**94.0**	**3**	**6.0**
Construct average			**40**	**79.6**	**10**	**20.4**

[a] Any difference in number of respondents from 50 is due to missing value(s)

[b] Valid percentage, i.e., percentage of responses, excluding missing values

Causes of CC were another investigated issue. The FDA results (Table 3) uncover that the sample students, on the average, have moderate knowledge of the causes of CC owing to that 66.0% of them could correctly judge on soundness of the five statements of this sub-construct. While the vast majority of these students know that human activities tangibly affect temperatures of the surface of the Earth (98.0%) and that the cause of CC is the global warming (94.0%), it is found that large proportion of these students (84.0%) do not know that environmental pollution is a cause, but not the principal cause, of CC. As well, nearly half of the sample students (48.0%) do not know that the transportation sector is not the sector with the highest contribution to CC. In other respects, nearly 30.0% of the sample graduate students have misconception of the position of the ozone hole in the CC mechanism. This confusion about location of the ozone hole in the CC process chain is not uncommon. Tobler et al. (2012) brought to notice that various earlier studies have disclosed varying misconceptions about CC which the general public holds, including the confusion about CC and ozone depletion. It is also surprising to find out that 15 of the sample students in the present study do not know that agricultural activities like plant and animal production contribute to CC though all of them already hold bachelor’s degree in agricultural sciences.

The students' responses to Statement 1 contradict sharply with their responses to statements 6, 9, and 10, where the responses of more than half of the respondents to these three statements stress the human role in CC and that it is more of man-made process than natural phenomenon. This can be an indication of inconsistent knowledge of CC among these students. Another possible explanation is that they did not focus much while reading the test statements and judging on their soundness. Since participation in this study was voluntary and anonymous, then some of them might have not dealt with this test seriously and responsibly.

Effects of CC were another issue that was investigated. It is attracting attention that the sample students have high knowledge of effects of CC; on the average, almost 79.6% of them correctly answered the five related statements (Table 3). In fact, Table 3 points out that more than 94.0% of the students could correctly identify the effects of CC. The only exception is the association of infectious and contagious animal, plant, and human diseases with CC, which nearly 14.0% of the sample graduate students do not know about. In view of these findings, it is concluded that the faculty members in charge of teaching the CCSAFS and CCMA in general pay more attention to effects of CC than to its nature and causes.

Overall, it is found that the sample agricultural science graduate students have high level of knowledge of the nature, causes, and effects of CC. However, while they demonstrate high levels of knowledge of the nature and effects of CC, they exhibit a moderate level of knowledge of its causes. The FDA outputs (Table 3) also pinpoint that these students lack knowledge about the relative contribution of industrial pollution to CC, the sector contributing the most to CC (the transportation sector), and role of natural variability in CC. This suggests a need for re-evaluation of content of both the CCSAFS and CCMA courses to ensure reasonably sufficient coverage of the various knowledge gaps identified by this study, despite realizing the fact that not all these students are of good academic caliber and that they, therefore, vary in academic performance and achievement.

Mitigation of CC was a sub-construct that consisted in this study from 15 statements (Table 4). Analysis of the sample students' feedback on these statements discloses that their knowledge of agricultural mitigation of CC is moderate. Only 40.9% of them, on the average, provided right answers to the 15 statements. The analysis results can be summarized in three points:

1- The sample students have high level of knowledge of four mitigation measures (Table 4): substitution of fossil fuel with fuel derived from renewable resources (94.0%); agroforestry (89.6%); resorting to public, rather than private, transportation means (87.8%); and reducing reliance on machinery in the agricultural works (72.9%).

2- The sample students exhibit moderate level of knowledge of four mitigation practices (Table 4): avoiding burning animal and plant residues (66.0%); replacing agricultural machinery and pumps that run on diesel with others that run on petrol (44.9%); conservation tillage (43.8%); and using hydrogen gas as a source of energy in the agricultural processes (40.0%).

