

TRI-CEA: Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth

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PI (Lead): Jingjing Wang, Award 2418345

Co-PI: Yolanda Lin

Co-PI: David Hanson

University of New Mexico (New Mexico)

Co-PI: Stephen Gomez, Subaward (Award 2418345)

Santa Fe Community College (New Mexico)

PI: Meghann Jarchow, Award 2418346

University of South Dakota (South Dakota)

PI: Carmela Guadagno, Award 2418347

Co-PI: Jill Keith

Co-PI: Cynthia Weinig

University of Wyoming (Wyoming)

PI: Kevin Lombard, Award 2418348

New Mexico State University (New Mexico)

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Contents

Overview	1
Executive Summary.....	2
Research.....	5
Research Thrust 1: Advance the Fundamental Science Of CEA.....	5
Tabulated Progress: Objective 1.1	5
Tabulated Progress: Objective 1.2	7
Tabulated Progress: Objective 1.3	10
Research Thrust 2: Assess Socioeconomic Impacts of CEA	11
Tabulated Progress: Objective 2.1	12
Tabulated Progress: Objective 2.2	16
Tabulated Progress: Objective 2.3	17
Tabulated Progress: Objective 2.4	19
Research Thrust 3: Enhance CEA Workforce Development and Outreach	19
Tabulated Progress: Objective 3.1	19
Tabulated Progress: Objective 3.2	24
Tabulated Progress: Objective 3.3	26
Education	28
Solicitation-Specific Project Elements	29
Research Capacity and Jurisdictional Impacts	29
Development of STEM Workforce and Early Career Faculty	30
Interjurisdictional Collaborations and Overall Project Integration	32
Broadening Participation	33
Evaluation	33
Special Conditions	35
Expenditures And Unobligated Funds	36
University of Wyoming	36
University of South Dakota	36

Below is a list of the primary acronyms used throughout the TRI-CEA Annual Report. Acronyms are defined at first use and compiled here for the reader's reference

Acronym	Meaning
BCSI	Bioscience Core Skills Institute
CEA	Controlled Environment Agriculture
DWC	Deep Water Culture
EC	Electrical Conductivity
EPSCoR	Established Program to Stimulate Competitive Research
IoT	Internet of Things
IRB	Institutional Review Board
LCA	Life Cycle Assessment
NMSU	New Mexico State University
NNHRRB	Navajo Nation Human Research Review Board
NFT	Nutrient Film Technique
PAR	Photosynthetically Active Radiation
SFCC	Santa Fe Community College
SOP	Standard Operating Procedure
TRI-CEA	Tri-State Controlled Environment Agriculture
USDA GAP	United States Department of Agriculture Good Agricultural Practices
USD	University of South Dakota
UNM	University of New Mexico
UW	University of Wyoming
Research Thrust 1 = Biophysics	
Research Thrust 2 = Socioeconomics	
Research Thrust 3 = Workforce, Outreach, and Education	

Overview

The **TRI-CEA project (NSF Award ID: 2418345-8)** is a Focused EPSCoR Collaboration (FEC) designed to advance Controlled Environment Agriculture (CEA) as a pathway toward secure food systems, enhanced community resilience, and economic development in rural communities. As the project progresses toward the completion of its second year, it continues to demonstrate strong progress toward its goals.

The project's vision is to advance the scientific understanding and socioeconomic application of CEA as a strategy for fostering long-term community resilience. By exploring multiple dimensions of CEA—from microbial communities in CEA systems to socioeconomic modeling to CEA micro-credentials—the project seeks to advance the science of CEA while exploring the systems that could make CEA a reality in rural regions that empower rural communities to adapt to diverse challenges while strengthening food security and supporting sustainable economic growth.

Through cutting-edge research and innovative technology, the TRI-CEA project aims to identify best management practices, create locally relevant educational pathways to train a skilled CEA workforce, and equip rural communities with the tools needed to face environmental and economic uncertainty.

TRI-CEA brings together an interdisciplinary team from five institutions across three EPSCoR jurisdictions: University of New Mexico (UNM), University of South Dakota (USD), University of Wyoming (UW), New Mexico State University (NMSU), and Santa Fe Community College (SFCC). These partners collaborate across three interrelated research thrusts:

- **Research Thrust 1: Advancing Fundamental Science of CEA** – Deepening understanding of the biological, especially microbial, and environmental dynamics that support successful CEA systems
- **Research Thrust 2: Assessing Socioeconomic Impacts of CEA** – Investigating how CEA systems are perceived by rural communities and evaluating their potential social, economic, and environmental impacts
- **Research Thrust 3: Enhancing CEA Workforce Development and Outreach** – Designing and implementing curricula and educational pathways that prepare a highly skilled workforce capable of advancing CEA practices, particularly in ways that engage with rural communities and mitigate environmental impacts for rural populations

Together, these objectives position TRI-CEA to make meaningful contributions to the national field of CEA research while directly benefiting the participating EPSCoR jurisdictions. The team's convergent approach integrates natural sciences, engineering, and socioeconomic research to advance scientific knowledge of CEA, especially hydroponic production; to inform and facilitate community adoption; and to enhance workforce readiness. TRI-CEA serves as a collaborative research and innovation project informed by regional priorities and community needs.

Executive Summary

The TRI-CEA project continued to make strong progress during Year 2 (September 1, 2025 – August 31, 2026) toward advancing CEA research, workforce development, and community engagement across New Mexico, Wyoming, and South Dakota. Supported through the NSF FEC program, TRI-CEA brings together an interdisciplinary team from the University of New Mexico (UNM), University of South Dakota (USD), University of Wyoming (UW), New Mexico State University (NMSU), and Santa Fe Community College (SFCC) to explore how CEA can strengthen food security and economic growth in rural communities.

Year 2 activities focused on advancing coordinated efforts across the project's three primary research thrusts: (1) advancing the fundamental science of CEA systems, (2) assessing the socioeconomic impacts of CEA, and (3) enhancing CEA workforce development and outreach. Despite some delays related to early project coordination, infrastructure readiness, and staffing transitions, the project maintained strong momentum and established a solid foundation for expanded implementation in Year 3.

Under Research Thrust 1, the Biophysics Subteam made significant progress deploying and operating hydroponic Deep Water Culture (DWC) and Nutrient Film Technique (NFT) systems across partner institutions. Participating institutions established synchronized experimental systems and began coordinated data collection focused on plant physiology, environmental conditions, and microbial community dynamics. UW conducted multiple kale (*Brassica oleracea*) growth experiments examining biomass accumulation, photosynthetic performance, and microbial community composition across hydroponic systems. Preliminary findings indicated that microbial communities converged rapidly after plant introduction despite initial variability among systems, providing important insight into microbial dynamics within CEA environments.

Across institutions, researchers deployed and refined environmental monitoring systems capable of collecting temperature, humidity, nutrient, dissolved oxygen, and Photosynthetically Active Radiation (PAR) data. UNM, in collaboration with CNM Ingenuity's Technology Solutions Lab, redesigned IoT-based monitoring devices to support affordable spatial environmental monitoring and cloud-based data collection using both Wi-Fi and cellular connectivity. These redesigned devices will support the planned cross-institutional experimental campaign in Fall 2026.

Research teams also advanced standardized operating procedures (SOPs) for hydroponic system operation, microbial sampling, and environmental monitoring to improve consistency and comparability across institutions. The Biophysics Subteam's progress has positioned TRI-CEA to conduct a fully integrated cross-jurisdictional research campaign in the coming year.

Under Research Thrust 2, the Socioeconomics Subteam focused heavily on community-engaged research and preparation for conducting listening sessions and surveys in partner communities. The project achieved a major milestone with the completion of designing three survey

instruments targeting community producers, consumers, and organizations. Institutional and tribal IRB approvals were secured through close collaboration with the Navajo Nation Human Research Review Board (NNHRRB) and Rosebud Higher Education Research Review Board (RHERRB), reflecting TRI-CEA's commitment to ethical research practices, Tribal sovereignty, and Indigenous data governance.

Community engagement efforts included ongoing collaborations with the Navajo Nation, Rosebud Sioux Tribe (Sicangu Lakota Oyate), Eastern Shoshone Tribe, and Northern Arapaho Tribe, where project teams presented TRI-CEA goals, obtained resolutions of support, and discussed community priorities related to food systems and CEA adoption. These activities strengthened relationships with local partners while ensuring that future research activities remain community-informed and culturally responsive.

USD also expanded its socioeconomic and sustainability research capacity through the hiring of Dr. Guillermo Marcillo, a new tenure-track faculty member who will lead future Life Cycle Assessment (LCA) activities beginning in Year 3. In parallel, researchers at UNM and UW advanced system dynamics modeling efforts related to crop production, pathogen management, and economic analysis. Preliminary socioeconomic datasets, including kale market pricing analyses and regional environmental datasets, are being prepared for public release to support future modeling and policy analysis activities.

Under Research Thrust 3, the Workforce Subteam focused on workforce development, outreach, and educational pathway development. The project conducted an industry-informed workforce needs assessment that identified plant production, pest management, instrumentation, and operational skills as critical workforce competencies for the CEA sector. Survey findings also highlighted the importance of business, project management, and system-thinking skills within the emerging CEA workforce landscape.

Building on these findings, the project refined its strategy for developing competency-based micro-credentials led primarily by SFCC. Discussions with multiple stakeholder groups highlighted the differing workforce development roles of two-year and four-year institutions – for example, highlighting the more targeted approach focused on transferable technical competencies of two-year institutions rather than the broader credentialing often pursued at four-year institutions. The project is preparing to pilot a micro-credential focused on instrument calibration and environmental monitoring tools during the 2026 TRI-CEA All-Hands Meeting in Wyoming.

Educational outreach expanded significantly during Year 2. TRI-CEA-supported activities reached hundreds of K–12 students, teachers, and community participants through workshops, field days, hydroponic demonstrations, and youth training programs. SFCC and partner institutions in New Mexico distributed hydroponic systems to 43 schools and trained 54 teachers. In South Dakota, USD partnered with Sicangu Co. and the Boys & Girls Club of Rosebud to create a youth hydroponics and entrepreneurship program that supports food sovereignty and workforce development.

The project also strengthened interjurisdictional collaboration and integration across all participating institutions. Monthly full-team meetings and regular subteam meetings fostered strong communication, cross-training, and collaborative problem-solving among faculty, staff, and students. Cross-institutional mentoring and student engagement activities have become a key component of TRI-CEA's workforce and research integration strategy.

Overall, Year 2 demonstrated meaningful advancement across TRI-CEA's scientific, educational, and community-engagement objectives. The project successfully expanded research infrastructure, strengthened rural and institutional partnerships, advanced workforce development planning, and laid the groundwork for integrated cross-jurisdictional experimentation and modeling activities scheduled for Year 3. These accomplishments position TRI-CEA to continue generating impactful research and scalable workforce solutions that support resilient food systems and sustainable economic growth across participating EPSCoR jurisdictions.

Research

This annual report highlights Year 2 progress of the TRI-CEA project, led by UNM in collaboration with partner institutions from Wyoming, South Dakota, and New Mexico. Over the past year, the project has advanced integrated efforts in biophysical research (led by the Biophysics Subteam), socioeconomic research (led by the Socioeconomics Subteam), and workforce development (led by the Workforce Subteam) to support CEA as a pathway for food security, resilience, and economic opportunity. Key accomplishments include expanding cross-institutional research systems, continuing engagement with rural communities, and advancing industry-informed workforce training and micro-credentials. While some activities experienced delays due to funding uncertainties and coordination complexities in Year 1, the project has maintained strong momentum and alignment with its strategic objectives. Collectively, these efforts position TRI-CEA to continue implementation, deepen collaboration, and broaden impact in the coming years.

Throughout the report, tabulated progress is presented in tables that follow the strategic plan tables, with the objectives, milestones, activities, along with associated accomplishments and progress to the end of the fiscal year color coded (i.e., the tables include projected activities by August 31, 2026). Each activity is color-coded to provide a clear, at-a-glance update on status. **Green** indicates that the activity has been completed or is on track for completion by the end of the fiscal year. **Yellow** indicates that progress is underway, but the activity will likely not be fully completed by the end of the fiscal year. **Red** indicates that the activity has not been completed due to identified challenges.

Research Thrust 1: Advance the Fundamental Science Of CEA

During Year 2 of the TRI-CEA project, the Biophysics Subteam made strong progress toward the goals of Thrust 1: Characterizing how environmental conditions, plant physiology, and microbial communities interact in controlled environment agriculture systems and influence crop performance. Through coordinated efforts across partner institutions, the team advanced system deployment, experimental research, and data integration aligned with Objectives 1.1, 1.2, and 1.3.

Tabulated Progress: Objective 1.1

Thrust 1: Characterize how the environment, plants, and microbes interact in hydroponic systems and affect crop yield and nutritional quality			
● Objective 1.1: Deploy and monitor CEA systems across different EPSCoR jurisdictions ● Objective 1.2: Measure environmental factors and plant physiological traits in CEA settings to assess impacts on yield and nutritional quality ● Objective 1.3: Characterize microbial community composition in CEA microsites			
Objective 1.1	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Finalize the design of CEA systems	Feasibility assessment and market analysis for the purchase and following deployment of Deep Water Culture (DWC) and Nutrient Film Technique (NFT) systems across institutions	*	Baldwin, Guadagno, Weinig (UW); Shultz (SFCC)

	Working towards establishing long-term partnerships with suppliers for systems procurement, maintenance, and training Provide a first characterization of microbial communities in all CEA microsites (e.g., water, mixed solutions, NFT system, plant roots)		
Activity 2: Purchase, and deploy CEA systems across institutions	All materials purchased and deployed at SFCC ahead of the all-hands meeting in NM for demonstration and training activities of all participants Deployment of systems at UW, UNM, and NMSU Training of all assisting personnel involved in the experimental times	*	Baldwin, Guadagno (UW); Shultz (SFCC); Green, Hanson (UNM); Lombard (NMSU)

* An asterisk indicates that no milestones were planned for that period.

Under Objective 1.1 (deployment and monitoring of CEA systems), the team continued to advance the implementation of hydroponic systems across sites, including Deep Water Culture (DWC) and Nutrient Film Technique (NFT) systems. By early 2026, participating institutions had operational systems supporting synchronized experimental trials. Despite temporary disruptions such as greenhouse renovations at SFCC during Spring 2026, research activities continued through system adjustments and student-supported work. Seed distribution across partner institutions was completed by March 2026, enabling coordinated experimental timelines and enhancing the comparability of results across sites.

