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Abstract

This study abroad program provided an opportunity to enhance the international experience and research skills of University of Nebraska-Lincoln (UNL) students within a multidisciplinary team's research-education goal on improving food security in Ethiopia. The experiential study component of the project included preparatory sessions during the Fall 2015 Semester at the UNL followed by a four- to five-week fieldwork experience in Ethiopia. Teams from the UNL and an Ethiopian university participated in survey data collection and field soil evaluations from farms in the Gerado area of South Wollo, Ethiopia. Having students interact with farmers increased student self-confidence and enhanced their leadership skills. Soil fertility evaluation provided the opportunity for students to apply soil health concepts in a practical setting, thus giving them a fuller understanding of these commonly challenging concepts. Throughout the study experience in Ethiopia, two UNL students wrote reflective journal entries each day and participated in daily wrap-ups. Students also gave presentations to staff at Wollo University and to fellow students and faculty at the UNL. In addition, they completed a final paper integrating the journal material and the experiential research work in Ethiopia. Students experienced cultural immersion while participating in this ongoing research project.

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10 The University of Nebraska-Lincoln Institutional Review Board approved the study protocol and all participants provided written informed consent prior to participation in the study (UNL IRB-20151215475EX).
11 Disclaimer: The use of any commercial name in this article is for information and not an endorsement of the product named.

Introduction

While experiential learning in any science promotes critical thinking and problem-solving (Ives-Dewey, 2009), soil science in particular requires active participation to maximize learning (Vaughan et al., 2017). Hands-on field experiences promote student problem solving competencies by applying concepts learned in the academic setting (Lobry de Bruyn et al., 2017). Specifically, experiential learning in soil science can equip students with a fuller understanding of bio-cultural adaptation and the multifaceted challenges of agricultural production, environmental degradation, drought, and food insecurity (Grover and Stovall, 2013). For example, participating in an activity like evaluating soil problems in the field and working directly with farmers can improve critical problem-solving skills and confidence levels, lead to further understanding, and help students effectively deal with soil issues in the future (McBroom et al., 2015). According to Bott-Knutson et al. (2019), students from the United States have limited international knowledge of agricultural production. Therefore, a study abroad can provide an opportunity to enhance student's international experience and research skills as well as adopt to new ways of thinking and their worldview (Braskamp et al., 2009).

This experiential study was initiated not only to evaluate soil health abroad but also to evaluate how working in the field and directly with farmers can develop student's thinking about soil health and food security. One country facing a critical problem of food security is Ethiopia (Ketema et al., 2018). Agricultural soils in Ethiopia are vulnerable to erosion and nutrient depletion, continuing to threaten soil productivity and the livelihood of smallholder farmers. The Tigray Province just North of Wollo has been recognized as having the most erosion-related land degradation in the world. For a country with 90 percent of its population being rural-based, a decrease in soil fertility, an increase in population, climate variability, and poor agricultural management practices continues to pose serious risks to agricultural production and food security (Pender and Gebremedhin, 2008). Erratic rainfall and recurrent drought have exposed the majority of the rain-fed farming population to food insecurity and perpetual poverty. Ten percent of the 31 million ha of agricultural land is arable, but that percentage is shrinking as these lands are losing their capability to support crops (Awulachew and Ayana, 2011). The arable soils in Ethiopia are most vulnerable to water and wind erosion and erosion-induced depletion of nutrients, the latter of which is common due to crop and residue harvests and the inability to replenish the soil with fertilizer among smallholder farmers (Gebrernichael et al., 2005).

Members of an interdisciplinary research team from the University of Nebraska-Lincoln (UNL), NE traveled to Ethiopia in Summer 2014 to lay the groundwork for research on food security, establishing collaboration agreements between their university and Wollo University in Ethiopia. The long-term goal of the project was not only to improve food security in Ethiopia but also to provide the opportunity to enhance the international experience and research skills of UNL students through multidisciplinary research. More specifically, the objectives of this study were to (1) engage students to practical activities including field sampling, laboratory analysis and conducting surveys to develop higher academic skills such as hypothesizing, design, and problem solving and (2) develop students' cognitive and professional skills by evaluating selected soil quality indicators of dryland and irrigated farms, interacting with local farmers, and communicating their experiences.