3- The sample students manifest low level of knowledge of seven mitigation practices (Table 4), three of which are related to reduced energy consumption (Statement 6 (percentage of students correctly judging on soundness of the statement is 12.8%), Statement 8 (16.3%), and Statement 9 (2.0%)); three relate to reduced GHG emission (Statement 4 (8.2%), Statement 7 (24.5%), and Statement 14 (6.1%)); and one of which is relating to increased carbon sequestration (Statement 11 (4.1%)).

Table 4. Graduate Students' Knowledge of Agricultural Measures of Mitigation of CC [a]

			Responses			
			Correct answer		Wrong answer	
No.	Statement	Answer	Freq.	% [b]	Freq.	% [b]
1.	Agroforestry represents one of the climate change mitigation measures	True	43	89.6	5	10.4
2.	Not burning animal and plant residues contributes to mitigation of climate change	True	33	66.0	17	34.0
3.	Substituting fossil fuels in agricultural operations with fuel derived from renewable sources such as the Sun, wind, and water falls contributes to mitigation of climate change	True	47	94.0	3	6.0
4.	Organic farming is counted as one of the adaptation to climate change actions	False	4	8.2	45	91.8
5.	Reducing the reliance on machinery in the agricultural works is considered as a climate change mitigation practice	True	35	72.9	13	27.1
6.	The adaptation to climate change measures include the production of fuel from plant and animal residues	False	6	12.8	41	87.2
7.	Limiting the use of chemical fertilizers (inorganic fertilizers) is an adaptation to climate change practice	False	12	24.5	37	75.5
8.	Thermal insulation of agricultural buildings like barns, warehouses, and farmers' and agricultural workers' dwellings is categorized as a climate change adaptation practice	False	8	16.3	41	83.7
9.	Use of energy-saving (energy-efficient) tools, equipment, and devices is a climate change adaptation action	False	1	2.0	49	98.0
10.	Increased reliance of farmers and agricultural workers on public transportation means and reduced reliance on their private vehicles in their transport contributes to mitigation of climate change	True	43	87.8	6	12.2
11.	Planting trees, in general, and afforestation, in particular, are counted as climate change adaptation practices	False	2	4.1	47	95.9
12.	Use of hydrogen gas as a source of energy in the agricultural processes is considered as a climate change adaptation action	False	19	40.0	28	59.6
13.	Replacing the agricultural machinery and pumps that run on diesel with others that run on petrol (benzene) is one of the climate change mitigation practices	True	22	44.9	27	55.1
14.	Use of suitable air filters in the animal production farms (animal houses and barns) and the similar closed farm facilities is considered as a climate change adaptation practice	False	3	6.1	45	93.9
15.	The no tillage agricultural practice is classified as climate change adaptation practice	False	21	43.8	27	56.2
Construct average			**20**	**40.9**	**29**	**59.1**

[a] Any difference in number of respondents from 50 is due to missing value(s)

[b] Valid percentage, i.e., percentage of responses, excluding missing values

The level of knowledge of the sample agricultural science students about mitigation of CC is somewhat shocking. Generally, their feedback on the 15 mitigation statements reflects inconsistency and contradiction. It is noticed that 94.0% of them know that CC is mitigated by substituting fossil fuels in agricultural operations with fuel derived from renewable sources. However, most of them do not know about the energy conservation practices addressed by statements 6, 8, 9, 12, and 13. It can be inferred from the results (Table 4) that most of these students on the one hand lack knowledge of the nature and effects on ecosystem of the listed mitigation practices and, on the other hand, confuse certain mitigation practices with adaptation practices. It seems that not only the delicate consequences of the listed mitigation practices are not clear in the minds of these students, but also the direct consequences. This means that the intricate processes involved in the listed mitigation practices, and their indirect, and even direct, effects, are not known to these students. Thereupon, development of knowledge of the mechanisms and processes involved in these practices, besides their direct and indirect effects on ecosystem, should be stressed in future teaching of the agricultural science graduate students. The principles on which these practices stand should be a fundamental part of their university education.