The UW team - PI Guadagno, co-PI Weinig, Senior Personnel Baldwin, designed and coordinated experimental trials led by graduate students Spiegelberg and Eastlund between October 2025 and July 2026. The experiments are meant to characterize 1) potential changes in the growth curve (and biomass accumulation) of kale growing in DWC and NFT systems, 2) high-throughput physiological traits such as chlorophyll a fluorescence - that might pick up different signals from plants grown with different methods, and 3) variation in microbiomes across multiple greenhouse and plant environments within both DWC and NFT production systems at the UW. Physiological measurements showed an initial significant difference in the unregulated heat dissipation, but this seemed to disappear during the following trials. Overall, preliminary results showed that above ground biomass accumulation did not differ between the two growing methods when referring to the initial part of the growing curve (less than 16 days). Additional experiments will dissect the influence of incoming radiation on the high-throughput traits vs. growing methods. Moreover, one NFT system has been now deployed at a production site - Papa Joe's produce in Sheridan, Wyoming - to test the applicability of the modeled curves to real sites in Year 3. For microbial samplings, the greenhouse air, stock solutions, circulating nutrient solutions, city water, inoculates, and plant rhizospheres were analyzed. Additional samples were also analyzed over a time course to better understand microbial community dynamics. Initial findings indicated that replicate systems initially exhibited variability following sterilization and prior to plant introduction; however, microbial communities converged within seven days of plant addition, with overlapping 95% confidence intervals. A follow-up

experiment, planned for Year 2, will evaluate whether rhizosphere microbiomes shift over time in response to changes in the surrounding solution microbiome.

In continuation with last year's efforts, NMSU has trained two undergraduate interns, Sarrah Trujillo and Shaun McKinnley, as part of project activities. Following this training, Shaun McKinnley transitioned to working with the UNM team in Albuquerque during the academic year, while continuing to support NMSU Farmington during academic breaks. This cross-institutional engagement reflects ongoing workforce development and student training efforts.

Tabulated Progress: Objective 1.2

Objective 1.2: Measure environmental factors and plant physiological traits in CEA settings to assess impacts on yield and nutritional quality			
Objective 1.2	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Build custom environmental IoT sensors for use in all jurisdictions	Design plant and environmental monitoring sensor systems with CNM Ingenuity Technology Solutions Lab (TSL) and input from other PIs Build sensor systems as part of 8-week summer Engineered Agriculture research experience offered at UNM Deploy completed sensor systems to other institutions Design an 8-week course incorporating CEA micro-credentials developed in Activity 3.1 and sensor systems designed in Activity 1.2.1 Organize travel to encourage participation in UNM CEA research experience Offer annual 8-week CEA summer research experience at UNM; students build the first sensor systems to be deployed across institutions	Continue improving/modifying sensor design based on Year 1 deployment and use; integrate with hydroponic system interfaces to monitor and collect data remotely Continue building sensor systems as part of CEA 8-week summer research experience	Green, Hanson (UNM)
Activity 2: 8-week summer Engineered Agriculture research experience (part of education and outreach in Activity 3.3.)		Offer annual 8-week CEA summer research experience at UNM	Green, Hanson (UNM)
Activity 3: Preliminary experimental testing	Run a suite of parallel pilot experiments across all institutions	Finalize data analysis from pilot experiments	Baldwin, Guadagno, Weing (UW); Shultz (SFCC); Green, Hanson (UNM); Lombard (NMSU)
	Characterize the most desirable set of environmental conditions to be used for kale plants during the following years (In coordination with Objective 1.2.1; 1.3.1) Test potential media to stabilize microbial communities	Compile the panel of environmental settings/conditions to be further characterized (In coordination with Objective 1.3.1; 2.3.1)	
Activity 4: Deep plant phenotyping experiments	*	High-throughput phenotyping will take place at each institution while low-throughput physiological measurements will	Guadagno (UW); Shultz (SFCC)

		be taken at the same time of microbial samplings (In coordination with Objective 1.3.2; 2.3.1; 2.3.2) Data analysis and preparation of the cross-institutional campaign #1 (In coordination with Objective 1.2.3 & 1.3.2)	
Activity 5: Cross-jurisdiction field campaign	*	All hands-on experimental campaign to collect physiological data and perform sampling across all institutions for crop nutrient analysis (In coordination with Objective 1.3.3)	Guadagno, Weinig, Keith (UW); Hanson, Green (UNM); Shultz, Gómez (SFCC); Lombard (NMSU); Jarchow (USD)

* An asterisk indicates that no milestones were planned for that period.

Significant progress was also made under Objective 1.2 (measurement of environmental and plant physiological traits in CEA settings to assess impacts on yield and nutritional quality). After completing the deployment of systems during the Summer 2025 and the decision to use Lacinato kale (also known as dinosaur kale, Tuscan kale, or black kale) for the system in January 2026. Lacinato kale is a high-value cultivar for CEA systems due to its upright, space-efficient growth habit and consistent crop architecture. Its characteristic dark blue-green, blistered leaves provide excellent aesthetic appeal, high visual uniformity, and market differentiation over standard curly varieties. The cultivar delivers a milder, sweeter flavor profile with a tender, less fibrous texture, making it highly desirable for premium consumer markets.

Participating institutions deployed and tested a range of environmental sensors to monitor light, temperature, humidity, nutrient conditions, and dissolved oxygen. Experimental trials conducted by UW during this period included both short and extended growth cycles, such as 16 to 32-day kale trials, which incorporated destructive and non-destructive measurements to capture plant growth dynamics and biomass accumulation. In parallel, the team began integrating environmental and plant data streams, creating a foundation for predictive modeling of crop performance under varying controlled conditions.

Activity 1.2.1: Deployment of environmental sensor devices has been delayed but will be employed by October 31, 2026, to accommodate a redesigned system being developed with Central New Mexico Community College Ingenuity’s Technology Solutions Lab. The updated design will enable the collection of temperature, humidity, and light intensity data through an affordable sensor array capable of spatial data collection across hydroponic systems. Additionally, the devices will support both Wi-Fi and cellular connectivity for improved data transmission. The devices will be deployed in time for use in the cross-institutional campaign.

Activity 1.2.2: The workshop, originally designed as an eight-week program, has been condensed into a six-week format. During the Summer 2026 workshop, students will build and test environmental sensor devices through redesigned full-day sessions that were developed in response to participant feedback from previous workshops. The workshop will focus on developing a sharable curriculum “Internet of Things (IoT) for CEA” and creating flexible teaching tools that also support TRI-CEA data collection needs. Selected students will serve as

testers and trainers, designing experiments to validate device performance prior to broader deployment. The workshop is open to anyone over 18. Participants include traditional university students, community college students, and practicing farmers.

Looking ahead, the project aims to expand participation in 2027 by offering improved online learning options, teacher training, and traveling workshops at additional rural sites, with the goal of increasing regional access and engagement.

Activity 1.2.3: Data collection activities are actively underway across institutions. NMSU is collecting temperature data twice daily (8:00 AM and 4:00 PM) along with Photosynthetically Active Radiation (PAR) measurements. UNM is collecting and analyzing spatial PAR and plant growth rate data, with “spatial” referring to measurements collected across multiple locations within each system. This includes collecting light intensity data to assess variability both between and within each hydroponic system. At NMSU Farmington, the team is fully operational and collecting fresh and dry biomass weights, PAR data, and greenhouse temperature measurements.

To ensure consistency across institutions, Jade Whitting (SFCC) is collaborating with Isaiah Spiegelberg (UW) to develop standardized operating procedures for parallel experiments.

UW completed analyses associated with the initial characterization of microbial communities in both DWC and NFT systems. These analyses included 16S biomarker gene sequencing, PERMANOVA testing to assess differences among microsites, and Principal Coordinate Analyses (PCoA), along with associated data visualization to interpret microbial community structure.

At UW, physiological measurements on plants grown both in DWC and NFT systems have been taken starting in October 2025. Three long (~33 days) experiments have been run to benchmark the growth rate of kale in the different systems. Along with biomass, physiological traits such as efficiency of photosystem II and stomatal conductance have been measured. An initial compiled analysis of the data has started and an initial growth curve model fit. Currently, only one suite of environmental settings for the greenhouse has been tested due to the already strong seasonality and diurnal variability of temperature.

Activity 1.2.4: NMSU deployed sensors in its greenhouse in Winter 2026 to better understand environmental conditions before the cross-institutional campaign. Preliminary analyses include qualitative comparisons between NFT and DWC systems, as well as the influence of fan placement and ambient light. While foundational elements are in place, some component-level refinements are still needed.

At UW, high-throughput data has been collected using the Multispeq instrumentation and a LI-COR LI-600. The Multispeq combines a fluorometer, chlorophyll meter, and spectrometer to measure plant photosynthesis and provide real-time estimates of plant vigor and health. The LI-COR LI-600 enables rapid measurement of stomatal conductance and chlorophyll *a* fluorescence on individual leaves, supporting high-throughput estimates of water use efficiency and photosynthesis. Using these instruments, data were collected on SPAD (an instantaneous measure of chlorophyll concentration), chlorophyll *a* fluorescence, leaf thickness, and stomatal conductance.

Activity 1.2.5: The cross-institutional research campaign has been rescheduled for Fall 2026. UW has shifted its campaign timeline to Fall to align with broader project coordination. NMSU Farmington is on track with data collection efforts, while UNM is nearing readiness for full-system integration. Minor technical issues related to Bluelab monitoring equipment and Wi-Fi connectivity within UNM’s secure network environment are currently being addressed in coordination with UNM IT and the manufacturer. These issues have not significantly affected progress toward grant activities or project objectives. The adjusted timeline was established to allow sufficient time for the completion of key preparatory components, including sensor development, plant phenotype characterization, and microbial community analysis. With these foundational elements nearing completion, the project is well-positioned to successfully implement the coordinated campaign in Fall 2026.

Tabulated Progress: Objective 1.3

Objective 1.3: Characterize microbial community composition in CEA microsites			
Objective 1.3	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Preliminary NFT experiments	Pilot experiments in existing NFT systems to confirm preliminary data and to finalize methodologies for consequent sampling and analysis	*	Weinig, Guadagno (UW)
Activity 2: Biogeography analysis	Run a suite of pilot experiments to characterize microbial communities in NFT and DWC systems at different environmental conditions (In coordination with Objective 1.2.3)	Finalize data analysis from pilot experiments and correlate differentially abundant microbial taxa with physiological data (In coordination with Objective 1.2.3)	Weinig, Guadagno (UW)
		Characterize microbial community at UW and from shipped samples from other institutions (In coordination with Objective 1.2.4)	
		Data analysis and preparation of the cross-institutional campaign #1 (In coordination with Objective 1.2.4)	
Activity 3: Cross-jurisdiction field campaign	*	Experimental campaign #1 to perform microbial sampling across all institutions (In coordination with Objective 1.2.5)	Weinig, Guadagno (UW)

* An asterisk indicates that no milestones were planned for that period.

Advances under Objective 1.3 (characterization of microbial communities) represent one of the most significant scientific contributions of this reporting period. During discussions at the March 9, 2026 meeting, the team identified substantial variability in microbial community composition across system replicates, even under controlled conditions. Analyses by UW indicated strong block effects, accounting for approximately 23% of observed variation between NFT systems and temporal changes over a 14-day experiment. This finding highlights the importance of microbial dynamics in CEA systems and is directly informing improvements in experimental design, including replication strategies and sampling approaches. Ongoing work has focused on aligning microbial sampling with plant growth measurements and expanding sampling to better capture interactions within the system.

Activity 1.3.1: The team completed pilot experiments in existing NFT systems to confirm preliminary data and to finalize methodologies for consequent sampling and analysis in Year 1. There were no milestones planned for Year 2.

Activity 1.3.2: Across all objectives, the team also made progress in standardization and integration. Beginning in January 2026, efforts were initiated to develop Standard Operating Procedures (SOPs) for system setup, environmental monitoring, and microbial sampling. These protocols are critical for ensuring consistency across institutions and will support future cross-site experimental campaigns. At the same time, the team explored the use of real-time monitoring technologies, including IoT based systems, to enhance data collection and improve the resolution of environmental and biological measurements.

Activity 1.3.3: As part of Objective 1.3, TRI-CEA has initiated cross-training sessions that have contributed to greater integration and coordination of research activities across TRI-CEA partner institutions. Discussions have emphasized the importance of standardized sampling protocols, shared methodologies, and consistent data collection practices, particularly in microbial and plant system research.

These sessions have also created space for aligning approaches to biophysical measurements and microbial analysis, helping to ensure comparability of results across sites. By fostering ongoing dialogue and knowledge exchange, the cross-training series are strengthening collaboration and supporting the development of a more cohesive, multi-institutional research framework.

Pilot experiments for microbial community characterization have been completed. Building on this progress, microbial samples collected from collaborating institutions will be analyzed in Fall 2026 to support broader cross-site comparisons and insights.

Looking ahead, planned activities will continue to build on progress within Thrust 1. The team will refine the experimental design to address microbial variability and strengthen replication across sites. Additional sensor deployment and expansion of real-time monitoring systems are planned to improve environmental data collection. A coordinated cross-institutional microbial sampling campaign is scheduled for Fall 2026, which will integrate protocols developed during this reporting period. In addition, the team is preparing for the in-person, all-hands meeting on June 22 and 23, 2026 at UW, which will support training, protocol alignment, and further coordination of experimental activities. During this time, SOPs for microbial community characterization experiments will be distributed to all collaborating institutions.

Overall, the Biophysics Subteam has made meaningful progress across all components of Thrust 1 during the current reporting period. The integration of system deployment, environmental monitoring, plant physiology, and microbial analysis positions the project to generate new insights into CEA systems and contribute to scalable solutions for resilient food production.

Research Thrust 2: Assess Socioeconomic Impacts of CEA

The Socioeconomics Subteam has made coordinated progress across Thrust 2 objectives, with a strong emphasis on laying the foundation for community-engaged research, advancing data

collection, and preparing for integrated modeling and policy analysis. Activities during Year 2 have primarily focused on Objective 2.1, while laying the groundwork for Objectives 2.3 and 2.4 through literature synthesis and early modeling discussions. Progress under Objective 2.2: Life Cycle Assessment (LCA) was delayed due to uncertainty in federal funding during the previous year, which impacted hiring timelines and slowed advancement of this activity.

Tabulated Progress: Objective 2.1

Thrust 2: Identify environmental, nutritional, and socio-economic drivers and impacts of CEA on tribal communities to enhance community resilience strategies via CEA ● Objective 2.1: Gathering community input to understand community perception and acceptance of CEA ● Objective 2.2: Life Cycle Assessment (LCA) to understand the environmental impacts of CEA ● Objective 2.3: Integrated system dynamics modeling of CEA ● Objective 2.4: Regulatory and Policy Analysis of CEA			
Objective 2.1	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Hold listening sessions	Fully staffed personnel including grad students and postdocs Conduct phase 1 listening sessions with campus and community partners to inform phase 2 focus groups/listening sessions Institutional IRB application (for at least 2 institutions) Tribal IRB application (for at least 1 tribe) Use the community feedback from phase 1 listening sessions to inform the development of the integrated CEA modeling framework in Objective 2.3.1	Continue to engage with campus and community partners who were part of phase 1 listening sessions to inform, guide, and provide feedback related to phase 2 focus groups/listening sessions Tribal IRB application (for at least 3 more tribes) Institutional IRB application (timeline may continue into year 3) Apply for IRB modifications, as needed and if applicable Upon institutional and tribal IRB approvals, conduct phase 2 focus groups/listening sessions with partner tribal communities Use the community feedback from listening sessions to continue informing the development of the integrated CEA modeling framework in Objective 2.3.1	Jarchow (USD); Keith (UW); Lombard (NMSU);
Activity 2: Hold focus groups	Draft a list of questions for focus groups [should be informed by listening sessions so IRBs would need to be updated when questions are finalized] Institutional IRB application (at least 2 institutions) Tribal IRB application (for at least 1 tribe)	Institutional IRB application (timeline may continue into year 3) Tribal IRB application (for at least 3 more tribes) Conduct focus groups with participants prioritized by community partners and feedback from listening sessions in Objective 2.1.1	Jarchow (USD); Keith (UW); Lombard (NMSU)

		Use the community feedback from focus groups to inform the development of the integrated CEA modeling framework in Objective 2.3.1	
Activity 3: Design surveys	Draft a general list of survey questions based on the team's previous work Institutional IRB application (at least 2 institutions) Tribal IRB application (for at least 1 tribe)	Finalize a general list of survey questions informed by findings from listening sessions and focus groups in Objectives 2.1.1 and 2.1.2 Tailor the general survey for each jurisdiction or tribal community Institutional IRB application (timeline may continue into year 3) Apply for IRB modifications, as needed and if applicable	Jarchow (USD); Keith (UW); Lombard (NMSU); Wang (UNM)
Activity 4: Execute surveys	*	Execute surveys in at least 1 pilot partner community (Navajo reservation)	Jarchow (USD); Keith (UW); Lombard (NMSU); Wang (UNM)
Activity 5: Analyze survey responses	*	*	Jarchow (USD); Keith (UW); Lombard (NMSU); Wang (UNM)

* An asterisk indicates that no milestones were planned for that period.