Methods

Course Background and Preparation for the Study Abroad

The class, "Agriculture: Global Food Security", was initiated by the Department of Agronomy and Horticulture and the College of Agriculture and Natural Resources at the UNL during Winter Break 2015-2016 to (1) provide students to travel abroad and gain "hands-on" experience in soil quality, (2) make them more globally aware – history, culture, religion etc., and (3) help them shape their career pathways. The preparatory plans included reading and discussing related literature, examining the languages and cultures to be experienced, reviewing the study abroad procedures, organizing contact information, and securing the timeline for the study abroad. The UNL Education Abroad Office provided a health and safety pre-departure orientation for the UNL program leads and the two undergraduate students who were travelling abroad. In addition, a study abroad blog website (https://unlcasnrstudyabroadethiopia.wordpress.com/) was developed, and students received video and photography training. Course materials – pre-testing of the soil quality procedures and analyses and survey questionnaires – were prepared and organized, at the UNL before traveling abroad.

Travelling Abroad

All members of the UNL team traveled to Ethiopia during the winter of 2015, a time that allowed students to observe crops at their peak growth period as well as a variety of irrigated crops, vegetables, and herbs at early growth stages; to make field and soil measurements; and to fully interact with and interview farmers. This experiential learning was conducted in South Wollo, near Dessie, Ethiopia, (11.0°N, 39.25°E) (Fig. 1), specifically at sites centered in Gerado (11.092348°N, 39.582257°E), a small village approximately 10 km southwest from Dessie. Gerado has an arable land area of approximately 770 ha. Small-scale flood irrigation is practiced on approximately 675 ha, primarily to allow for growing a second crop after the main season cereal crops are harvested in December. Ethiopia has two rainy seasons (Bayable et al., 2021): The heavier of the two, Kiremet, occurs from mid-June to August, with August recording the highest monthly precipitation of the year with an average of 145 mm per year. The second season, Belg, which occurs during March and April, records an average precipitation of 83 mm per year. Temperatures stay relatively constant throughout the year, and in Kombolcha, the average minimum temperature was 24^{o}C in January 2015 with maximum of 31^{o}C in June 2015.