Adaptation to CC was the third principal component of the present study. Frequency distribution analysis (Table 5) discloses that, in general, the sample agricultural science graduate students possess high level of knowledge of the agricultural practices of adaptation to CC. The average percentage of the sample master's students who provided correct answers to the 15 test statements is 72.4% and more than 83.0% of the sample students know about 10 of the listed adaptation practices (Table 5). Meantime, two adaptation practices are known by only 70.8% of the sample students, which are the use of genetically-engineered alternative crops and crop varieties (Statement 1) and integrated farming (Statement 12). On the other hand, three agricultural adaptation practices are known by much lower percentages of the sample students: employment of biotechnology and genetic engineering (Statement 11 (14.3%)), securing supplementary (new) water resources (Statement 5 (16.3%)), and growing cover crops (Statement 8 (32.6%)).

Discrepancy appears again in respondents' feedback on statements of this sub-construct. While the results (Table 5) show that 70.8% of the respondents know that replacing crop varieties with genetically-engineered alternatives is a CC adaptation action, about 85.7% of them do not know that employment of biotechnologies and genetic engineering in the agricultural operations is an adaptation. It appears that the majority of these students do not know what biotechnology and genetic engineering really are. This identifies a knowledge gap that may find roots in the current curricula of the CCSAFS master's program. In addition, while academic caliber and performance of some agricultural science graduate students is not that high, part of this discrepancy can be ascribed to the fact that participation in this study was voluntary and anonymous. This might have affected the degree of seriousness with which some of the participants dealt with the test. They might have not cared much about the final result of their test, and, in consequence, did not concentrate much while reading the test statements, which were of varying levels of difficulty; the CCMAKS, which is seemingly direct and simple, is somewhat arduous, not that plain or direct.

The researchers made an attempt to compare the findings of the current study with those of previous studies. However, literature search retrieved only one investigation of graduate students' knowledge of CC (Table 6), which is the study of Dalelo (2011). This researcher explored CC literacy of graduate students in four programs at Addis Ababa University in Ethiopia, with an attempt to cover all major geographical and conceptual aspects of CC literacy. The study sample included 91 students in the master's programs of Environmental Science, Geography and Environmental Studies, and Geography and Environmental Education. This researcher found that the sample students demonstrated slightly above average performance on the whole. However, they exhibited poor performance in some fundamental areas relating to the science behind CC, past trends in temperature and rainfall, and impact of CC on Africa. It is attracting attention that many of the students had low, or no, information about the actual and projected effects of CC on poor countries, including those in Africa. As well, the students' awareness of some of the principal measures proposed at global level was also non-satisfactory. However, even though the students in the present study seem far more knowledgeable of the CC nature, causes, effects, mitigation, and adaptation than the students in the study of Dalelo (2011), we can not jump to this sort of conclusion because the instruments used in these two studies are perfectly different. The instrument employed in the study of Dalelo (2011) is a knowledge test that addresses four facets of CC literacy; the CC basic science, causes, effects, and adaptation and mitigation measures. The CCMAKS addresses these issues, however, from perfectly different perspective and in a different way.

Table 5. Graduate Students' Knowledge of Agricultural Measures of Adaptation to CC [a]

