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Science of Climate Change in Agricultural Courses

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Abstract. Climate change adaptation is required knowledge for students and graduates from colleges of agriculture since recent crop production and food security are influenced by climate change. Thus, understanding the dynamics of climate change is important to support farmers to adapt to future conditions. However, not all students and graduates understand the concept and application of climate change with regard to the dynamics of food production and future food security. While agriculture faces the challenge of climate change adaptation, agricultural courses have not kept pace by incorporating climate change science into the curricula. To address this issue, eleven syllabi in selected agricultural courses from 100 to 700 levels were reviewed in the year of 2018 and 2019 to observe the integration of climate change science into the syllabi. The results suggest that educators, instructors or course designers should consider the following before creating the courses: (1) the specific interests and needs of students; (2) linking global climate change to local problem in agriculture, (3) applying lessons across disciplines, and (4) encouraging active student participation. In addition, the syllabi should meet the needs of a specific course level, such as the topical interests and learning needs with lesson updates on a regular basis. By applying these components to future syllabi, the integration of climate change science into agricultural courses will better facilitate climate change adaptation concepts, curricula and applications for all students, graduates and crop producers.

1. Introduction

The youngest generation, especially students in the universities have grown up in an age of the earth warming, rising sea levels, devastating wildfires, and frequent “once in a century” storms. They are taking their future into their own hands [1]. They understand their power to make a change. They need people already in power to act now to address the worsening climate crisis [2]. In this case, given the scientific consensus on the impact of global warming and climate change on agriculture, educators should teach the scientifically accepted perspective on global warming and climate change – not debate it. The reason is that debate and controversy lie not in the scientific arena, but in the social, economic, and political approaches to mitigating and adapting climate change and global warming [3].

Adaptive farming systems and climate change adaptation are required in all aspects of agricultural practices to provide food security both now and in the future [4]. Graduates from agricultural colleges are expected to understand the phenomenon of climate change and have to be able to identify adaptive land management systems to reduce greenhouse gas emissions. However, not all students in agricultural colleges have enough knowledge to be comfortable discussing the relationship between climate change and land management practices.

Teaching and learning about climate change and global warming are not easy, but they are possible. Students cannot directly monitor the change due to time and space. Therefore, in order to learn about climate change, it is essential for students to learn how to interpret, analyze, explain, and evaluate climate data. Students have to be provided opportunities to think systematically about the earth’s energy budget, climate systems, climate change and adaptive landscape management strategies. They need to learn about investigating the energy use, carbon emissions and carbon sequestration data. It is crucial that students are given opportunities to make decisions concerning their own personal actions and behaviors as well as those of the societies in which they live [3], [5].

Previous studies demonstrate a variability of willingness among instructors/educators in agricultural colleges to teach climate science-based issues to students, although they know the information is essential to support crop and animal producers [6], [7]. Scientific evidence indicates that the climate is changing and that agricultural systems will be directly and indirectly affected to varying degrees depending on regional and local conditions [8]. It is predicted that farmers and land managers will face increasingly disruptive weather patterns, which will cause big challenges in agriculture and forestry [9]. Climate change will significantly decrease the crop yield up to 35% yearly in important crops in the U.S. and around the world [10], [11].

Recently, the necessity of teaching students to support climate adaptation is increasingly being recognized [12]. A recent survey indicates that training educators in climate science was one of the most important priorities in universities in the United States [13]. Several other studies show that agricultural advisers have doubts about their ability to teach and share about global warming or climate change issues to farmers or land managers, but they are willing to have additional training and gain information on climate science topics [7], [12]. However, examples of syllabi integrating climate change into agricultural courses are very limited and a systematic review of these developed syllabi has not been conducted. By investing in syllabi development that is both topically relevant and grounded in established theory for higher education, students and alumni from agricultural colleges can adapt to changing conditions using scientifically sound approaches that are both ecologically, socially, and economically relevant.

To solve this gap, eleven developed and implemented syllabi were reviewed to check if there was an integration of climate science and climate change issues into the course content during 2018 to 2019. The goal of this review is to summarize and share the lessons learned from a range of agricultural courses potentially related to climate change or adaptive land management. This information will be used to create guiding recommendation for future syllabi and curriculum development projects and other efforts to establish similar goals related to climate science adoption in agricultural courses.

2. Methodology

During 2018 and 2019, eleven published syllabi from various courses in Murray State University were identified including *Soil Science; Soil Management; Soil & Water Engineering; Agricultural Environmental Management Systems; Agroecology; Sustainable Agriculture; World, Food, Agriculture & Society; Advanced Soil Fertility; Contemporary Issues in Agriculture; Plant Science; and Crop Management*. Some syllabi were taught by several instructors in different sections and others were taught by a single instructor.