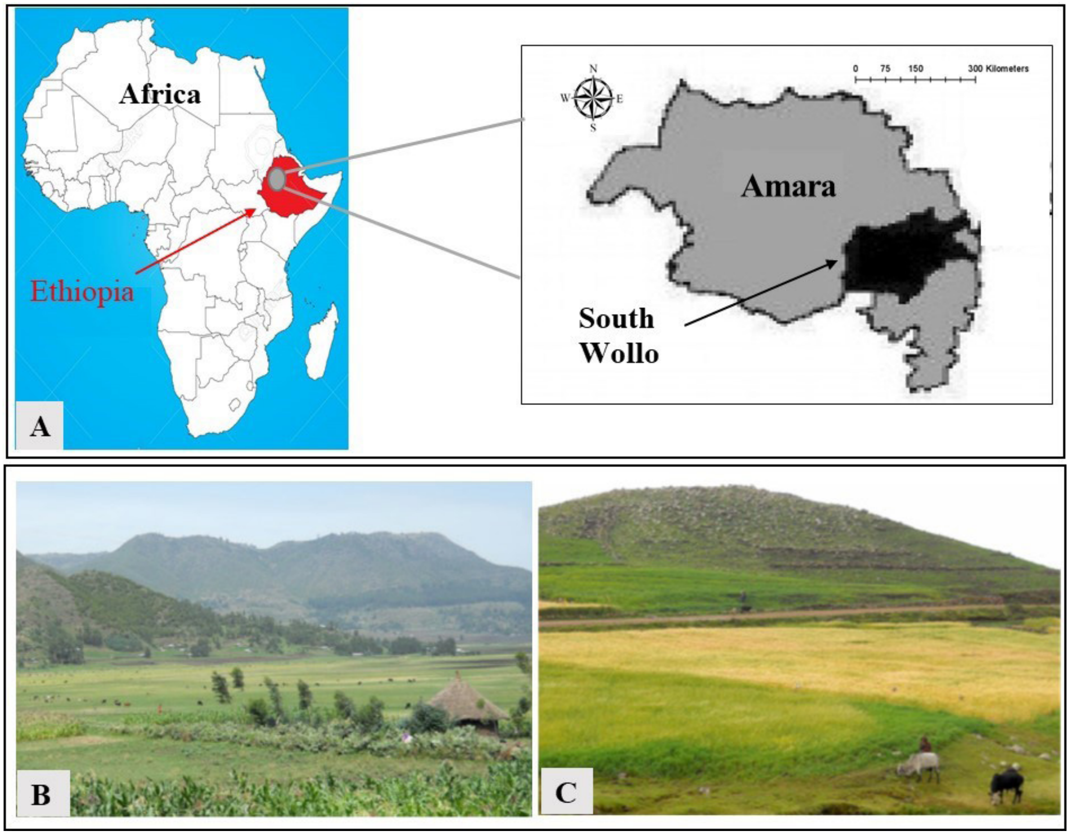

Figure 1. Location of Ethiopia on the African continent and location of the study site in South Wollo, Ethiopia (A), and photos of the sampling sites (B and C). UPS of the site is 11.092348°N and 39.582257°E with Vertisols as a soil taxonomy classification.

Thirty farms, 15 dryland and 15 irrigated, were selected based on the farmers' availability, and their access and willingness to share information. These farms ranged in size from 0.25 ha to 1 ha and grew teff (*Eragrostis tef*), wheat (*Triticum aestivum*), sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare*), maize (*Zea mays*) and other similar crops. Soils in the study farms were silty clay to silty clay loam and classified as Vertisols (clayey soils that shrink and swell extensively upon changing soil moisture conditions, FAO World Reference) with a high shrinking-swelling potential. At the time of arrival of the UNL team, most fields had just been tilled (< 15 cm) after the cereal crop harvest using traditional oxen driven marasha (Fig. 2) prior to soil sampling and field measurements. The marasha is a common traditional farm implement used up to four times (Berhe et al., 2012) after harvest to prepare seed beds before planting.

Data Collection While Abroad

As part of the experiential learning, two students conducted a qualitative and quantitative survey (Fig. 3 A and B). This questionnaire was developed with the assistance of the UNL Bureau of Sociological Research, and the University of Nebraska Institutional Review Board, UNL reviewed and approved the study protocol and all supporting documents. Farmers were asked to complete a paper survey comprised of three parts: demographics, land management practices, and soil quality perceptions. The demographic questions pertained to length of land operation, while the questions focused on the land management practices were designed to provide insights into traditional farming practices that may impact soil conditions. The third component of the survey examined farmers' perceptions of soil management practices, including questions on the types of crops grown, the input used, drainage problems and erosion, the presence or absence of earthworms (Lumbricina), and soil conservation practices.