Under Objective 2.1 (gathering community input to understand perceptions and acceptance of CEA), the team achieved a major milestone in the development and preparation of three Navajo Nation surveys targeting producers, consumers, and community organizations. Between January and February 2026, survey instruments were refined and aligned with IRB protocols across institutions. By March 13, 2026, all three surveys had been programmed into Qualtrics, were approved by the Navajo Nation, and are undergoing alpha testing by student interns. The team established a deployment strategy centered on in-person engagement at chapter meetings and farming events, with full rollout planned for summer 2026 to encourage with peak community participation.

Activity 2.1.1: NMSU converted a postdoctoral position into a full-time Program Specialist Sr. role, now filled by Tionna Tapaha, to better support project implementation. Institutional Review Board (IRB) approvals have been successfully obtained, including NMSU IRB approval (Winter 2025) and Navajo Nation Human Research Review Board (NNHRRB) approval on February 17, 2026 (Protocol NNR-26.574).

Alongside survey development, the team strengthened its approach to community engagement and data governance, directly supporting Objective 2.1. Throughout February and March 2026, the subteam emphasized data sovereignty and secure data handling practices as discussion topics in their regularly scheduled meetings and in their research practices. A dedicated computer was set up at NMSU for secure storage of qualitative data, and the team explored the data security of transcription tools to support interview analysis. These efforts ensure that data collection and management practices align with tribal expectations and ethical research standards.

Due to concerns related to data sovereignty, confidentiality, and the use of uploaded audio data by third-party AI transcription platforms such as Otter.ai, NMSU does not permit the use of Otter.ai on university computers. To ensure secure handling of qualitative research data, audio recordings from surveys and interviews will be stored locally on a computer within the NMSU Anthropology Ethnography Lab. The computer will remain in a locked room and will be accessed only by Sarrah Trujillo during the course of the project. Audio files will be manually transcribed into Word documents and maintained locally without being uploaded to external websites or cloud-based transcription services.

The outreach and engagement efforts related to IRB submission in Year 2 for the TRI-CEA project were led by the NMSU team, who conducted a series of presentations and consultations with Navajo Nation chapter houses and affiliated organizations during late 2025. These efforts focused on providing an overview of the TRI-CEA project and securing chapter house resolutions to support IRB submission and research activities within their communities.

The Navajo Nation IRB process plays a critical role in ensuring that research is conducted in partnership with tribal communities and in alignment with tribal sovereignty and community priorities. Within TRI-CEA, these processes support the co-development of research questions and activities with community members through established procedures for obtaining Chapter resolutions and letters of support prior to research implementation. The Navajo Nation IRB also upholds principles of data sovereignty, ensuring that data collected through the project remains the property of the Navajo Nation and is managed in accordance with tribal protocols and expectations. In cases where both institutional and tribal approvals are required, the Navajo Nation IRB holds authority over other IRB approvals for work conducted within Navajo Nation communities. Furthermore, all presentations, publications, peer-reviewed manuscripts, and dissemination materials are reviewed through the Navajo Nation IRB process. The IRB also emphasizes reciprocal dissemination, requiring that research findings be shared back with participating communities, tribal leadership, and policymakers to ensure transparency, accountability, and community benefit.

Activity 2.1.2: The team developed a fact sheet and a poster to clearly communicate project goals, activities, and community relevance to project partners and collaborators. The fact sheet was revised in December 2025 and used during community meetings as a key resource to facilitate discussions and obtain Chapter House resolutions and letters of support for IRB approvals at both NMSU and the Navajo Nation.

In November 2025, the NMSU team initiated work on this activity with a presentation to the Navajo Nation Farm Board Association at the Many Farms Chapter House in Arizona. Building on this engagement, the team continued outreach in December 2025 with multiple chapter house meetings across New Mexico. On December 8, the NMSU team presented at the Nenahnezad Chapter House, followed by the Shiprock Chapter House on December 10. They

Collaborative Research: RRI FOC: Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth

Benefits

- No soil needed
- Year-round crop production inside greenhouses/indoor
- Space Efficient
- Reduced water usage
- Faster Growth Rate
- More control over environmental conditions that can avoid soil-borne diseases and contaminated soil, etc.

Overview

Our project is based on CEA, or Controlled Environment Agriculture, specifically Hydroponic systems such as the NFT (Nutrient Film Technique) and the DWC (Deep Water Culture). This form of agriculture may help combat food insecurity on this planet. We do not know how these systems may be adopted in communities, the social economic or what the training needs may be to operate these types of systems. The study is taking place in Ibadan, Nigeria, South Ogun State/ Oyo State.

Drawbacks

- Expensive (energy, nutrients, indoor space)
- High Maintenance
- Uniform Plant Types (mostly vegetables)
- Technical Expertise and training needed
- Vulnerable to some disease and pests
- Requires greenhouses

Source: <https://www.researchgate.net/publication/326144444>

Source: <https://www.researchgate.net/publication/326144444>

Objectives:

- Advocate fundamental science of Controlled Environment Agriculture (CEA) identify the intention of hydroponic systems on the environment, plants and water as well as their pros and cons and nutritional value
- Assess Socio-economic impacts of CEA further community engagement, help to understand opportunities and challenges and feasibility of CEA
- Site Mission Development: Non-commercial training opportunities for CEA systems

Hydroponic Systems:

The NFT is a table of pipes which constantly circulates nutrient rich water to help the roots of seedlings to have consistent access to the nutrients they need to grow

Deep Water Culture

The DWC is another hydroponic system which has a tub where the plants, in containers, are floating on the water in order to submerge the roots. DWCs are also a very common hydroponic system.

Source: <https://www.researchgate.net/publication/326144444>

Source: <https://www.researchgate.net/publication/326144444>

Why is this important:

Some communities have struggled with growing enough crops and food. With Controlled Environment Agriculture (CEA) systems like greenhouses and hydroponics, there is potential to increase food production year-round and decrease water usage. While CEA systems may have a lot of benefits, they are expensive and we don't know a lot about their operation on the African nation, the training needs of local economic impacts which is why we are conducting this project.

Contact Information

info@rri-foc.org
info@rri-foc.org
info@rri-foc.org

collaboratively with chapter leadership to discuss research considerations and obtain formal resolutions necessary for IRB approval. These engagements represent a critical step in ensuring that project activities are conducted with appropriate community awareness, input, and approval, aligning with the project's commitment to ethical research practices and meaningful community partnership.

The UW team adapted the fact sheet from NMSU for use in the presentation to the Wind River Inter-Tribal Council. The UW team received approval for the TRI-CEA project from the Council. This was required before submission to the UW IRB. The approval from the Northern Arapaho representatives on the Wind River Inter-Tribal Council counts for IRB approval for the Northern Arapaho Tribe on the Wind River reservation. The next step was to submit project materials to the Rocky Mountain Tribal IRB, which is the IRB of record for the Eastern Shoshone Tribe. Those materials were submitted in early March 2026.

grant final approval for conducting listening sessions, focus groups, and surveys in the Navajo Nation (step 2). The UW team received UW IRB approval on February 3, 2026 for conducting listening sessions and surveys in their tribal partner communities. UNM initiated its IRB process using shared materials to ensure consistency across institutions. During February 2026, the Socioeconomic Subteam coordinated closely to address Navajo Nation requirements, including discussions around certificates of confidentiality and data management plans. These efforts have resulted in a coordinated, multi-institutional compliance framework that supports research across rural and local communities.

In addition to the council presentation, the UW team met directly with community partners affiliated with the Restoring Shoshone Ancestral Food Gathering group. These meetings provided an opportunity to discuss the proposed research, gather feedback, and align the project with community priorities and cultural considerations. Together, these activities supported a collaborative and community-engaged approach to the IRB submission process.

Activity 2.1.4: Following NNHRRB approval (Protocol NNR-26.574), survey implementation is underway in approved Navajo communities and affiliated organizations. The three surveys are being deployed through in-person events on tablets. The NMSU team is currently piloting the surveys to ensure functionality and refine interviewer-assisted data collection methods, where trained team members input responses on behalf of participants. Full deployment is anticipated in Summer 2026.

Tabulated Progress: Objective 2.2

Objective 2.2: Life Cycle Assessment (LCA) to understand the environmental impacts of CEA			
Objective 2.2	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Expand USD's life cycle assessment (LCA) expertise	Conduct search for new LCA faculty member	USD offers a LCA course	Jarchow, New faculty hire (USD)
	New LCA faculty member start (August 2025)	Conduct a search for a new applied data science faculty member	
Activity 2: Conduct LCA of CEA systems across project regions	*	Define LCA goal and scope Create life cycle inventory and determine sources for needed data in collaboration with Objective 2.3 Coordinate with Objective 1.2 to ensure that needed data will be collected Coordinate with Objective 2.1 to ensure that needed data will be collected in surveys	Jarchow, New faculty hire (USD)

* An asterisk indicates that no milestones were planned for that period.

Under Objective 2.2 (Life Cycle Assessment of CEA), progress is expected to resume following earlier delays. USD has completed a successful faculty search to support this effort, and the newly hired faculty member will begin contributing to the project in Year 3. This position will lead the LCA activities, which will strengthen the integration between the socioeconomic and biophysical aspects of the TRI-CEA project.

Activities 2.2.1&2: USD conducted a faculty search for a LCA position during the 2024–2025 academic year; however, the selected candidate declined the offer. The search was subsequently broadened to applied data science, resulting in the successful hiring of Dr. Guillermo Marcillo. Dr. Marcillo will attend the all-hands meeting in June, which will allow him to connect with the TRI-CEA project even before he begins full-time in August 2026.

Although an LCA course was not offered in Year 2 because of the failed search in Year 1, USD developed and received approval for a new course, Thinking in Systems (SUST 401/501), which incorporates LCA, will be offered in Fall 2026, and will be taught by Dr. Marcillo. With the hiring of Dr. Marcillo, the team is now better positioned to advance the life cycle assessment (LCA) and data integration components of the project. This addition will provide dedicated capacity to develop the life cycle inventory and identify critical data sources in coordination with Objective 2.3. Dr. Marcillo will also work closely with teams leading Objective 1.2 to ensure that the necessary experimental and production data are collected consistently across project activities. In addition, coordination with Objective 2.1 will help ensure that relevant socioeconomic and community-level data are incorporated into surveys and outreach efforts, supporting a more comprehensive and integrated assessment framework for the project.

Fortunately, the associated graduate student mentoring activities were not delayed because a master’s student who Dr. Marcillo is currently advising is planning to transfer to USD to conduct the TRI-CEA LCA research.

Tabulated Progress: Objective 2.3

Objective 2.3: Integrated system dynamics modeling of CEA			
Objective 2.3	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Develop a modeling framework	Draft a general modeling framework based on responses from community Phase 1 listening sessions (in coordination with Objective 2.1.1)	Iterate on the modeling framework with community feedback from community listening sessions and focus groups (in coordination with Objectives 2.1.1 and 2.1.2)	Lin, Wang (UNM)
Activity 2: Data collection and management	Collect and compile various datasets (costs, weather, sunlight exposure, socioeconomic data, etc.) Create database and/or repository for data, including metadata for collected data for internal use	Continue to collect and compile various datasets (costs, weather, sunlight exposure, socioeconomic data, etc.) in collaboration with Objective 2.2	Lin, Wang (UNM)
		Release a public version of database and/or repository for data, including metadata for collected data, alongside CEA v1	
Activity 3: Build an integrated system dynamics model of CEA	*	Use the experimental data from Objective 1.2 to estimate two types of crop production functions	Lin, Wang (UNM)
		Build an integrated system dynamics model of CEA (version 1)	

* An asterisk indicates that no milestones were planned for that period.

Activities under Objective 2.3 (integrated system dynamics modeling of CEA) have focused on building the conceptual and analytical foundation for future modeling work. The team

advanced a comprehensive literature review on the socioeconomics of CEA, with significant progress made by late February 2026. Student researchers have contributed to synthesizing economic and social dimensions of CEA, including food systems, and access in rural communities. Findings from this work and modeling plans were presented at the April 6, 2026, full-team meeting and informed the identification of key variables and relationships for integrated modeling. In addition, early discussions have begun on incorporating socioeconomic drivers into system dynamics models, including how to integrate local perspectives alongside biophysical data.

Activity 2.3.1: The team is developing a system dynamics modeling framework informed by an ongoing literature review, with plans to finalize an initial version at the Year 2 all-hands meeting in June 2026. Community feedback will be obtained and incorporated later in the summer and into Year 3.

Activity 2.3.2: A public release of selective project datasets is planned for summer 2026, including industry survey data, kale price data, and county-level datasets for New Mexico (including weather, sunlight exposure, and socioeconomic data). A public release of literature review data and outputs is planned for fall 2026.

Using the kale price data as an example, undergraduate student Galen Osten produced a time-series decomposition of kale prices in the Chicago and New York wholesale markets (in addition to the Los Angeles wholesale market analysis in Year 1), separating trends, seasonal components, and residuals. These findings provide foundational economic insights on volatility, seasonality, and pricing patterns. These are important inputs into modeling work on consumer preferences and production viability.

Activity 2.3.3: Student researchers across two institutions (UNM and UW) have collaborated to estimate crop production functions using experimental data from Objective 1.2 and add socioeconomic components. Student researchers have also developed a draft submodel of optimal kale harvesting under specific environmental conditions (led by PhD student Ziqing Xie) and a draft submodel for optimal pathogen control in CEA systems (led by PhD student Sujaan Aryal). Both submodels are ready to be incorporated into the integrated system dynamics model. Initial modeling framework development will occur this summer, and a fully integrated model is expected to be completed in Fall 2026.