			Responses			
			Correct answer		Wrong answer	
No.	Statement	Answer	Freq.	% [b]	Freq.	% [b]
1.	Replacing the crop varieties to plant with genetically-engineered alternatives represents a climate change adaptation action	True	34	70.8	14	29.2
2.	Irrigating plantations using the drip irrigation method is categorized as an adaptation to climate change practice	True	41	83.7	8	16.3
3.	Expanding the areas of green surfaces and establishing new green surfaces like parks and gardens constitute climate change adaptation practices	True	46	93.9	3	6.1
4.	Diversification of crops in the same agricultural land area is classified as a climate change adaptation measure	True	44	89.8	5	10.2
5.	One of the climate change mitigation practices is securing supplementary water sources, e.g., by exploration of new water wells	False	8	16.3	41	83.7
6.	Planting drought-tolerant plant varieties represents an adaptation to climate change	True	49	98.0	1	2.0
7.	One of the adaptation to climate change practices is selection of plant varieties having low water requirement	True	43	87.8	6	12.2
8.	The climate change mitigation practices include planting cover crops such as legumes	False	15	32.6	31	67.4
9.	Crop rotation represents a climate change adaptation practice	True	42	85.7	7	14.3
10.	In terms of its processes, procedures, and tools, precision agriculture is classified as a climate change adaptation action	True	42	85.7	7	14.3
11.	Employment of biotechnologies and genetic engineering in the agricultural operations is a practice that aims at mitigating climate change	False	7	14.3	42	85.7
12.	Integrated farming corresponds to a climate change adaptation action	True	34	70.8	14	29.2
13.	Water harvesting is a practice that categorizes as a climate change adaptation measure	True	41	85.4	7	14.6
14.	Enforcing the weather monitoring systems and supporting them with early warning systems is an adaptation action	True	41	83.7	8	16.3
15.	Surrounding the sloping and non-sloping agricultural lands with appropriate vegetative belts is a practice that corresponds to adaptation to climate change	True	43	87.8	6	12.2
Construct average			**35**	**72.4**	**13**	**27.6**

[a] Any difference in number of respondents from 50 is due to missing value(s)

[b] Valid percentage, i.e., percentage of responses, excluding missing values

Literature search retrieved many published studies of CC knowledge and awareness of undergraduate students (Table 6). While the list given in Table 6 is not an exclusive list of these studies, it presents the majority of the most relevant studies published in the English language over the past two decades. It should be spotlighted that we think that it is not much sound or meaningful to hold comparisons between the results of such studies and the results of the present study because the population of the present study is master’s students of agricultural sciences specializing in CCSAFS. On this account, these students are mostly much more knowledgeable of CC than undergraduate students. Consequently, the researchers think that the present study and the study of Dalelo (2011) provide baseline data on CC knowledge of master’s students and they, hence, will serve − for many years to come − as key reference for similar future investigations.

Table 6. Examples of Previous Investigations of Climate Change Knowledge of University Students[1]

		Sample university students				Climate change facet investigated					
Reference	Country	Undergraduate	Graduate	University/College	Faculty	General knowledge	Nature	Causes	Effects	Mitigation	Adaptation
Gazzaz and Aldeseet (2021)	Jordan	√	X	Jarash Private University	- Agricultural Sciences - Physical Sciences	X	√	√	√	X	X
La Torre et al. (2020)	Italy	√	X	Sapienza University of Rome	- Medicinal Science - Allied Medicinal Sciences	X	X	√	√	X	X
Akrofi et al. (2019)	Algeria	√	X	University of Tlemcen	All university faculties	X	√	√	√	X	X
Barreda (2018)	The Philippines	√	X	Partido State University	All university faculties	√	X	X	X	X	X
Mugambiwa and Dzomonda (2018)	South Africa	√	X	University of Limpopo	- Health Sciences - Human Sciences - Science and Agriculture	√	X	√	√	X	X
Ogunsola, Araromi, and Adeshina (2018)	Nigeria	√	X	- University of Ibadan	All university faculties	X	√	√	√	X	X
Yang et al. (2018)	China	√	X	- Harbin Medical University - Sichuan University - Sun Yat-sen University - Fujian Medical University - Huazhong University of Science and Technology	- Medicinal Science - Nursing Sciences - Public Health	X	√	√	√	√	√

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[1] As regards the investigations of undergraduate students’ knowledge of CC, the list presented in Table 6 is not exclusive or exhaustive; several published works were excluded being not tightly-related to the theme and scope of the present study.