Students were responsible for soil sampling, analyses and field measurements (Fig. 3 C and D). Two soil core samples were collected from each of the 15 dryland and 15 irrigated plots using 5.8 cm diameter by 5 cm height stainless steel core samplers. Each sample core was transferred to a plastic bag and transported to the soil laboratory at Wollo University. The students were given a vacant working space at Wollo University but had to set up the laboratory using supplies and equipment they brought with them (pH meter, sieves, Solvita supplies, sample bags, lab notebooks, core samplers). They also had to purchase additional supplies from local stores. Soil pH, electrical conductivity (EC), bulk density, wet soil aggregate stability, sorptivity, soil C respiration (CO2-C), and potential N mineralization (PNM) were determined for each field. Soil pH and EC were measured in a 1:1 water-soil ratio and determined using an Oakton Portable Waterproof meter (Spectrum Chemical MFG Corp.). Bulk density was determined after oven drying the core soil samples at 105oC for 24 hours. Aggregates stability was measured following the methods outlined in Six et al. (2004). Sorptivity, which is the early stage of water infiltration, was measured as described by Smith (1999), and CO2-C and PNM were measured following the method developed by Haney et al. (2004). Data on soil parameters and from the surveys

Figure 2. The traditional tillage method implanted in Ethiopia. Ethiopian farmer with his oxen and marasha (A), and Ethiopian maresha plough (B). Pictures Credit: Charles Wortmann, UNL and Ethiopian Institute of Agricultural Research, Farm Mechanization Directorate.

Figure 3. Meet and greet with farming community over traditional tea and bread (A), students participating in conducting the survey of farmers (B), and collecting soil samples (C and D) in South Wollo, Ethiopia. UPS of the site is 11.092348°N and 39.582257°E with Vertisols as a soil taxonomy classification.

were analyzed using analysis of variance, and a t-test (SAS Institute, 2011) was used to compare soil quality between dryland and irrigated farms. Significance was considered at the probability level < 0.05. At the end of this experiential study, students gave presentations to Wollo University staff/faculty and administrators, and representatives from the Gerado Kebele farmers.

Post-travel Activities

After returning to the UNL in the Spring 2016 Semester, a survey, which developed by the university and approved by the UNL Institutional Review Board, was administered to the students to examine the efficacy of their learning. This survey included four parts: (1) organization of the trip, (2) personal emotional and family support, (3) outcomes of the trip, and (4) additional written comments. Students completed the survey and no extra credit was given for participation. Students met weekly for progress discussions and feedback on reports and the written report being developed to Wollo University and the UNL. They also gave presentations to the Department of Agronomy and Horticulture at the UNL and at the 2016 International Association of Students in Agricultural and Related Sciences (IAAS) Summit held in Lincoln, NE.

Results and Discussion

Survey results from the 30 smallholder farmers in Gerado, Ethiopia, in December 2015 can be found in Table 1. This survey was conducted not only to collect data on the farmers' soil management practices and soil quality perceptions but also to develop the students' teamwork and leadership skills. According to Rhykerd et al. (2006), interacting students with farmers can increase their self-confidence and enhance their leadership skills. Based on the results, irrigation has improved the crop yields in Gerado per season and has increased the number of crops planted per year. Because of access to communal sharing of stream-diverted irrigation, farmers are able to grow a larger variety of crops, including vegetables like tomatoes, carrots, onions and cabbage (Table 1). Water application in this region is based on access to water, not on crop water requirement. In Gerado, water is communally shared among farmers; each farmer is allowed use of the diverted stream water for his or her plot for a few days every two weeks. Because of this scheduling, farmers tend to over apply water in the plot furrows.

Soil Fertility Evaluation as a Useful Tool for Learning Experience

Soil fertility evaluation in real-life farming situations can provide the opportunity to apply these concepts in a practical setting, thus giving students a fuller understanding of these commonly challenging concepts (Appel et al., 2014; Khan, 1994). The values of soil fertility parameters like pH, EC, bulk density, aggregate stability, sorptivity, CO2-C, and PNM for irrigated and dryland farms were analyzed by the students, and the results are presented in Figure 3. Students learned how to use the information that they obtained from the farmers to explain the results from the soil health indicators (Table 2). For example, students found that agricultural management can affect the soil health indicators measured. There is evidence of soil salinity in Gerado, where the irrigation systems are still new. Managing Vertisols in Gerado may be challenging as flood irrigation can waterlog the soils and prevent water infiltration. Tillage was observed in the assessment to have a negative effect on aggregate stability and C respiration due to frequent marasha cultivation, as many as four times before sowing (Nyssen et al., 2011).