Collaboration and knowledge exchange have also supported progress under Objective 2.3. Beginning in January 2026 and continuing through scheduled cross-training sessions on March 23 and April 13, 2026, the team has created opportunities for students and faculty to share research and build interdisciplinary connections. These sessions have strengthened alignment between the socioeconomics and biophysics teams and have helped define the structure for future integrated modeling efforts. The Socioeconomic Subteam led a dedicated modeling workshop in May 2026 to further refine variables, link sub-models, and advance an integrated framework.

Tabulated Progress: Objective 2.4

Objective 2.4: Regulatory and Policy Analysis of CEA			
Objective 2.4	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Document the existing CEA regulatory and policy framework	*	Continue to document the existing CEA regulatory and policy frameworks in each jurisdiction in collaboration with Objectives 2.1.1 and 2.1.2	Wang (UNM)

* An asterisk indicates that no milestones were planned for that period.

Work related to Objective 2.4 (regulatory and policy analysis of CEA) has been initiated through literature review and ongoing discussions on socioeconomic drivers and barriers. While this objective is scheduled for more intensive development in later project years, current activities have begun identifying key policy-relevant factors, including community perceptions, adoption barriers, and economic feasibility considerations. These early efforts will inform future analyses and ensure that policy considerations are grounded in empirical data collected through surveys and community engagement.

Looking ahead, the team is entering an important implementation phase across all Thrust 2 objectives. During summer 2026, the team will complete beta testing of the Navajo Nation surveys and finalize data management protocols. Full survey deployment will take place in summer 2026, with coordinated efforts across institutions and expanded student involvement to support data collection. The Socioeconomic Subteam advanced integrated modeling through the May 2026 workshop, ensuring that socioeconomic variables are incorporated into broader project models.

Finally, the team has aligned its work with annual reporting requirements and strategic plan tracking. Collectively, these efforts position the Socioeconomics Subteam to deliver meaningful contributions to Thrust 2 while building a strong foundation for data-driven modeling, policy analysis, and community-informed outcomes.

Research Thrust 3: Enhance CEA Workforce Development and Outreach

The Workforce Subteam advanced TRI-CEA's workforce development efforts during this reporting period by focusing on building the foundation for micro-credential development, strengthening cross-institution collaboration, and expanding outreach and engagement activities to support CEA workforce pathways. Activities conducted between Fall 2025 and Spring 2026 reflect coordinated progress across institutions, while also identifying key challenges that are shaping the next phase of implementation.

Tabulated Progress: Objective 3.1

Thrust 3: Empower tribal communities through interdisciplinary training aimed at long-term retention of a highly skilled CEA workforce
• Objective 3.1: Develop CEA micro-credentials at community colleges • Objective 3.2: Establish articulation agreements and provide a cross-institution mentoring and training network • Objective 3.3: Community outreach, education, and collaboration

Objective 3.1	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Design CEA micro-credentials with/for SFCC (proof of skills competency) 1. Food safety 2. Occupational Safety 3. Chemical Handling & Safety 4. Meter & Sensor Operations & Maintenance 5. Data Collection 6. Water quality / nutrient testing & control 7. Hyd. System Maintenance 8. Hyd. Controls Systems 9. Lighting 10. Plant production 11. Pest mgmt. 12. Waste mgmt. 13. Sensor Development 14. Data Analysis	Outline what a credentialing course might look like (existing examples Microscope, safety, small volume measurement); and levels of skill for each Form advisory committee to guide/confirm micro-credential skills testing Work with advisory, university collaborators, tribal entities for any skills missing in the proposed set of micro-credentials. (soft skills? cultural resources?) in coordination with Objective 2.1.1 and 2.1.5 Identify SFCC faculty and resources that can be committed to embedding credentialing in their course(s) Develop assessments for micro-credentials 1-4	Modify existing SFCC CEA curriculum to align with micro-credential assessments 1-4 Integrate assessments 1-4 into existing SFCC CEA curriculum (pilot/test) Use feedback from pilot and advisory to modify/refine assessments 1-4 to fit general CEA curriculum or procedures to modify curriculum to fit micro-credential assessment requirements Develop assessments for micro-credentials 5-8	Frauenglass, Gómez (SFCC)
Activity 2: Implement micro-credential program across community colleges, universities, and participating tribes	UNM plans and leads recruitments trips across state to encourage interest and participation SFCC develops a curriculum for workshops to train micro credential evaluators. SD and WY identify institutions that could provide micro-credentials Identify third-party validation for micro-credentials (CEA Alliance, CEAGlobal, FarmTech Society, Assoc. for Vertical Farming, etc.)	Develop partnerships with other community colleges or summer experiences for micro-credentialing (share curricula, identify faculty and resources, ensure local student interest and tribal participation) Finalize framework for collaboration with SFCC for training others in micro-credential assessment Train instructors at UNM's Engineered Agriculture summer research experience in delivering micro-credentials embedded in the curriculum Workshops to train evaluators at least 2 other institutions for integration of assessments Work with advisory to secure third party validation of micro-credentials 1-4 Observe outcomes from pilot program at SFCC	Green, Hanson (UNM); Frauenglass, Gómez (SFCC); Guadagno (UW); Lombard (NMSU)

Advancement of Objective 3.1 (develop CEA micro-credentials at community colleges) focused on increasing awareness of CEA workforce opportunities and strengthening engagement with industry and community partners. Throughout Fall 2025 and Spring 2026, the Workforce Subteam facilitated discussions during both workforce-specific and full-group TRI-CEA meetings, including the full-group session on March 2, 2026. Engagement with industry stakeholders during this period revealed a critical gap in awareness and understanding of micro-credentials,

with many employers placing greater emphasis on credentials that take longer to earn such as internships, courses, and certificates. This feedback highlighted the need for targeted outreach and education efforts to better communicate the value of micro-credentials, which students can earn quickly, regardless of whether they are able to complete a full degree (or even a course), which is consistent with the realities of teaching at two-year institutions.

The Workforce Subteam has begun developing strategies to engage employers more directly in the validation and implementation of training pathways, while also expanding data collection

Industry Survey Results

Data Summary

Table 1: Demographics by Organization Size

Organization Size	Count
more than 25	6
10-25	4
fewer than 10	3

Table 2: Demographics by Company Focus

Company Focus	Count
Food production	4
Lighting and food production	1
Education	1
Technology development for growing	1
Hydroponic supplies	1
Indoor greenhouse and distribution center	1
Postharvest Technologies	1
food production & technology	1
technology	1
food production and employing underserved population	1

Table 3: Priority Scores by Skill Set

Rank	Skill Set	Average Score
1	plant production	4.00
2	pest management	3.58
3	safety	3.58
4	data handling	3.54
5	Meter Sensor operations	3.46
6	data collection	3.46
7	nutrient management	3.46
8	lighting	3.31
9	soiless systems operations and maintenance	3.23
10	soiless systems control	3.08
11	energy management	3.00
12	water quality testing	2.85
13	waste management	2.42

efforts. The workforce survey, initially distributed in late October 2025, to 37 CEA-related organizations, resulting in 15 responses. The findings indicate that employers prioritize strong foundational horticultural skills, with plant production identified as the most critical competency, followed by pest management, safety, and data handling. Mid-level priorities included meter and sensor operations, data collection, nutrient management, lighting, soilless systems, and energy management, while water quality testing and waste management ranked lower. Overall, the results suggest that employers are seeking technicians with solid production knowledge supported by operational and technical capabilities.

The survey also revealed demand for a “business-savvy technician” who combines horticultural expertise with project management, budgeting, and operational planning. Respondents highlighted gaps in

areas such as controls engineering, robotics, construction knowledge, and supply chain planning, including crop selection aligned with market demand. These findings suggest that workforce training should integrate technical production skills with business and system-thinking competencies.

Finally, the survey showed that internship opportunities remain limited but present opportunities for growth. Approximately one-third of respondents reported active internship programs, often connected to universities or supported through external funding. While some employers recognize certifications such as USDA GAP and OSHA, requirements are not consistent across organizations, indicating a need for flexible, competency-based training pathways aligned with industry needs.

Activity 3.1.1: The efforts to develop CEA micro-credentials at community colleges were grounded in a systematic assessment of workforce needs. Beginning in October 2025, the Workforce Subteam, mostly during our cross-institutional biweekly team meetings, designed and deployed a workforce skills survey to better understand industry demand for both technical and professional competencies. Responses were collected and analyzed between December 2025 and February 2026.

As the Workforce Subteam met with different stakeholders, including the External Advisory Board, faculty members from other academic institutions, CEA business owners, and micro-credentialing organizations, the team also recognized important differences in approach between two-year and four-year institutions. Community colleges, particularly SFCC, emphasized the value of micro-credentials as demonstrations of competency in specific workforce skills, while four-year institutions more often focused on broader credentialing pathways such as courses, certificates, minors, and degree programs. These discussions helped refine the framing of Objective 3.1 activities and highlighted how differing institutional missions and student goals shape workforce development strategies across the TRI-CEA partnership.

Guided by the expertise of Senior Personnel Frauenglass and Co-PI Gómez, the team began refining the suite of proposed micro-credentials outlined in the strategic plan, drawing from existing models such as SFCC's algae curriculum and adapting them for broader CEA applications. SFCC also began exploring how existing CEA curriculum could be modified to align with proposed micro-credential assessments and competency-based evaluation approaches. Initial discussions focused on integrating and piloting assessments within existing SFCC coursework. Concurrently, the team continued discussions around the development of additional assessments associated with future micro-credentials identified in the strategic plan.

As discussions progressed, including key meetings on February 17 and March 3, 2026, the team shifted toward emphasizing transferable skills, such as instrumentation, calibration, and data collection, that can be validated across institutional and industry contexts rather than focusing solely on full credential development (see the next activity for more details). This shift was informed by ongoing challenges related to industry validation, particularly the absence of a centralized CEA credentialing body. In response, the team is preparing to pilot an initial micro-credential focused on calibration and measurement tools (e.g., pH meters, EC meters, water quality instrumentation) at the TRI-CEA all-hands annual meeting in Wyoming on June 22–23, 2026. This pilot will include hands-on assessments and will serve as a scalable model for future credential implementation, including the training of evaluators to ensure consistency across partner institutions.

Activity 3.1.2: Concurrent with these efforts, the team explored opportunities to leverage and adapt existing micro-credential frameworks to accelerate development and ensure relevance. In particular, the group has been in active discussions with the Bioscience Core Skills Institute (BCSI) to seek guidance on the design and implementation of micro-credentials. BCSI is a workforce-development and credentialing organization focused on biotechnology, bioscience, and biomanufacturing careers supported by the greater biotech industry. SFCC has a long relationship with BCSI in the development and evaluation of micro-credentials for applied skills.

BCSI has provided guidance on CEA micro-credential development that will meet the standards of the biotech industry. Several of these micro-credential transfer directly to the CEA -field.

The conversations with BCSI, along with a review of BCSI's existing programs, have informed the team's approach to structuring CEA-related credentials. This exploration has focused on identifying adaptable components that can be integrated into TRI-CEA's objectives while maintaining a strong emphasis on industry-aligned, competency-based outcomes.

The Workforce Subteam has also been conducting outreach to identify potential partners for third-party validation of the proposed micro-credentials. Despite engaging with multiple institutions and organizations, including discussions with Kansas State University and the University of Maine, as well as broader outreach efforts led by the UW to professional associations, no suitable partner with the capacity or interest to provide formal validation was identified. This highlighted a broader gap in the CEA field regarding standardized credentialing bodies and further reinforced the team's shift toward internally validated, competency-based models that can still hold value for employers.

To support long-term program development, PI Guadagno led discussions at UW with faculty and the Associate Dean of the College of Agriculture, Life Sciences, and Natural Resources. These conversations expanded beyond micro-credentials to consider broader academic pathways in CEA, including curriculum development, degree integration, certificates, minors, and future micro-credential opportunities. Discussions also focused on aligning faculty capacity and institutional resources to support sustainable CEA educational programming. This work represents an important step toward institutionalizing CEA education and workforce development opportunities beyond the TRI-CEA project.

Building on these efforts and looking ahead, the team plans to reassess Objective 3.1 at the Year 2 all-hands meeting to ensure continued alignment between the evolving micro-credential strategy and broader project goals. This process will further strengthen the collaborative framework across partner institutions while recognizing SFCC's leadership role in the development and implementation of micro-credentials within the TRI-CEA project. SFCC has made progress in developing a collaborative model for training and assessment, laying the groundwork for broader integration across project activities as the micro-credentials continue to mature. As part of this ongoing effort, SFCC will finalize the collaborative framework for training others in micro-credential assessment during the June All-Hands Meeting in Laramie, Wyoming, where two participants from UW and two participants from USD will receive training to support future implementation and collaboration across institutions.

In the interim, project activities are progressing in parallel to support future integration. During the upcoming year, UNM will focus its summer Engineered Agriculture workshop on enhancing curriculum related to the construction and coding of newly redesigned IoT environmental monitoring devices. These devices will be deployed across TRI-CEA partner institutions as part of a cross-institutional data collection campaign aligned with Objective 1.2. As micro-credentials are finalized, they will be incorporated into this training to support competency-based learning and assessment.

Tabulated Progress: Objective 3.2

Objective 3.2: Establish articulation agreements and provide a cross-institution mentoring and training network			
Objective 3.2	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Establish articulation agreements	Develop and expand relationships between 2-year and 4-year institutions that have potential for developing articulation agreements in CEA. Identify departments and individuals involved at each institution in developing and/or approving articulation agreements. Coordinate with Objective 2.1 to identify tribal colleges that may be interested in establishing articulation agreements	Begin developing articulation agreements, including common course numbering or other factors for educational standards per state, between 2-year and 4-year institutions Begin seeking approval for articulation agreements between 2-year and 4-year institutions	Gómez (SFCC); Lombard (NMSU); Jarchow (USD); Keith (UW); Hanson (UNM)
Activity 2: Build a cross-institution mentoring/feedback network	Identify and recruit mentors from partner institutions, including faculty, graduate students, and industry professionals Establish a framework for mentor-mentee matching based on students' interests and career goals and available mentors Develop expectations for mentor-mentee partnerships regarding meeting frequency, content, and goals Establish initial expectations for mentee and mentor participation	launch the mentorship program with an initial cohort of mentees and mentors Organize virtual or in-person skill-building workshops and networking events to support mentor-mentee partnerships Develop initial feedback frameworks to gather feedback from mentors and mentees Establish a plan to implement feedback in the next cohort Determine if initial expectations were met	Gómez (SFCC); Lombard (NMSU); Jarchow (USD); Keith (UW); Hanson (UNM)

Progress toward Objective 3.2 (establish articulation agreements and provide a cross-institution mentoring and training network) was demonstrated through strengthened collaboration and early development of coordinated workforce pathways. Through regular meetings held from Fall 2025 through Spring 2026, the team engaged partners from universities, community colleges, Extension programs, and industry organizations to align workforce strategies and share resources. Collaborative discussions on January 20 and February 3, 2026, expanded TRI-CEA's network to include national partners such as the Kentucky Horticulture Council and the University of Maine, creating opportunities to exchange best practices and explore joint workforce initiatives.