To establish the level of the integration of climate change science in each syllabus, the analysis was based on: (a) the proportion of climate change topic(s) in the syllabus, (b) the nature of the information the climate change topic(s) provided, (c) the nature of the teaching and the learning methods associated with the topics, and (d) the frequency of assessment based on climate change. To establish the proportion of the curriculum that made up climate change, the units in the syllabi served as units of analysis. The units that contained climate change topics for each syllabus and proportions were calculated using percentages.

The percentage was calculated by dividing the number of climate change unit(s) identified by the total number of units in the syllabus and the result multiplied by 100.

3. Results and Discussion

Table 1 shows that different levels of courses provide various amounts of integration of climate science topics into agricultural courses. In general, the higher the level, the greater the integration. This was related to the nature of the courses. All of higher level of the courses have lessons related to adaptive land management systems for sustainability. The absence of climate change science in the crop science course can be explained by its inclusion in the 100-level course of Contemporary Issues in Agriculture.

Table 1. Climate Change Science Integration in Various Levels of Agricultural Courses

Course Level	Name of the Course	Climate Change Information	% of Climate Change in the Syllabus
100	Contemporary Issues in Agriculture	Present	2-5
200	Crop Science	Absent	-
300	Soil Science, Agricultural Environmental Management Systems, World Food Agriculture & Society	Present	30-40
400	Soil & Water Engineering and Soil Management	Present	30-50
500-600	Agroecology, Sustainable Agriculture & Advance in Soil Fertility	Present	25-60
700	Climate Change Impact on Agriculture	Present	100

The climate science integration in Soil Science and Soil Management (300-400 courses) focused on the benefits of soil organic matter and soil quality indicators (Table 2.) Both of the topics were mainly related to agricultural production and soil health. By learning this lesson, students will have better critical thinking about the relationship between soil properties and mitigation of global warming. For example, more soil organic matter content in the soils means better carbon sequestration, and, therefore, less greenhouse gas emissions from farm land. Conservation tillage and crop rotation will improve soil quality, thus preventing soil erosion and degradation. This will result in more carbon being stored in the soil profile. During this study, 99% of the students in both classes were interested in knowing how common land management practices in each state contribute to the level of soil organic matter in the topsoil. In addition, they indicated that tillage practices in their hometowns created soil compaction leading to soil erosion and lower soil quality.

In the 300, 500 and 600 level courses (Table 3.), the science of climate change was integrated in these courses under "carbon and nitrogen cycles." In these lessons, students were introduced to the relationship between C and N cycles in agricultural soils and natural soils as well as provided various forms of C and N that contribute to global warming. Topics on different tillage systems and the use of different commercial N fertilizers were also introduced to see how these inputs influence the dynamics of climate change. They learned about the negative effects of climate change on crop production as well as how to mitigate them by reducing greenhouse gas emissions through practices such lowered use of fossil fuels, and greater use of renewable energy sources such as wind and solar.

Students discussed and described the impact conventional tillage has on C and N cycles. These activities empowered the students to speak about climate change and mitigation. This learning process provided information to the students about adaptive land management systems to help in lowering CO2 emissions from soil surface [13], [14]. The integration of climate change science into 300, 500 and 600 course levels was varied from 30 to 60%. In the 300-course level, Soil Science, the topic of C and N cycles was introduced in natural fields by focusing on the need to store more C in soils and reduce the process of denitrification and volatilization by incorporating conservation tillage systems. At the course level of 500 and 600, students learned more details about the implications of land management practices that disturb the cycles. For example, plowing will increase CO2 emissions from topsoil, but no-till systems for 10 years in silt loam soils increased soil organic C significantly. Continuous no-till corn production in central Kentucky for over 40 years increased the depth of topsoil up to 15 cm compared to conventional tillage. Using the actual research data gave students a better understanding of the contribution of local common soil management practices to climate change dynamics by measuring the concentration of selected C and N forms in the soils.

Table 2. Teaching Soil Organic Matter & Soil Quality Indicators in *Soil Science and Soil Management courses*

Specific Objectives	Content	Teaching & Learning Objectives	Evaluation
Identify the importance of soil organic matter to improve soil fertility and reduce greenhouse gas emissions by increasing soil C sequestration	How does soil organic matter content improve soil structure, nutrients and biology, thus improving crop growth and production?	Describe the impact of various land management systems on soil organic matter content	How to increase soil organic matter and what factors do control the dynamics of soil organic matter in the agricultural land
Understand physical, chemical and biological soil quality indicators and identify what activities and factors can influence these indicators	Why is monitoring the changes of soil quality indicators crucial to mitigate global warming?	Discuss the benefits of soil quality indicators to prevent soil degradation, particularly related to the capacity of agricultural soils to store carbon	Explain how to improve soil quality, especially related to mitigation of greenhouse gas emissions

At the 700-course level (Table 1.), the main focus for students to learn was understanding of global climate change and food production systems. The content was the science of climate change, the indicators of climate change, which climate variables directly and indirectly affect agriculture, projected climate change, the role of our food systems in climate change, how farmers adapt to climate change, and how smart farming systems will help to reduce global warming. Since this course is for graduate students, they are expected to have previous knowledge about food systems and crop production factors which will help them to better understand the concept of adaptive agricultural management to meet the goals of reducing greenhouse gas emissions. This study indicates that the syllabi provide a package of teaching materials to educators who wish to deliver climate-related information to a variety of students in a college of agriculture.