Student Recommendations for the Gerado Farmers

Based on the results of the soil fertility evaluation, the students provided several recommendations to the Gerado farmers. Soil quality can be determined by assessing the physical, biological and chemical properties of the soil. Gerado soils have increased vulnerability to salinity due

Table 1. Survey results from 30 smallholder farmers (15 irrigated, 15 dryland) in Gerado, South Wollo, Ethiopia, in December 2015.

Characteristic[a]	Responses
Mean age number of years farmed	21 years
Common crops	Tef, wheat, cabbage, carrots, tomatoes
Common pests perceived by farmers	"Wag" (fungus), caterpillars
Percentage who does not cover soils between cropping seasons	90%
Percentage who tills their soils	96%
Percentage who adds organic matter to soils	50%
Percentage who has increased fertilizer use since beginning farming	76%
Percentage who has seen an increase in pest presence since beginning farming	53%
Percentage who observes soil surface crusting	66%
Percentage who observes water ponding on the surface of the soil	53%
Percentage who says their soils are healthy	66%

[a]UPS of the site is 11.092348°N and 39.582257°E with Vertisols as a soil taxonomy classification.

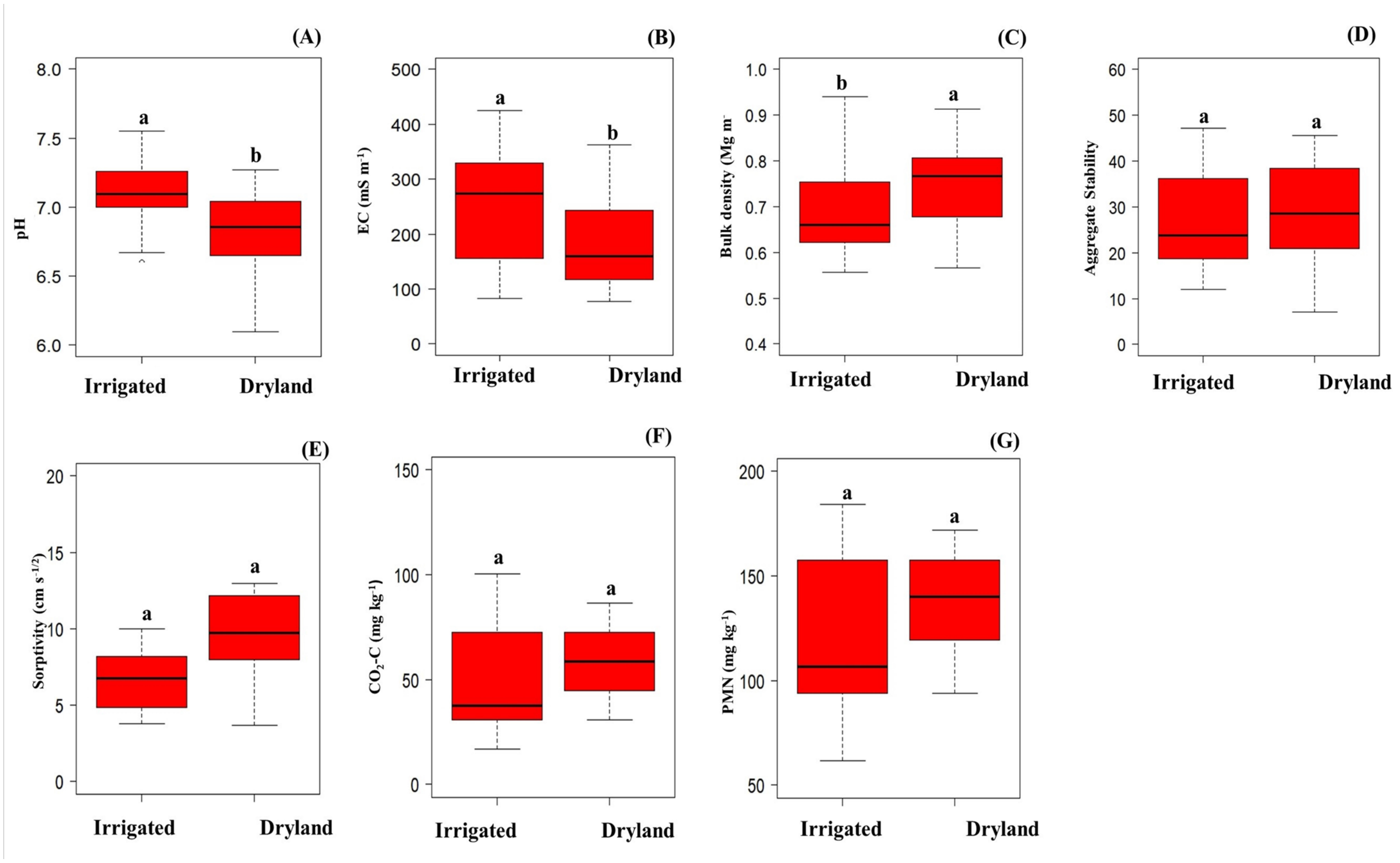

Figure 4. Soil pH (A), electrical conductivity (B), bulk density (C), aggregates stability (D), sorptivity (E), soil C respiration (CO2-C) (F), and potential N mineralization (PNM) (G) in Gerado, South Wollo, Ethiopia. Bars with the same letters are not significantly different. Vertical bars indicate standard errors. n represents none significant differences between irrigated and dryland soils. UPS of the site is 11.092348°N and 39.582257°E with Vertisols as a soil taxonomy classification.