These collaborative efforts also informed the exploration of multiple workforce training pathways, including internships, registered apprenticeships, and short-term training modules. During the February 3, 2026 Workforce Subteam meeting, internships were identified as a critical entry point into the CEA workforce, while registered apprenticeships emerged as a promising model for structured, paid training aligned with employer-defined competencies. Across all pathways, there was a consistent emphasis on hands-on learning and mentorship, highlighting the importance of integrating academic training with real-world experience. Initial

steps toward a cross-institution mentoring network began in December 2025, including outreach to students and the development of a mentoring survey to better understand participation and needs. These efforts provide a foundation for more formalized articulation agreements and mentoring structures in future project years.

Under Objective 3.2, the TRI-CEA cross-training series has emerged as a key mechanism for workforce development by creating a structured, cross-institutional learning and mentoring environment. These sessions bring together faculty, researchers, and students to share knowledge across disciplines, with a focus on plant physiology, microbial systems, and CEA. Student researchers from UW and USD have led presentations on topics such as environmental controls in plant systems, microbial community dynamics, and community-engaged research, receiving real-time feedback from faculty and peers.

This interactive format has functioned as an applied mentoring model, strengthening students' research communication skills, technical understanding, and confidence. At the same time, students in attendance benefit from observing these exchanges, gaining exposure to critical thinking, scientific dialogue, and collaborative problem-solving. Collectively, these activities are building a skilled, interdisciplinary workforce prepared to advance CEA research and implementation.

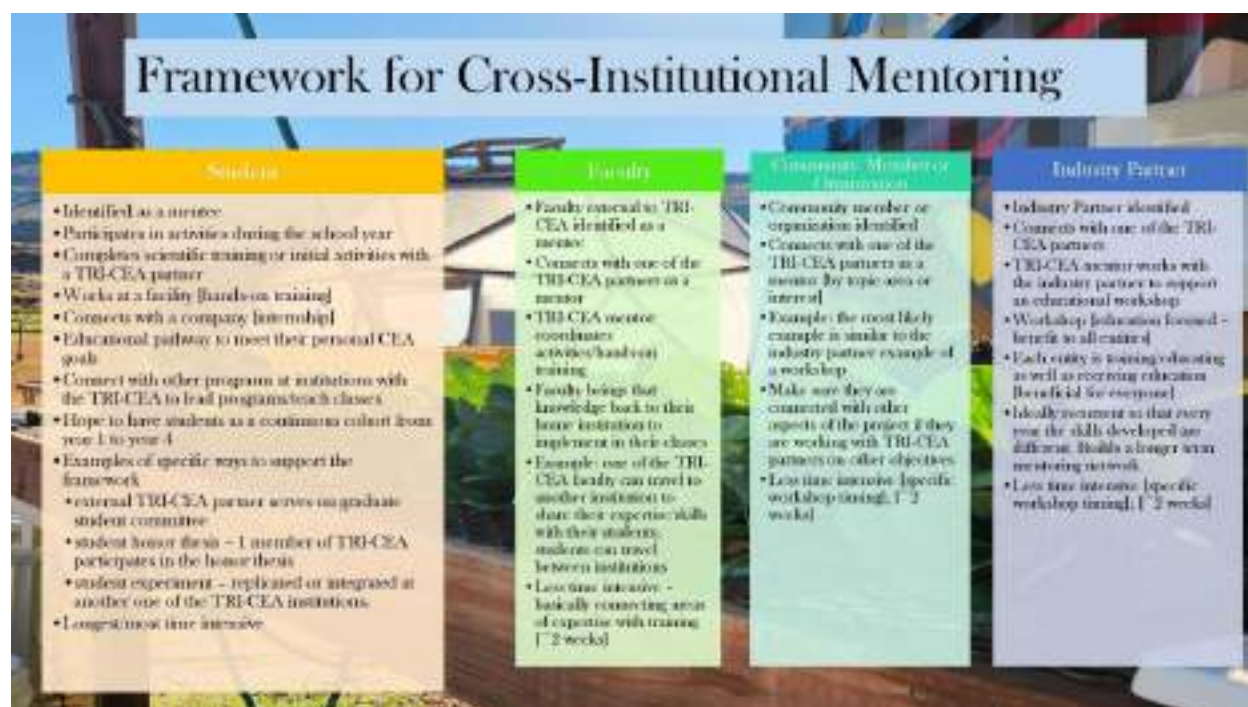
Activity 3.2.1: As described in previous sections of this annual report, workforce-training objectives can vary among different types of higher education institutions. For example, technical colleges often have a strong focus on teaching students skills that are required for immediate job placement within a specified field, whereas many 4-year degrees have a broader focus. Articulation agreements can serve as an effective bridge between associate and bachelor's degrees, allowing students to gain specific technical expertise and broader conceptual understanding in those fields. Articulation agreements also offer pathways for students with associate's degrees to apply those credits toward bachelor's degrees.

Through TRI-CEA our institutions have established and begun establishing articulation agreements between 2-year and 4-year institutions. In Year 2, NMSU has initiated collaborations with its Department of Plant and Environmental Sciences and the College of Agricultural, Consumer, and Environmental Sciences, with formal introductions requested in March 2026 with SFCC. SFCC has also engaged the Agricultural Consumer and Environmental Sciences office of the Associate Dean of Academic Programs at NMSU. USD has provided a letter of support to SFCC indicating interest in establishing an articulation between USD's B.S. in Sustainability and an A.S. in CEA that SFCC is proposing to develop. USD's conversations with Southeast Technical College in Sioux Falls, SD, about developing an articulation agreement between USD's B.S. in Sustainability and Southeast's A.S. in Horticulture Technology have been elevated to conversations that include the Dean and Provost at USD and Southeast, respectively.

Activity 3.2.2: The TRI-CEA team has implemented monthly virtual cross-training sessions based on a Year 1 mentoring framework. These sessions, led by students, support knowledge sharing and relationship-building across institutions. Feedback mechanisms and standard operating procedures have been developed to enhance effectiveness. Additional mentoring resources are

available through institutional programs, and UNM, NMSU, and UW have drafted SOP and mentoring guidelines for staff and interns.

On March 6, 2025, Carmela Guadagno and Jill Kieth collaboratively developed the TRI-CEA mentoring framework, which was subsequently presented to the full project team during a meeting held at the conclusion of the Spring 2025 semester.



TRI-CEA Mentoring framework

NMSU has drafted an expectations guide for Farmington staff and interns, which was reviewed in April 2026. This will pertain to onboarding new interns and staff at the NMSU Farmington Agricultural Science Center (ASC) in general, and expectations of interns and mentoring interns specifically.

Tabulated Progress: Objective 3.3

Objective 3.3: Community outreach, education, and collaboration			
Objective 3.3	Milestones		Responsible parties
	Year 1	Year 2	
Activity 1: Sharing research findings with tribal communities	Determine tribal priorities and guidance for communication through listening sessions Ensure tribal approval for culturally sensitive information, including benefits and drawbacks (in coordination with Objective 2.1.1)	Continue to engage with tribal partners to guide research presentations	Jarchow (USD); Guadagno, Keith (UW); Lombard (NMSU)
Activity 2: ArtScience outreach	*	Collaborate with artists via Shared. Futures ArtScience Fellowship to develop artwork that will be publicly shown in New Mexico	Lin (UNM)

Activity 3: Host community sessions for community to learn about CEA	Plan logistics of initial Q&A sessions in coordination with Objective 2.1.1	Hold initial sessions in coordination with Objective 2.1.1	Jarchow (USD); Guadagno, Keith (UW); Lombard (NMSU)
	Develop content plans for initial sessions in coordination with Objective 2.1.1	Develop feedback forms for participants and community members involved with planning in coordination with Objective 2.1.1	
	Ensure tribal approval for culturally sensitive information, including benefits and drawbacks (in coordination with Objective 2.1.1)	Develop and provide forms to gauge sentiment about CEA before and after the session in coordination with Objective 2.1.1	
	Develop educational materials to be shared at sessions– work with Cooperative Extension. Include example CEA set-up	Integrate feedback into plans for following sessions Host community sessions in at least 2 communities	
Activity 4: Deploy free CEA systems in tribal schools and communities	Identify and contact tribal schools and organizations interested in hosting CEA systems in coordination with Objective 3.3.3	Identify recipients of at least 5 free additional CEA systems in coordination with Objective 3.3.3	Jarchow (USD); Guadagno, Keith (UW); Lombard (NMSU); Gómez, Shultz (SFCC)
	Develop an equitable system to disseminate materials to inform the community about the opportunity	Continue disseminating information about and encouraging interest in the lottery for CEA systems	
	Organize a system to assist communities with their CEA set-up	Engage support for CEA operation to ensure success	
	Have at least 1 CEA system established with a tribal school or community organization	Develop a follow-up framework to learn about communities' experiences with their CEA set-up Have at least 5 additional CEA systems established with a tribal school or community organization	

* An asterisk indicates that no milestones were planned for that period.

Activity 3.3.1: Under NNHRRB protocol NNR-26.574, the Navajo Nation has established a framework for data sharing, including biannual conferences, reporting requirements, and eventual transfer of all project data to the Nation. Project personnel are also engaging in Indigenous data sovereignty training, including participation in the 2026 U.S. Indigenous Data Sovereignty Governance Summit.

Activity 3.3.2: ArtScience outreach is currently delayed but is expected to progress in Year 3 once project outputs are ready for dissemination through partners such as Explora Science Center and Children's Museum of Albuquerque.

Activity 3.3.3: NMSU Farmington has conducted extensive outreach through multiple events, including a field day with over 250 attendees, K–5 educational programming reaching approximately 400 students, and a May 16, 2026 plant sale and open house featuring TRI-CEA programming. Additional efforts include the Seeds of Change teacher program and ongoing integration of community feedback.

USD advanced workforce development and community outreach initiatives through the installation of two hydroponic systems at the Akeley Lawrence Science Center, creating opportunities for experiential learning and educational programming. Working alongside Sicangu Co (<https://www.sicangu.co/>) and the Boys & Girls Club of Rosebud, USD contributed to the development of a youth-focused hydroponics program that combines practical training in hydroponic production and system management with introductory business and entrepreneurial skills. USD also supported regional conversations around sustainable agriculture and food sovereignty through engagement with the 2025 South Dakota Local Food Conference and the 2025 Sicangu Food Summit.



Denyse Ute (UW Graduate Student) - Conference presentation

SFCC and partners have expanded educational outreach by distributing hydroponic systems to 43 schools and training 54 teachers. Additional collaborations include Navajo Technical University, Mariano Lake Chapter House, Navajo Preparatory High School, and NMSU Grants Campus, further strengthening regional engagement.

Activity 3.3.4: During the summer of 2026, UNM will collaborate with SFCC and NMSU to purchase hydroponic CEA systems under the guidance of SFCC. SFCC and NMSU will host community outreach events for rural schools and community organizations to disseminate information about CEA systems, encourage participation in the system lottery process, and identify eligible recipients for at least five additional free CEA systems. These events will also serve as opportunities to increase awareness of controlled environment agriculture and expand community engagement across rural regions. Following recipient selection, SFCC and NMSU will provide training and technical guidance on the assembly, operation, and maintenance of the CEA systems to support successful implementation and long-term use. In addition, the team will develop a follow-up framework to better understand participants' experiences with their CEA set-up, identify ongoing support needs, and inform future community engagement and workforce development efforts.

Summary of Research Thrust 3 (enhance CEA workforce development and outreach): Overall, the Workforce Subteam has made substantial progress between Fall 2025 and Spring 2026 in establishing the foundational elements necessary to support a skilled CEA workforce across Objectives 3.1–3.3, including workforce needs assessment, partnership development, and initial training design. While challenges related to credential validation and industry alignment have emerged, these insights have informed a more adaptive and targeted approach moving forward. Efforts in Summer 2026 and beyond will focus on piloting micro-credentials, expanding internship and apprenticeship pathways, and strengthening industry engagement to ensure that TRI-CEA workforce initiatives are both relevant and impactful.

Education

Education and research integration has been a central component of the TRI-CEA project, with activities intentionally designed to embed learning opportunities across all three research

thrusters. Undergraduate students, interns, and early-career researchers have been actively engaged in hands-on research, including hydroponic system deployment, environmental monitoring, microbial analysis, and socioeconomic data collection. For example, multiple undergraduate interns at NMSU and UNM have contributed to data collection and cross-institutional coordination, while students at UW have supported laboratory analyses, modeling efforts, and literature synthesis. Educational programming is tightly coupled with research activities, including an 8-week summer research experience and upcoming IoT-focused workshops where students, including community members such as farmers, will design and test sensor technologies used in project experiments. Outreach and dissemination efforts have been extensive, reaching broad audiences through K–12 programming (~400 students), training of 74 educators, community workshops, rural engagement sessions, and large-scale events, including field days with over 250 participants. Additionally, distribution of hydroponic systems with partners to 48 schools and ongoing community partnerships have further expanded access to CEA knowledge. Together, these efforts demonstrate a strong integration of education and research that supports workforce development while broadly disseminating project findings to academic, community, and industry audiences.

As part of its outreach and educational activities, NMSU will utilize a USDA-supported elementary teacher development initiative (USDA-NIFA 2025-69018-45077) during Summer 2026 to introduce 20 educators from 11 rural schools to CEA concepts and applications. Working alongside UNM, the project team will also coordinate a randomized selection process through which participating schools may be awarded one of five hydroponic CEA systems. These systems will be incorporated into classroom and community-based STEM learning activities, with implementation and instructional support provided by TRI-CEA personnel.

Solicitation-Specific Project Elements

Research Capacity and Jurisdictional Impacts

USD has strengthened its research capacity by successfully hiring Dr. Guillermo Marcillo as a tenure-track assistant professor, with a significant portion of his role dedicated to research. This addition expands institutional capacity in sustainability and controlled environment agriculture (CEA)-related work. In response to recommendations from the TRI-CEA External Advisory Committee, USD has also increased its research focus on the business dimensions of CEA. TRI-CEA-funded PhD candidate Glen Marshall has contributed to this effort by collaborating with Dr. Rand Wergin to integrate business expertise into CEA research. Additionally, USD leveraged TRI-CEA funding to support participation in a National Science Foundation EPSCoR E-CORE proposal, demonstrating how the project is being used to expand research opportunities and competitiveness.

The UNM team has been collecting preliminary and baseline data using the instruments and methods planned for an upcoming cross-institutional campaign. Across participating institutions, findings indicate that heterogeneity in environmental conditions, both within and between hydroponic systems, is an uncontrollable but significant factor that should be

incorporated into modeling efforts. The team noted that additional figures illustrating these findings could be provided for reporting purposes, with particularly strong datasets currently available from UW's lab.

Shaun McKinley, a first-year undergraduate at UNM, has contributed significantly to maintaining hydroponic systems and collecting data throughout the year. His efforts have strengthened UNM's research capacity, enabling the institution to actively participate in the upcoming fall cross-institutional campaign. His role has been particularly important in ensuring consistent system monitoring and data collection. Jade Whiting also supported UNM's research capacity during the spring semester by assisting with hydroponic system setup and data collection while renovations were underway at the SFCC greenhouse. Her prior experience in CEA systems contributed to the continuity and quality of research activities. Early-career faculty development has also been strengthened through new hires and cross-institution mentoring and training networks.