Table 6. Examples of Previous Investigations of Climate Change Knowledge of University Students [1] (Continued)

		Sample university students				Climate change facet investigated					
Reference	Country	Undergraduate	Graduate	University /College	Faculty	General knowledge	Nature	Causes	Effects	Mitigation	Adaptation
Arto-Blanco and Meira-Cartea (2017)	- Mexico - Spain	√	X	Miscellaneous	- Educational Sciences - Engineering Sciences - Physical Sciences - Social and Human Sciences	√	X	√	X	X	X
Zerrudo, Salain, and Salain (2017)	The Philippines	√	X	Basilan State College	- Arts - Community Nutrition - Educational Sciences - Nursing Sciences - Physical Sciences - Social Sciences	X	X	X	X	√	√
Agboola and Emmanuel (2016)	Nigeria	√	X	- University of Ibadan - Ladoke Akintola University of Technology	All university faculties	√	√	X	√	X	X
Ojomo, Elliott, Amjad, and Bartram (2015)	Nigeria	√	X	- University of Lagos - University of Uyo	- Engineering Sciences - Environmental Sciences - Law	√	X	X	√	X	X
Oruonye (2011)	Nigeria	√	X	- Taraba State University - Taraba State Polytechnic	- Educational Sciences	√	X	X	√	X	X

[1] As regards the investigations of undergraduate students' knowledge of CC, the list presented in Table 6 is not exclusive or exhaustive; several published works were excluded being not tightly-related to the theme and scope of the present study.

Table 6. Examples of Previous Investigations of Climate Change Knowledge of University Students [1]

		Sample university students				Climate change facet investigated					
Reference	Country	Undergraduate	Graduate	University /College	Faculty/ Program	General knowledge	Nature	Causes	Effects	Mitigation	Adaptation
Dalelo (2011)	Ethiopia	X	√	Addis Ababa University	- Environmental Science - Geography and Environmental Education - Geography and Environmental Studies	√	X	√	√	√	√

[1] As regards the investigations of undergraduate students' knowledge of CC, the list presented in Table 6 is not exclusive or exhaustive; several published works were excluded being not tightly-related to the theme and scope of the present study.

However, from an educational perspective, the results of the current study flow in harmony with results of some previous studies in that a need for curriculum reform is identified. The present study found that the sample agricultural science master's students have limited understanding of CC-related processes and actions that involve complex pathways and that they hold various misconceptions related to CC, in spite of the fact that, on the average, they have high knowledge of the CC nature, causes, effects, and adaptation. This finding brings to light the argument of Molthan-Hill et al. (2019) that CCESD is prone to the problem that some institutions and academics favor to focus more on less than more complex topics within the ESD framework. The results of the study of Cordero, Todd, and Abellera (2008) too pinpointed profound misconceptions about CC among university students. These researchers too identified a need for CC curricula reform and stressed on introduction of effective, action-oriented learning activities. Likewise, Ayanlade and Jegede (2016) discovered a need for introduction of CC studies in Nigerian universities since more than 71.0% of their sample university graduates mentioned that CC studies should be incorporated into university education as compulsory course(s), both in the undergraduate and postgraduate studies. Moreover, Competente (2019) researched into attitudes of pre-service teachers towards CCE and potential inclusion of it in their future teaching. He reported that the sample teachers had low awareness on CC and certain misconceptions of it. In view of the study results, he underlined a need for the university curricula to supply the students with activities to raise their CC awareness. The study of Filho et al. (2021) is particularly noteworthy. Based on analysis of how universities in 45 countries handle CCE, these researchers reached to the conclusion that not all the universities are fully prepared for addressing CC in the curricula and that further improvements are in effect needed. Indeed, there is a need for development of curricula that add the most suitable CC mitigation and adaptation measures and practices to each discipline (Molthan-Hill et al., 2019). Additionally, the plans and programs set for promoting adaptation and mitigation require multidisciplinary approaches (Filho et al., 2021). In view of this, the researchers in the present study maintain that, as far as CCESD is concerned, the curricula development process ought to address the multidisciplinary nature of this topic and, thereupon, the curricula development team itself should be multidisciplinary in nature, integrating specialists and experts in physical sciences, agricultural sciences, educational sciences, and social sciences.