Table 2. A compilation of the soil health indicators, including the findings and the accompanying student explanations from 30 smallholder farmers (15 irrigated, 15 dryland) in Gerado, South Wollo, Ethiopia, in December 2015.

Soil health indicator[a]	Findings	Students' comments
Soil pH and EC	Higher average soil pH and EC for irrigated farms than for the dryland farms	Addition of salts from surface water irrigation and lack of precipitation leach soluble salts out of the root zone and can cause higher pH and EC in irrigated farms (Feng et al., 2017).
Soil bulk density	Low bulk densities measured for both dryland and irrigated farms	Both dryland and irrigated farms utilized drainage furrows made by the maresha from planting to harvest, which may cause low bulk densities in the short term but can create poor aggregation and compaction in the long run (Chen et al., 2019; Zuber et al., 2015).
Sorptivity and low water-stable aggregates	High sorptivity and low water- stable aggregates for both dryland and irrigated farms	Tillage may increase sorptivity. The low water-stable aggregates in the soils may be associated with residue removal, frequent tillage, and lack of incorporation of organic material (Bartlova et al., 2015).
CO2-C and PNM	Low CO2-C and PNM range for both dryland and irrigated soils	Respiration and N mineralization depend on temperature, the amount of organic matter, water content, and the frequency of tillage (Davidson et al., 2000).

[a]UPS of the site is 11.092348°N and 39.582257°E with Vertisols as a soil taxonomy classification.

Figure 5. Student responses to the survey questions regarding the experiential learning study after their return from Ethiopia.

Table 3. Additional student comments regarding the experiential study.