Through its involvement in TRI-CEA, USD has developed a strong working relationship with Sicangu Co, enhancing its engagement with rural communities. Participation in and sponsorship of events such as the South Dakota Local Food Conference and Sicangu Food Summit have contributed to increased local food capacity and food sovereignty efforts across South Dakota.

For SFCC, understanding the microbiome within aquaponic systems has become increasingly important. Regulatory agencies have consistently requested microbiome-related data as part of the approval process for aquaponics produce, yet SFCC has had limited internal capacity to address this area independently. Collaboration with UW and UNM has significantly advanced this effort by expanding access to expertise, research capacity, and technical support. This partnership has strengthened SFCC's ability to engage in microbiome-related research and respond more effectively to emerging regulatory and industry needs.

Development of STEM Workforce and Early Career Faculty

UNM will offer a newly developed workshop titled *IoT for CEA* during June and July 2026 on the UNM main campus. The workshop will focus on building Internet of Things (IoT) skills applicable to controlled environment agriculture (CEA) while advancing the design of environmental monitoring devices intended for deployment across TRI-CEA partner institutions. The updated device platform will support the collection of spatial environmental data within and between hydroponic systems, an identified challenge within the biophysics research group. In collaboration with CNM Tech Solutions Lab, the team is redesigning previously used devices to enable cloud connectivity via cellular networks, improving flexibility for off-campus applications and expanding accessibility for remote participants by addressing limitations of prior Wi-Fi-dependent designs. The 2026 workshop will emphasize the development and testing of a scalable curriculum and IoT device platform that can be readily shared across institutions and programs. Selected participants (1–2 individuals) will design research projects using the newly developed devices, generating data that will serve both as a teaching resource during the workshop and as a testing mechanism prior to distribution to TRI-CEA collaborators in Fall 2026.

Additionally, participation in the summer Engineered Agriculture research experience will further prepare attendees to train others, supporting the future expansion of in-person satellite workshops in rural and geographically distant communities beyond Central New Mexico.

NMSU will leverage a USDA-funded (USDA-NIFA 2025-69018-45077) elementary teacher training program this summer to train 20 teachers from 11 rural schools on CEA. Together with UNM, the team will establish a lottery program (i.e., by a random drawing among interested applicants) for the community school participants to apply for free CEA hydroponic systems (5 available this year) to be deployed in their schools for STEM and CEA education with the assistance of the project team.

USD has expanded workforce development efforts through both institutional partnerships and community-based programming. Engagement with the South Dakota Biotechnology Association has supported proposal development and ongoing discussions around CEA opportunities within the state. Additionally, USD established new connections with Southeast Technical College leadership to explore an articulation agreement between their Horticulture Technology program and USD's Bachelor of Science in Sustainability, strengthening educational pathways.

USD installed two hydroponic systems within the Akeley Lawrence Science Center, which serve as platforms for student education and outreach. USD also supported broader workforce and community engagement through sponsorship of the 2025 South Dakota Local Food Conference and the 2025 Sicangu Food Summit, reinforcing its role in advancing local food systems and food sovereignty.

USD, in collaboration with Sicangu Co, worked with the Boys & Girls Club of Rosebud to develop and offer a teen hydroponics training program. This program provides hands-on training in hydroponic system operation, maintenance, and development, while also incorporating business planning skills to prepare youth for future workforce participation in CEA-related industries.

Laura Green's six-week course represents an important pathway for continued workforce development by providing participants with practical skills and improved methods applicable to controlled environment agriculture (CEA) and related industries. These experiences help participants build transferable workforce competencies that can support current employment opportunities as well as future career advancement. Complementing this effort, the development of micro-credentials has emerged as a particularly impactful strategy for supporting employability, especially within rural communities where flexible, skills-based training opportunities can provide meaningful workforce access. Information gathered through workforce and employer surveys helps guide the development of curricula, workshops, and training activities to better align with identified industry needs and employer expectations. Collectively, these efforts are also increasing awareness of CEA systems as a viable approach for workforce development, economic opportunity, and sustainable food production in arid and underserved communities.

Yolanda Lin, an assistant professor at UNM and Co-PI on the TRI-CEA project, successfully submitted her tenure package in Fall 2025. This milestone reflects the project's role in

supporting the professional development and advancement of early career faculty through leadership opportunities, collaborative research, and cross-institutional engagement. A major advancement in this area is the hiring of Dr. Guillermo Marcillo as a tenure-track assistant professor. His appointment significantly enhances USD's capacity for research and education in sustainability and CEA-related fields. This directly supports research capacity-building objectives focused on faculty development and long-term institutional strengthening.

Interjurisdictional Collaborations and Overall Project Integration

Interjurisdictional collaborations continue to strengthen coordination and engagement across all TRI-CEA partner institutions. The full project team meets monthly to support communication, alignment of activities, and cross-institutional planning. In addition, the three primary subteams—Biophysics, Socioeconomics, and Workforce Subteams—meet either biweekly or every three weeks to advance objective-specific activities and maintain project momentum. These meetings also serve as cross-training opportunities, allowing faculty, staff, and students from multiple campuses to share expertise, discuss challenges, and provide updates on ongoing work. Participation in both the full-group and subgroup meetings has remained strong across all partner institutions, reflecting a high level of collaboration and engagement throughout the project.

Shaun McKinley, a UNM undergraduate student, has facilitated stronger collaboration between UNM and NMSU. Through funding from NMSU, he is working with collaborators in Farmington including Kevin Lombard and Tionna Tapaha during academic breaks and the summer. This cross-institutional engagement has improved communication and coordination between the two institutions.

Jade Whiting's experience working across multiple institutions, including UW and SFCC, has supported collaboration by helping to share knowledge and practices between sites. Her involvement has contributed to stronger connections among TRI-CEA partner institutions.

Student researchers across UNM (Ziqing Xie and Sujaan Aryal) and UW (Isaiah Spiegelberg and Isaac Eastlund) have collaborated to estimate crop production functions and cost functions using experimental data from Objective 1.2 and socioeconomic data collected under Objective 2.3. Parallel, PI Wang (UNM) is serving on the thesis committee for UW Master's student Isaiah Spiegelberg.

Initial development of the integrated CEA modeling framework will occur this summer, with dedicated time at the Year 2 all-hands meeting for the full team to collaboratively work on it. A fully integrated model is expected to be completed in Fall 2026.

USD and SFCC have deepened their academic program collaborations. USD has provided a letter of support to SFCC indicating interest in establishing an articulation between USD's B.S. in Sustainability and an A.S. in CEA that SFCC is proposing to develop. Ongoing collaboration contributes to overall project integration goals, which emphasize sustained multi-state coordination.

Both Shaun McKinley and Jade Whiting have contributed to overall project integration by supporting alignment of practices and coordination across institutions. Jade Whiting's experience at both UW and SFCC has been particularly valuable in sharing and standardizing hydroponic system protocols across sites. Additionally, Shaun McKinley brings an important perspective as a member of the Navajo Nation, contributing to the project's broader goal of integrating diverse perspectives and strengthening community relevance within TRI-CEA activities.

All five institutions have actively contributed to TRI-CEA's overall project integration through consistent participation in regularly scheduled meetings, full-group convenings, and cross-training sessions. These activities have facilitated collaboration, coordination, and knowledge exchange across institutions and project components. This aligns with cross-cutting integration activities that support coordination across Thrusts 1, 2, and 3, ensuring cohesive project implementation.

Broadening Participation

Involvement of elementary schools, high schools, colleges, rural researchers, and first-generation college students was evident throughout Year 2. Partnerships with organizations, workforce centers, and advisory members strengthened this focus.

For example, USD's efforts have engaged a wide range of participants, including elementary school students through Boys & Girls Club programming, high school students through the teen hydroponics training program, university students, rural communities, and participants in statewide events and networks. This multi-level engagement demonstrates a comprehensive approach to expanding access and participation in CEA-related education and workforce opportunities.

Evaluation

The Year 2 External Evaluation Report was provided to the TRI-CEA project on May 27, 2026 and describes TRI-CEA as a project making strong progress as a multi-institutional, transdisciplinary research effort. The evaluator highlights the team's continued momentum, progress toward Year 2 goals, and development of a cohesive collaborative network across institutions, disciplines, faculty, students, and community-engaged work. The report emphasizes that the strong relationships and meaningful progress built in Years 1 and 2 position the team well to navigate the expected challenges of transdisciplinary research.

At the same time, the evaluation identifies several areas needing focused attention as the project moves into Year 3. These include strengthening student integration across institutions, improving coordination across research teams and data streams, increasing cross-disciplinary understanding, preparing the team for community-engaged work, and developing a clearer shared narrative for how the three research thrusts converge.

Key strengths identified for TRI-CEA:

- *Strong collaboration network:* The overall TRI-CEA network is fully connected, with no isolated members or subgroups, and strong cross-institutional ties are visible across all five partner institutions.
- *Effective research team structures:* The three research teams (Biophysics, Socioeconomics, and Workforce) meet regularly, maintain good attendance, use advance agendas, and share meeting notes; faculty overwhelmingly rated the meetings as effective or very effective.
- *Meaningful student development:* Students reported gaining skills in hydroponic systems, data collection and analysis, ArcGIS, dynamic modeling software, mixed methods, scientific communication, IRB processes, and cross-institutional collaboration.
- *Strong alignment with student academic and career goals:* Nearly all students described their TRI-CEA experience as relevant to their academic and professional goals, with many connecting it directly to thesis or dissertation work.
- *Faculty relationship-building and capacity growth:* Faculty described gains in relationship development, disciplinary broadening, and technical skills, with concrete outputs including co-designed surveys, a socioeconomic literature review, and new working relationships.
- *Commitment to Indigenous data sovereignty and tribal self-determination:* The report notes that TRI-CEA demonstrates respect for tribal self-determination and approaches CEA implementation as involving relational, cultural, and technical considerations.

Key challenges identified for TRI-CEA:

- *Student cross-institutional ties need strengthening:* Student connections are broad but often low-intensity, and high-intensity student relationships are concentrated within institutions rather than across them.
- *Coordination remains challenging across teams and sites:* Research teams reported challenges with aligning institutional roles, integrating data streams, coordinating protocols, and sustaining consistent participation.
- *Cross-disciplinary understanding is uneven:* Faculty confidence is stronger in technical areas than in community- and workforce-facing areas, and student familiarity with the Socioeconomics team's work is especially limited.
- *Community-engaged work requires continued preparation:* Faculty are not yet broadly familiar with the basics of research with tribal communities, and community perceptions of CEA and priorities are still being clarified.
- *Convergence strategy needs attention:* Faculty expressed uncertainty about whether the project's broad scope can converge into publishable outcomes within the four-year timeline.
- *Micro-credential development remains complex:* The micro-credential initiative faces challenges due to the absence of industry validation structures and limited stakeholder familiarity with credential-based pathways.

In response, the TRI-CEA team plans to take the following actions:

- Dedicate time during the All-Hands Meeting in Summer 2026 for the three subteams to advance key coordination priorities, including protocol alignment for Biophysics, data integration planning for Socioeconomics, and near-term micro-credential validation planning for Workforce
- Conduct a mid-project scope review in Fall 2026 to assess whether current activities remain aligned with feasible project deliverables and to update the strategic plan as needed
- Schedule a series of meetings in the coming year to further discuss the evaluation report, develop strategies for responding to key recommendations, and ensure that the team continues to retain and build upon its existing strengths.

The TRI-CEA team would also like to note two important contextual considerations. First, current funding levels do not support full participation by all project members in all project-wide activities. For example, USD does not have sufficient travel funding budgeted for all participants to attend out-of-state all-hands meetings. As a result, the team will need to be strategic in prioritizing participation and engagement opportunities.

Second, the team would like to clarify that engagement with rural communities, especially tribal partners, must be approached thoughtfully and intentionally. While increasing team understanding of community-engaged research with local communities is important, direct engagement with tribal partners should not be expected of every project member. Relationship building requires trust, continuity, and respect for tribal partners' time and priorities. TRI-CEA team members who already have established relationships are proceeding carefully and deliberately to ensure that engagement remains respectful, appropriate, and aligned with community needs.

Overall, the evaluator emphasized that TRI-CEA's challenges are typical of complex transdisciplinary projects and should be viewed as expected components of collaborative, community-engaged research rather than indicators of project weakness. The report repeatedly notes that TRI-CEA has built a strong foundation of trust, communication, and cross-institutional collaboration that many multi-state initiatives struggle to achieve. The report concludes that TRI-CEA is well-positioned for a strong finish if Year 3 continues to focus intentionally on coordination, cross-disciplinary understanding, student integration, and the development of a clear shared narrative connecting the Biophysics, Socioeconomics, and Workforce components into a cohesive whole.

Special Conditions

Special conditions do not apply to the TRI-CEA project.

Expenditures And Unobligated Funds

Over the collaborator sites, funding uncertainties in Year 1 and early Year 2 shifted institutional processes leading to delayed spending. University of New Mexico and New Mexico State University will be able to hit programmatic spending targets by the end of Year 2, August 31, 2026. Because both UNM and NMSU incorporated their heaviest program spending as part of summer education and training and experiment implementation, spending won't be reflected in account reporting until August.

University of Wyoming

Last year the Wyoming Research Office, facing uncertainty in funding during the early part of the year, chose to delay advertising the Postdoc position and proceed cautiously with new hiring until the situation became clearer. Currently the call is open, and interviews will be starting in June 2026 – 42 applications have been received.

UW expects to reach between 48% and 50% of direct costs for Year 2 by August 31st, equal to ~\$505,000. So far, we have spent 38%, equal to ~\$360,000. A breakdown of summer 2026 expenses looks like: \$88k instrumentation (new models available for cameras); \$22k faculty summer salaries; \$12k undergraduates' salaries; \$12k summer salaries for grad students; \$30k Postdoc (3 months & moving expenses); \$11k in materials and supplies for summer experiments. Additional amounts will be spread over the future salaries' months for the same so far missing personnel to ensure that the workload from year one/two will be achieved without delays.

University of South Dakota

As was the case with UW, the uncertainty that occurred during Year 1 of the project affected USD's spending in Year 2 of the project. The largest shortfall in spending occurred because USD was delayed 1 year in hiring a new tenure-track faculty member whose salary and start-up funds will be paid by the TRI-CEA grant. USD had a failed search in Year 1, repeated the search in Year 2, and had a successful outcome. Dr. Guillermo Marcillo was hired, and he will be starting in August 2026. USD had budgeted for the TRI-CEA grant to fund Dr. Marcillo's salary at 100% in Year 2, which will now be shifted to Year 3. The second largest shortfall in spending occurred with the subaward to Sicangu Co, whose funding is being used to pay part of a staff member's salary and materials and supplies for their outreach. The staff member left Sicangu Co, and their position was vacant for a significant period of time. This delayed Sicangu Co's spending, but the work on TRI-CEA has continued, and Sicangu Co has a plan to catch up from the funding delay.

USD expects to reach ~45% of the total award for Years 1 and 2 by August 31st, which is equal to ~\$204,000. Anticipated spending that is not reflected in the current budget include Jarchow's summer salary, a graduate student stipend, travel to the all-hands meeting and professional meetings, and Sicangu Co staff and outreach activities.