4. Conclusions

This study analyzed the level of knowledge of agricultural science graduate students about CC, with emphasis on mitigation and adaptation practices of agriculture, in an effort to assess the extent to which these students can, and are prepared to, take active role in CC mitigation and adaptation efforts. One associated objective was to develop comprehensive CC knowledge scale (the CCMAKS) that can be employed in similar future research. The scale was designed in such a way as to cover a wide spectrum of the domains of the climate-related knowledge (the CC nature, causes, effects, mitigation, and adaptation) and to include questions of varying levels of difficulty.

The analysis unveiled that the agricultural science graduate students possess high level of general knowledge of CC (nature, causes, and effects), moderate level of knowledge of agricultural mitigation of CC, and high level of knowledge of agricultural adaptation to CC. Moreover, these students have high levels of knowledge of the effects and the nature of CC and moderate level of knowledge of its causes. Based on these findings, it is concluded that these students have limited understanding of CC-related issues, actions, and practices involving somewhat sophisticated pathways. In addition, our findings point out that the agricultural science master's students hold various misconceptions related to CC, in spite of the fact that, on the average, they have high knowledge of the CC nature, causes, effects, and adaptation. In light of this, it is concluded that there is margin for improvement of the CC knowledge of these students and their future peers through curricular reform.

A higher level of knowledge of the causes of CC can lead to enhanced awareness of CC mitigation in the agricultural sector. Even though the good understanding of the nature, causes, and impacts of CC is quite important, it is not adequate to get the agricultural science graduate students prepared to respond to CC and its consequences. Since people's knowledge of CC can affect success of CC mitigation and adaptation initiatives and programs, the herein identified gaps in knowledge call for prompt action. Appropriate interventions are badly needed. Teaching of the guiding principles and the underlying mechanisms of CC mitigation and adaptation needs to be further strengthened. This will improve CC learning and create appropriate understanding and sufficient knowledge of how to mitigate CC and adapt to it in the agricultural sector. Further, as Filho et al. (2021) indicated, effects of CC go across broad range of disciplines. Thereupon, it is highly important for curricula and instructors to take this issue into consideration as part of CC teaching and research programs of universities to support deep learning of CC. A shift towards action-oriented teaching and learning is particularly recommended.

The graduate students are good change agents once their knowledge base is well established. Several gaps in knowledge of the agricultural science graduate students have been identified, especially the causes of CC and the practices through which agriculture can mitigate it. On this account, the CC core courses in the agricultural science master's program of CCSAFS need to be re-constructed in such a way as to ensure that the knowledge gaps identified by this investigation are filled. The CC agricultural mitigation and adaptation practices, in addition to the causes, mechanism, processes, and pathways of CC, should be further integrated into the current curricula, particularly in the two core courses CCSAFS and CCMA, while the involved faculty members should be encouraged to address these knowledge gaps and focus on expanded coverage of the corresponding new course content.

Dissemination of knowledge is highly important for ensuring that knowledge grows and spreads amongst the various stakeholders and that it is turned into action. The students of today are the leaders and policy makers of tomorrow. They will effectively serve as change agents once their knowledge base has been well established. Albeit knowledge does not all the time translate into action, it is a prerequisite for taking action, and the effective CC actions require sound knowledge. In effect, knowledge about how agriculture can mitigate CC and adapt to it can be the most powerful driver of adoption of mitigation and adaptation practices and involvement in mitigation and adaptation initiatives and programs at the country level. In consequence, extension of CC education beyond its most popular aspects of nature, causes, and effects is highly recommended for the agricultural science university students, in general, and the agricultural science graduate students, in particular.

Acknowledgments

The researchers sincerely thank Prof. Ali J. Al-Sharafat (Jarash University, Jordan), Prof. Ihab H. Ghabeish (Balqa University for Applied Sciences, Jordan), and Prof. Mahmoud M. Abu-Allaban (The Hashemite University, Jordan) for their kind referring of the research tool. Their valuable comments and suggestions contributed much to validity and reliability of the research instrument, credibility of the study, and integrity of its outcomes.

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