Student Responses	
1	The orientation helped me be well prepared for this trip.
2	The orientation helped me stay healthy on this trip.
3	The orientation helped me decide what to bring along on this trip.
4	Hiking to where the farmers work with a backpack of field equipment was a test in stamina and coordination.
5	This research project helped me to expand my horizons and my understanding of soil sciences.
6	I recommend students go on a study abroad experience during their time at their university.
7	This taught me that soil quality has a big part to play in environmental health and that it's everybody's responsibility, not just farmers.
8	This research helped me to find some correlation between the farmer's perception of their soil quality and measured soil quality.
9	This trip helped me to learn that food security can't be explained or solved in a straightforward approach.

to the spread of communal flood irrigation, poor drainage, and the lack of efficient crop water management plans. In addition, frequent tillage creates light and porous soils ideal for sowing but resulting in less water stable aggregates. As a result, the soils are highly susceptible to erosion, poor drainage, the accumulation of soluble salts, and depletion of soil nutrients. However, 60% of farmers believed their soils were healthy, based only on their satisfaction with current crop yield, albeit a low one. Current soil management practices contribute little to no improvement to the soil, with the majority of farmers not protecting the soil between cropping. The availability of irrigation has doubled cropping intensity, which, in turn, has increased tillage frequency, coupled with 73% of farmers increasing their use of synthetic fertilizers. The majority of the farmers had noticed negative soil quality indicators such as surface crusting, surface water ponding and the lack of earthworms.

Student Reflection

This project was more than just an academic challenge. Completing it and directly working with farmers can bring a sense of pride and accomplishment (Rhykerd et al., 2006). Although the sample size for the survey was small (two undergraduate students), the results provide some general information that can be used to inform future programs. Based on the survey results reported in Figure 5, the students agreed the trip was well organized and experiences were aligned with the course outcomes. As a result of the excellent orientation the students received beforehand (see Table 3 Comments 1-3), they were prepared for the trip. In addition, the students said that they adjusted to new people and the unfamiliar surroundings through productive interactions. Research on the ability to adjust to study abroad and the ability to benefit from has suggested that this trait helps improve student confidence for exploring new places and people (Grant et al., 2019).

The students also grew close to the farmers and learned from them and their culture. The students' work definitely went beyond the academic: they listened to music, went sightseeing, and experienced Ethiopian culture. All of these activities helped them adapt to everything new around them. They also agreed that their emotions remained fairly consistent and stable throughout the trip. Family support is vital because it both makes it easy for students to adjust to studying abroad and increases the benefits they gain from it (Petzold and Moog, 2018; Pimpa, 2003). Lastly, according to the survey results, the students agreed that they learned a lot from this research project and that the journals provided to them helped them reflect on their travels. In addition, they encouraged other students to study abroad sometime during their university experience (Table 3 Comment 6) as such experiences are priceless in teaching students valuable life skills, helping them to understand the correlation between perceived soil health versus reality (Table 3 Comment 8), and allowing them to see that food security is an extensive, complicated grand challenge (Table 3 Comment 9). Another outcome from this research project was that the students had a unique opportunity to further their understanding of soil science and expand the horizon of their current knowledge (Table 3 Comment 5).

Summary

Student Comments on the Survey Data

Agricultural science students generally don't perceive how experiential learning is crucial to not only integrate their classroom learning with hands-on experience, but also familiarizing them with the workplace in their chosen careers. Although only two undergraduate students participated in this activity, the findings of this case study can give indicators on the importance of hands-on experience in improving student's global awareness and critical thinking. Participation in this activity successfully resulted in students gaining insight into food security, increased the student's understanding of soil health concepts, and provided them opportunity to enhance their research skills. It was clear that this kind of teaching helped students in gaining concrete experience by applying the theory and their personal experience into practice, which helped inspire one of the participants to work in the Youth Development Sector of the Peace Corps in the Middle East, specifically as the training and content manager for the Model United Nations in Morocco and another student to pursue a MSc and PhD in Climate Science. To sum up, this case study provides a useful framework for both educators and learners alike in agricultural sciences who plan to benefit from such experience abroad, especially when student experiential learning is integrated within the research scope. Hands-on learning can provide the teacher the opportunity to be more than just an information dispenser, but also a co-explorer of knowledge, resulting in students acquiring more knowledge and skill, and enhancing depth and relevance of learning. Although it is acceptable in studies like these to have a small number of perspectives, further assessment of such experiential learning studies with a higher sample size of students may be preferred.

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