Appendix A. Summarized List of Accomplishments.

Summarized List of Accomplishments

Revised to include the name associated with each accomplishment and complete, concise summaries.

Type	Name	Institution	Research Thrusts	Complete Summary
Grant	Meghann Jarchow	USD	Socioeconomics	E-CORE: Biotechnology and Beyond - Broadening Participation and Driving Growth in South Dakota, grant, NSF, pending, submitted 15 July 2025, \$10M
Grant	Meghann Jarchow	USD	Socioeconomics	NSF E-CORE - Collaborative Research: Research Infrastructure: E-CORE: Biotechnology and Beyond - Broadening Participation and Driving Growth in South Dakota None, but this will build upon the capacity that we are building with the TRI-CEA grant
Grant	Meghann Jarchow	USD	Workforce Development and Outreach	SSTEM: Facilitating STEM student success: Recruitment, mentoring, and career readiness University of South Dakota; NSF; not awarded; \$750,000. The dates would have been 9/2025 to 8/2031
Collaboration	Meghann Jarchow	USD	Workforce Development and Outreach	Partnered with the Boys & Girls Club of Vermillion to do youth education about growing plants hydroponically. Started April 2025, ended September 2025; Vivian Omondi and Glen Marshall were the TRI-CEA participants
Collaboration	Meghann Jarchow	USD	Workforce Development and Outreach	Partnered with the Vermillion Area Community Garden to help build local food capacity in Vermillion. Started May 2025, ended August 2025; Vivian Omondi and Glen Marshall were the TRI-CEA participants
Collaboration	Meghann Jarchow	USD	Workforce Development and Outreach	The team expanded collaborations with the Boys & Girls Club of Vermillion. The team has been working with them to do hydroponic plant demonstrations/education. They expanded this effort by seeking and receiving a \$5000 grant from the Dakota Hospital Foundation.
Product	Glen Marshall	USD	Socioeconomics	These were conference abstracts/presentations, and TRICAE support was acknowledged at the 65th Mountain Plains Business Conference, October 17-18, 2025.
Product	Glen Marshall	USD	Socioeconomics	The product was the presentation and its slides. "Barriers and Opportunities in Underserved Markets: Insights for Sustainable Business and Social Entrepreneurs" Presented at the Beacom Scholar Series, February 2, 2026. which covered mixed methods research aimed at sustainable consumption and its barriers, with special emphasis on rural, indigenous communities in the Great Plains.
Collaboration	Jingjing Wang	UNM	Socioeconomics	The team helped with recruiting volunteers and providing CEA consulting for participating middle schooler teams. PI Wang was invited to be a keynote speaker and talked about CEA for communities at the award ceremony. Contributed to collaborative outreach and K-12 education. The collaboration was initiated in August 2025 and lasted till January 2026. The competition event was held at UNM on January 27, 2026.
Grant	Jingjing Wang	UNM	Socioeconomics	Middle Rio Grande Conservancy District: Agricultural water users' preferences for water conservation programs in the Middle Rio Grande Basin. Awarded. 07/01/2025 – 07/31/2026, \$51,887.
Product	Ziqing Xie Lead & Jane Sawerengera Co author	UNM	Socioeconomics	Co-created poster for UNM Economics Research Day. Partially funded by the grant. Nov 14, 2025, - Econ Research for a better new Meico, ARiD Research Symposium Nov 14, 2025, Nov 15, 2025 - NM research symposium, October 17, 2025, CWE Mini Conference, Jun 21, 2026 AHM TRI-CEA, July 26 - 28 2026, Agricultural & Applied Economics Association
Product	Ziqing Xie	UNM	Socioeconomics	Title: A Dynamic Bioeconomic Model for Aquaponic Farms. Acknowledged TRICEA grant. Presented poster "A Dynamics Bioeconomic Model for Aquaponic Farms" at UNM Discovery Week, Fall 2025, Center for Water and the Environment (CWE) Mini-Conference, Economic Research for a Better New Mexico, ARID Research Symposium, and New Mexico Symposium. First prize award at ARID Research Symposium. Judges' Favorite award at Fall 2025 Center for Water and the Environment (CWE) Mini-Conference.
Grant	Kevin Lombard	NMSU	Socioeconomics	Lombard, K. A (Principal), Ornelas, I (Co-Principal) AFRI PDAL Program, Seeds of change: Training elementary educators to implement the Yéego! healthy eating and gardening program. Awarded

Type	Name	Institution	Research Thrusts	Complete Summary
				Sept 15, 2025, \$499,334.00 3/ years. Federal United States Department of Agriculture National Institute of Food and Agriculture Award Number: 2025-69018-45077
Grant	Kevin Lombard	NMSU	Socioeconomics	Vitale, P. (Principal), Heerema, R. (Co-Principal), Lombard, K (Co-Principal). Delgado, E (Co-Principal), Sapkota, G. (Co-Principal) “. Foundational Research on Yellowhorn (Xanthoceras sorbifolium) as a Drought-Resilient Production System for Arid Agriculture," USDA AFRI, \$735,953.00, Submitted September 2025. Status: Currently Under Review
Grant	Kevin Lombard	NMSU	Socioeconomics	Salmasi, S. Z. (Principal), Loest, Clint (Co-Principal), Lombard, K. A. (Co-Principal), "Sustainable Medicinal Forage for Sheep and Goats Production in Northern New Mexico," Western SARE Pre-Proposal, \$350,000.00, Status: Currently Under Review, Effective Start Date: 2025. Letter of Intent submitted. Invited for full proposal due in March 2026. Western Sustainable Agriculture Research and Education (WSARE). SARE is supported by the Sustainable Agriculture Research and Education (SARE) program under a cooperative agreement with the University of Maryland, project award no. 2024-38640-42986, from the U.S. Department of Agriculture's National Institute of Food and Agriculture
Grant	Kevin Lombard	NMSU	Socioeconomics	Sanyal, Debankur (Principal), Lombard, K. A. (Co-Principal), Das, Srabani (Co-Principal), Tronstad, Russell (Co-Principal), Halldorson, Matt (Co-Principal), Mukherjee, Avik (Co-Principal). "Soil Health Assessment and Economic Evaluation of Biochar Use in the Southwest Agriculture," Western Sustainable Agriculture Research and Education (WSARE) Full-proposal, \$350,000.00, Description: Full-proposal stage, Status: Currently Under Review, Effective Start Date: August 2026.Full proposal submitted in March 2026. Western Sustainable Agriculture Research and Education (WSARE). SARE is supported by the Sustainable Agriculture Research and Education (SARE) program under a cooperative agreement with the University of Maryland, project award no. 2024-38640-42986, from the U.S. Department of Agriculture's National Institute of Food and Agriculture
Product	Tionna Tapaha	NMSU	Socioeconomics	Products the team created were with summer interns and included a fact sheet and a poster. The fact sheet was revised in December 2025 and used during community meetings to obtain Chapter House Resolutions/letters of support for IRB approvals at NMSU and Navajo Nation.
Collaboration	Kevin Lombard	NMSU	Socioeconomics	Received the hydroponic systems and assembled them on Jun 20, 2025. NMSU received a hydroponic system from Santa Fe Community College (SFCC) on June 20, 2025. With the SFCC team, the system was assembled in the ASC Farmington Greenhouse.
Collaboration	Lois Stanford	NMSU	Socioeconomics	The team have developed the three surveys: Producer, Consumer, and Community Organization over the Summer 2025. The student hires (Brandon Francis, Tionna Tapaha, and Sarrah Trujillo) have attended Navajo chapter house meetings to discuss the project and upcoming surveys. The NMSU Agricultural Experiment Station in Farmington, under the direction of Dr. Kevin Lombard, hosted a field day in summer 2025 and introduced the project. The steps to obtain NMSU and Navajo IRB are complicated. the team have completed the pieces and are working on the IRB sections, with plans to submit, September 2025. Surveys will take place during Fall 2025, later than planned, but well within the target to complete by mid-2nd year of the project.
Poster	Sarrah Trujillo/Shawn McKinley/Tionna Tapaha/Kevin Lombard	NMSU	Socioeconomics	Collaborative Research: RII FEC: Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth, Poster presentation, New Mexico EPSCor, New Mexico Research Symposium. 2025-11-15 00:00:00
Outreach	Kevin Lombard, Tionna Tapaha, Brandon Francis	NMSU	Socioeconomics	Outreach, ASC Farmington K-5th grade Farm Day, September 25 - Oct 9, 2025, NM. Four schools 3rd-5th grade; about 400 youth. 5-6 educational talks and pumpkin giveaway. Agricultural science center at Farmington
Outreach	Kevin Lombard/Brandon Francis	NMSU	Socioeconomics	Upper Fruitland Chapter House, NM December Chapter House Meeting Dec 16, 2025, Overview of TRI-CEA and chapter house resolution for IRB submission
Outreach	Kevin Lombard/Brandon Francis	NMSU	Socioeconomics	Gadii'ahi/To K'oi Chapter House, August Chapter Meeting Dec 11, 2025. Overview of TRI-CEA and chapter house resolution for IRB submission
Outreach	Kevin Lombard/Brandon Francis	NMSU	Socioeconomics	Shiprock Chapter House, NM December Chapter House Meeting Dec 10, 2025, NM. Overview of TRI-CEA and chapter house resolution for IRB submission

Type	Name	Institution	Research Thrusts	Complete Summary
Outreach	Kevin Lombard/Brandon Francis	NMSU	Socioeconomics	Nenahnezad Chapter House, NM December Chapter House Meeting Dec 8, 2025. Overview of TRI-CEA and chapter house resolution for IRB submission
Outreach	Kevin Lombard/Brandon Francis	NMSU	Socioeconomics	Navajo Nation Farm Board Association, Many Farms Chapter House, AZ meeting Nov 20, 2025, Overview of TRI-CEA and chapter house resolution for IRB submission
Outreach	Kevin Lombard/Brandon Francis/Tionna Tapaha	NMSU	Socioeconomics	Shiprock Ag Days, Shiprock, NM April 7, 2026, Tabling event in representation of the ASC Farmington activities, including TRI-CEA. About 70 people present.
Collaboration	Brandon Francis/Tionna Tapaha	NMSU	Socioeconomic/Workforce Development and Outreach	Farmington Municipal Schools (FMS) Native American STEM Festival. Wed, April 22, 2026. Hands on activity with about 300 k-12 students.
Outreach	Kevin Lombard and others	NMSU	Socioeconomic/Workforce Development and Outreach	NMSU College of Agricultural, Consumer, and Environmental Sciences Open House, Las Cruces, NM. Tabling event on ASC Farmington activities, including TRI-CEA. April 25 2026
Collaboration	Brandon Francis/Tionna Tapaha/Kevin Lombard	NMSU	Socioeconomic/Workforce Development and Outreach	NMSU ASC Farmington Open House, Farmington, NM. Friday May 15, 2026. Hands on demonstration of hydroponic and greenhouse. Tabling event on ASC Farmington activities including TRI-CEA.
Poster Presentation	Tionna Tapaha, Shaun McKinley, and Kevin Lombard	NMSU	Biophysics/Socioeconomics/Workforce Development and Outreach	T. Tapaha, B. Francis, S. McKinley, S. Trujillo, K. L. Stanford, B. Francis, and K. Lombard (2026). Harnessing Controlled Environment Agriculture (CEA) to Secure Sustainability and Economic Growth: Tri-CEA. New Mexico Water Resources Research Institute (WRRI) 2026 Animas and San Juan Watersheds Conference, San Juan College, Farmington, NM. May 27-28, 2026. Poster Presentation WRRI Conference in the Animas and San Juan Watersheds
Oral Presentation	Brandon Francis, Emiliano McLane, Karletta Chief, Wilzave Guzman, William Norris, Kevin A. Lombard	NMSU	Socioeconomics	Brandon Francis, Emiliano McLane, Karletta Chief, Wilzave Guzman, William Norris, Kevin A. Lombard (2026). Four Corners Indigenous Farm Assessment: Soil, Land-use, Controlled Environment Agriculture and COVID-19 Impacts on Navajo farmers in the San Juan River Valley. New Mexico Water Resources Research Institute (WRRI) 2026 Animas and San Juan Watersheds Conference, San Juan College, Farmington, NM. May 27-28, 2026. Poster Presentation WRRI Conference in the Animas and San Juan Watersheds. Northwest Ag Restoration Project, Transformation Network and Tri CEA
Poster Presentation	Lois Stanford and Sarrah Trujillo	NMSU	Socioeconomics	L. Stanford and S. Trujillo (2026). Examining Community Perceptions to Hydroponics Agriculture on the Navajo Nation. New Mexico Water Resources Research Institute (WRRI) 2026 Animas and San Juan Watersheds Conference, San Juan College, Farmington, NM. May 27-28, 2026. Poster Presentation WRRI Conference in the Animas and San Juan Watersheds
Poster Presentation	Kevin A. Lombard, Tionna Tapaha, Shaun McKinley, Sarrah Trujillo, and Lois Stanford	NMSU	Biophysics/Socioeconomics/Workforce Development and Outreach	K.A. Lombard, T. Tapaha, B. Francis, S. Mckinley, S. Trujillo, B. Francis and L. Stanford (2026). Harnessing Controlled Environment Agriculture (CEA) to Secure Sustainability and Economic Growth: Tri-CEA. Navajo Research Conference. Dine' College, Tsaille, AZ June 15-17, 2026. Report to Navajo Nation Human Research Review Board, policy makers, practitioners and community members as part of NNR 26.574 Navajo Nation IRB approval. Poster Presentation Navajo Nation Research Conference
Oral Presentation	Brandon Francis, Emiliano McLane, Karletta Chief, Wilzave Guzman, William Norris, Kevin A. Lombard	NMSU	Socioeconomics	Brandon Francis, Emiliano McLane, Karletta Chief, Wilzave Guzman, William Norris, Kevin A. Lombard (2026). Four Corners Indigenous Farm Assessment: Soil, Land-use, Controlled Environment Agriculture and COVID-19 Impacts on Navajo farmers in the San Juan River Valley. Harnessing Controlled Environment Agriculture (CEA) to Secure Sustainability and Economic Growth: Tri-CEA. Navajo Research Conference. Dine' College, Tsaille, AZ June 15-17, 2026. Report to the Navajo Nation Human Research Review Board under NNR.21.398, University of AZ Oral Presentation, Navajo Research Conference. Northwest Ag Restoration Project, Transformation Network and Tri CEA
Poster Presentation	Tionna Tapaha, Shaun McKinley, Sarrah Trujillo, Lois Stanford, Brandon Francis, and Kevin Lombard	NMSU	Biophysics/Socioeconomics/Workforce Development and Outreach	T. Tapaha, B. Francis, S. Mckinley, S. Trujillo K. L. Stanford, B. Francis and K. Lombard (2026). Harnessing Controlled Environment Agriculture (CEA) to Secure Sustainability and Economic Growth: Tri-CEA. American Society for Horticultural Sciences Annual Conference, Dallas, TX, August 3-7, 2026. Scientific presentation. Poster Presentation ASHS Conference
Product	Glen Marshall	USD	Socioeconomics	These were conference abstracts/presentations, acknowledged TRICEA grant. The conference abstracts can be found at these links - Link #2 Presented a poster at the Upper Midwest Association for Campus Sustainability conference in Decorah, IA and gave two conference presentations at the Mountain Plains Business Conference in Omaha, NE