One approach that contributes to the durability of the syllabi is their flexibility; the syllabi can be used in different courses depending on the level of the courses, the educators, and the available resources. Additional strengths that were noted by students may provide important lessons for future syllabus developers. These included the opportunities to present course material in an accessible format (e.g. on line, or printed); an interdisciplinary syllabus development team; and collaboration among educators. Though students and instructors recognized these strengths, the traits were sometimes associated with tradeoffs and challenges.

Instructors and educators reported that a narrow focus on incremental climate adaptation allows the students to ignore larger issues such as farm viability, soil variability and crop/commodity sustainability. One of the biggest challenges that the instructor faced when teaching about climate change adaptation via adaptive land management systems was to ensure that students keep the big picture in mind. This illustrates that tension sometimes occurred between providing general and specific information through a climate change lesson.

Table 3. Carbon and Nitrogen Cycles in the Soil Science and Advance Soil Fertility Syllabus

Specific Objectives	Content	Teaching & Learning Objectives	Evaluation
The students will be able to a. Describe how C and N cycled in nature and agricultural soils	The C & N cycles	Let students: Discuss & illustrate the C & N cycles	Explain how the C & N cycles are disrupted in agricultural soils

	Specific Objectives	Content	Teaching & Learning Objectives	Evaluation
b.	Outline the importance of the C & N cycles related to soil fertility & crop production	The importance of C & N cycles	Identify & explain the stages in C & N cycles	Discuss solutions to sustain the C & N cycles
c.	Describe ways the C & N cycles are disrupted in agricultural soils	Ways by which the C & N cycles disrupted	Discuss the importance of the C & N cycles to human & plants	
d.	Describe why do CO2, CH4 and N2O contribute to global warming	Identification of C & N forms which considered greenhouse gases	Gather information from library and internet on human activities which disrupt the C & N cycles Discuss ways by which human activities disrupt C & N cycles	

Further challenges include: insufficient course evaluation; an unsatisfactory balance between instruction and class discussion; ensuring that multiple courses did not duplicate the specific lesson's content; and the need for courses designed around topics such as water availability, crop production, livestock production, human health, soil quality, carbon storage and food security as they relate to climate change. The observation shows the active learning approach is well suited to students in agriculture especially for 300 to 600/700 course levels. Hands-on learning in a group setting aligns well with established college learning strategies. This approach has been proposed as an antidote to traditional technology transfer, which some call ineffective and outdated [15]. Strategies for project-based learning in climate change science education include: (a) linking global climate change to local problems in agriculture, (b) applying lessons that cross disciplines, and (c) encouraging active participation of students by sharing ideas from everyday life [16]. By incorporating these strategies into climate change science in various courses in the college of agriculture, we can better facilitate lessons and climate adaptation concepts for all students as well as the crop producers.

4. Conclusions

As climate change topics become significantly more important in agriculture, it will be increasingly necessary for colleges of agriculture to be prepared and knowledgeable about climate change and adaptation. Development of lessons and syllabi related to climate change science for different courses will support this need, although not all educators/instructors currently have a good understanding of the subject. Best practices from soil scientists and ecologists can help instructors of climate-focused syllabi to tailor educational content and approaches to students.

The findings from this study suggest that the instructors or educators should consider the following recommendations. (1) Syllabi should be created to meet the needs of a specific course level, including topical interests and learning needs. Educators have to be flexible and responsive to the needs of students. (2) Integration of scientific knowledge about climate change, agricultural practices, extension and research reports, and local crop production is important to create lessons that are powerful. However, climate change lessons require updating on a regular basis. (3) When designing syllabi, educators must be cognizant of trade-offs associated with the depth of the course content. (4) The use of a project-based education approach for global warming lessons by utilizing local problem solving, integrating multiple disciplines, and implementing measurable outcomes is suggested.

By integrating these concepts, the course content is likely to have an impact on students' knowledge about climate change science as related to agricultural production. The most important thing is to engage students by tapping into their concerns, questions, and interests as well as inspiring and empowering students to use project-based learning of climate change science as a meaningful tool for change.

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