Type	Name	Institution	Research Thrusts	Complete Summary
Collaboration	Jill Keith	UW	Socioeconomics	Changes in tribal business councils and a lack of clarity around current IRB requirements for the Eastern Shoshone and the Northern Arapaho tribes on the Wind River reservation contributed to delays in seeking specific IRB approvals. A new subgroup of researchers and graduate students at UW is focused on IRB submission and review by tribal partners. This work is in collaboration with the UW High Plains American Indian Research Institute [HPAIRI]. Project participants Jill Keith and Denyse Ute participated. A new sub-group of the TRICEA group also formed over the summer. This subgroup focuses on IRB submissions and approvals. Notes with attendees are in the shared Google folder. There was PI, co-PI, and student involvement from each TRICEA institution. UW participants included Jill Keith and Denyse Ute.
Collaboration	Jill Keith	UW	Socioeconomics	Expanded collaboration - working with faculty member in Plant Sciences at UW related to growing native plants using CEA.
Grant	Jill Keith	UW	Socioeconomics	The team were awarded supplemental funds on the team's USDA-NBTS project. None of these funds are currently earmarked for TRI-CEA activities specifically. However, these funds support Jill Keith's work with tribal partners [Eastern Shoshone, Northern Arapaho], particularly around outreach, community engagement, and educational opportunities for Native American students in food, agriculture, natural resources, and human sciences. USDA-NBTS Sustaining Pathways for Tribal Student Recruitment, Engagement, and Success. Supplemental funding invitation. \$250,000; award number 2024-70411-43329.
Outreach	Jill Keith	UW	Socioeconomics	Opening Conversation to CBO's (Community-Based Organization): Restoring Ancestral Food Groups, Wind River Food Sov Project and Wind River Schools. November 2025 to present.
Outreach/Presentation	Jill Keith/Denyse Ute	UW	Socioeconomics	Presentation to the RSAFG in August 2025 and the Wind River Inter-tribal Council in November 2025; meeting with tribal community partners as part of the Restoring Shoshone Ancestral Food Gathering group.
Product	Denyse Ute/Jill Keith	UW	Socioeconomics	Abstract and poster presentation (graduate student Denyse Ute as lead author and presenter) at the Native American Nutrition Conference. Title: Resilient By Design. Partially supported by TRI-CEA; Controlled Environment Agriculture (CEA) was included in the poster within the food production section as part of a broader discussion on interconnected systems and was further referenced verbally as an example of experiential learning related to colonization and climate change. Conference Poster Presentation, Native Nutrition Conference, Minneapolis MN, Sept 14-16, 2025.
Grant	Stephen Gomez	SFCC	Workforce Development and Outreach	NSF-ATE THRIVE - one of six projects selected to prepare a proposal due on October 26. \$1M/3yrs. This is for aligning the Water Technologies curriculum between DACC and SFCC to train operators and technologists. CEA will be incorporated into the water conservation curriculum.
Collaboration	Stephen Gomez	SFCC	Workforce Development and Outreach	SV CEA - Discussions on CNMs desire to put a hydroponics greenhouse facility at the south valley campus. They will build and maintain the facility and SFCC will provide the curriculum and instructors. These are preliminary discussions and the details still have to ironed out. Started 8/25.
Collaboration	Stephen Gomez	SFCC	Workforce Development and Outreach	RG CEA - Rio Grande HS has the funds to build the teaching systems (SFCC donated a turnkey aquaponics system to the lab. The teacher Angie Angstrom is very excited to get the program going. Pedro Casas is advising on the aquaponics systems and advised on the algae cultivation systems. Started spring 2025. They have funding to set up an aquaponics classroom and greenhouse on campus.
Collaboration	Stephen Gomez	SFCC	Workforce Development and Outreach	SNL/UNM has developed an economic system to store heat from solar PV. There are discussions to use this system to heat our greenhouse and get off the natural gas. Solar PV is solar photovoltaics. This preliminary meeting was about how to utilize Sandia technology in the SFCC greenhouse. SNL is looking to see if LDRD money can be used from Sandia to work on this. Ken Armijo- Sandian Nat'l Labs, Sang Han - UNM.
Outreach	Stephen Gomez	SFCC	Workforce Development and Outreach	Santa Fe Chamber of Commerce 2026 Legislative Reception CEA, Water and Algae programs table to meet with legislators before Legislative Session Jan 26 2026
Product	Stephen Gomez	SFCC	Biophysics	Chapter on Macroalgal Systematics in the updated edition of Seaweed in Health and Disease Prevention. Fleurence J and Levine I (eds) Academic Press (due out in early spring) - Wasn't supported by this grant

Type	Name	Institution	Research Thrusts	Complete Summary
Product	Laura Green	UNM	Biophysics	Collected datasets for kale grown in UNM hydroponic systems, unpublished test data sets primarily supported by TRI-CEA grant. Collected multiple data sets to assess light variability and kale growth rate in both hydroponic systems (NFT and DWC) to practice our data collection methods and assess which data are most useful to add to the model in the fall cross-institutional campaign. Shaun and I will be working on analyzing our data and in the next couple of weeks
Outreach	Laura Green/David Hanson	UNM	Biophysics	Presentation for Central New Mexico Community College Internet of Things Deepdive Class "IoT for CEA" "IoT use in Plant Biology and Controlled Environment Agriculture (CEA)" presented February 26, 2026 by David Hanson and Laura Green. Presented at IoT classroom in CNM Ingenuity's Fuse Makerspace for students of Internet of Things Deepdive Class
Collaboration	Jingjing Wang	UNM	Socioeconomics	Purchasing 10 Hydroponics systems for Farmington Area schools to use as training for school children and promotion of CEA practices and benefits with NMSU providing the training and guidance for the teachers leading the efforts in the schools.
Product	Isaiah Spiegelberg	UW	Biophysics	A poster abstract titled "Exploring Hydroponic Head Lettuce Performance: Deep Water Culture vs. Vertical Production Systems" was published in HortScience on September 2, 2025. NSF support from the TRI-CEA project was acknowledged, and the poster was presented at the 2025 American Society for Horticultural Science Annual Conference in New Orleans, Louisiana.
Grant	Carmela Rosaria Guadagno	UW	Biophysics	Submitted the NSF proposal "PCL-Test Bed: A Modular, AI-Integrated Cyber-Physical Platform for Adaptive Control Toward Resilient and Resource-Efficient Agriculture" in December 2025. The proposal requested \$10,678,385
Grant	Carmela Rosaria Guadagno	UW	Biophysics	Awarded "Exploring the Plant Phenome in Controlled and Field Environments" through the USDA Hatch Program. This project is meant to support cross-state collaboration and it funds travels and activities for the HATCH NC1212 group. Information on the HATCH program can be found at: https://www.nifa.usda.gov/grants/programs/capacity-grants/hatch-act-1887
Grant	Carmela Rosaria Guadagno	UW	Biophysics	Submitted a U.S. Department of Energy grant, "The Role of the Photosynthetic Electron Transport Chain in Drought Tolerance" (PI: C.R. Guadagno), totaling \$708,819 in February 2026.
Grant	Carmela Rosaria Guadagno/Michael Baldwin	UW	Biophysics	Submitted the USDA proposal "Data-Guided Cultivation: Integrating AI Models into Robotized Systems to Optimize Production Efficiency, Nutritional Value, and Profitability" (Co-PI: C.R. Guadagno), requesting \$1,150,000. The project aims to integrate artificial intelligence and automation technologies into controlled environment agriculture systems.
Grant	Carmela Rosaria Guadagno	UW	Biophysics	Submitted a proposal to the USDA-NIFA Data Open Framework program. Not funded.
Product	Carmela Rosaria Guadagno	UW	Biophysics	Submitted the manuscript "Exploring Heat Dissipation and Energy Partitioning within Photosystem II Toward Light Optimization in Controlled Environment Agriculture" to Photosynthetica on February 20, 2026. The study examines photosynthetic energy allocation and light-use efficiency in controlled environment agriculture systems.
Product	Carmela Rosaria Guadagno	UW	Biophysics	Karimi, F., and Guadagno, C.R. (2026) published "Far-red Light Photon Flux Density Modulates Fruit Production, Morphology, and Photosynthetic Efficiency in Strawberry" in the Journal of the American Society for Horticultural Science. The study demonstrated the influence of far-red light on strawberry yield, plant morphology, and photosynthetic performance.
Product	Carmela Rosaria Guadagno	UW	Biophysics	Presentation: North American Plant Phenotyping Network – HATCH Workshop, Overview of University of Wyoming, accomplishments 2024/2025 and plans for 2026, East Lansing (MI), 2026
Product	Carmela Rosaria Guadagno/Michael Baldwin	UW	Biophysics	The University of Wyoming launched the Controlled Environment Agriculture (CEA) Network in Fall 2025 to advance workforce development, research, and industry collaboration in controlled environment agriculture. Led by Dr. Carmela Guadagno, the network connects industry, academic, and community partners to provide student training opportunities, support collaborative research, and expand innovation in CEA technologies across Wyoming and beyond. Press release at: https://www.uwyo.edu/news/2025/10/uw-launches-controlled-environment-agriculture-network.html
Collaboration	Carmela Rosaria Guadagno/Michael Baldwin	UW	Biophysics	STEM-ology days for CEA in the Science Institute of University of Wyoming (Nov 2025). STEM-ology, a monthly series of themed science, technology, engineering and mathematics (STEM) events for all

Type	Name	Institution	Research Thrusts	Complete Summary
				ages, at the University of Wyoming, offers events including Toddler Tuesdays, Senior Science Fridays and fun-filled family Science Saturdays. https://www.uwyo.edu/news/2025/11/stem-ology-provides-controlled-environment-agriculture-activities-for-all-ages-this-month.html
Collaboration	Carmela Rosaria Guadagno/ Michael Baldwin	UW	Biophysics	The University of Wyoming CEA Center collaborated with the Science Initiative Roadshow, Wyoming NASA Space Grant Consortium, and other campus partners to deliver controlled environment agriculture outreach and workforce development activities throughout the 2025–2026 academic year. These efforts reached more than 1,800 K–12 students through STEM Days, STEM-ology CEA Week, Youth in STEM events, and public engagement activities, increasing awareness of controlled environment agriculture and STEM career pathways across Wyoming.
Grant	Meghann Jarchow	USD	Socioeconomics	Sicangu Co, through its Sicangu Health Initiative, collaborated with the University of South Dakota to deliver community-based education on container gardening and hydroponics in Mission, South Dakota. The <i>Home Garden Class: Container Gardening & Hydroponics</i> provided participants with practical skills in sustainable food production and increased awareness of controlled environment agriculture opportunities.
Grant	Meghann Jarchow	USD	Socioeconomics	Submitted the proposal “ <i>CRISP: Center for Rural Infrastructure and Security Partnerships: A National Security Research Center for Excellence</i> ” on April 22, 2026. The proposed center would have advanced collaborative research and partnerships focused on rural infrastructure, security, and community resilience. The proposal was not funded.
Grant	Meghann Jarchow	USD	Socioeconomics	Title = South Dakota Rural Health Center of Excellence: Innovation and Economic Development-Driven Community Health; the rest of the information is the same as the proposal above

Appendix B. IRB Approvals.



To: Kevin Alan Lombard
From: , Chair
NMSU IRB
Date: 02/21/2026
Action: **Administrative Approval**
Action Date: 02/21/2026
Protocol #: 2509207965A001
Study Title: Harnessing Controlled Environment Agriculture (CEA) to Secure Sustainability and Economic Growth
Expiration Date: 01/27/2031
Last Approval Date: 02/21/2026
Risk Level:

The amendment to the above-referenced protocol has been APPROVED following Administrative Review by the IRB Committee that oversees the use of humans as experimental subjects.

If the research involves collaboration with another institution then the research cannot commence until the IRB review board receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date. Please allow sufficient time for continued approval. You may not continue any research activity beyond the expiration date without approval from the Committee. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study termination.

Adverse Events: Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported in writing within 10 working days.

Amendments: Any changes to the protocol that impact human subjects, including changes in experimental design, equipment, personnel or funding, must be approved by the IRB Committee before they can be initiated.

Prospective new study personnel must, where applicable, complete training in human subjects research and in the HIPAA Privacy Rule before participating in the study.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Lois Lois Stanford, Investigator
Anowar A Islam, Department Head
Brandon William Francis, Study Personnel
Tionna R Tapaha, Study Personnel
Shaun G McKinley, Study Personnel
Sarrah Kathleen Trujillo, Study Personnel



Consent to Participate in a Research Study

KEY INFORMATION

You are being invited to take part in the following research study: **Tribal Community Resilience under Climate Change: Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth (Tri CEA)**

Researcher(s):

The person(s) conducting this study is(are) Kevin A. Lombard and Lois Stanford

Principal Investigator: Dr. Kevin Lombard, Ph.D.
Ph.D.
Professor of Horticulture
New Mexico State University
Phone: (505) 960-7757
Email: klombard@nmsu.edu

Co-Investigator: Dr. Lois Stanford,
Academic Department Head
New Mexico State University
Phone: (575) 648-6092
Email: lstanford@nmsu.edu

WHAT ARE THE PURPOSES AND PROCEDURES OF THIS STUDY?

There has been limited investment in relevant research, community engagement, and workforce development, especially on the Navajo Nation underpinning year-round food production in, for example, greenhouses and hydroponics, commonly referred to as controlled environment agriculture or CEA for short.

By doing this study, the researchers hope to determine best practices for food production and to build a better understanding of the social and economic impacts related to year-round food production in CEA systems. The outcomes will appear as a policy report to the Navajo Nation leaders and may also appear as articles, presentations and creative or digital works.

WHAT WILL HAPPEN TO YOU IF YOU ARE IN THIS STUDY?

- We would like to offer seed packets of commonly grown vegetables in gratitude for your participation and time.
- You will be asked to complete one of three surveys depending on if you identify yourself as a fruit and vegetable consumer (e.g. purchase food from a grocery store), community leader (for example a school or senior citizen center), or agricultural producer (for example a farmer).
- The producer and community leader surveys include a combination of multiple-choice type questions and open-ended questions where you can provide additional details.
- Data collection will be face to face by _____ (identify self).
- For the multiple-choice type questions, we will log your responses directly into a tablet

1 _____ participant's initials



or laptop.

- For open-ended questions, we will use a hand-held recorder to log your responses to obtain an accurate transcript of your responses.
- The survey will take anywhere from 20 minutes to 1 hour.

WHY ARE WE ASKING YOU TO PARTICIPATE IN THIS STUDY?

You are being asked to participate in this study because we are seeking feedback about year-round farming from grocery store consumers of produce (fruits and vegetables), community leaders, and farmers to better understand where technical service providers can focus efforts regarding things like greenhouse and hydroponic production.

WHAT IS THE DURATION OF THIS STUDY?

Your participation in this research will last 20 minutes to 1 hour. It will involve a survey with multiple choice type questions and open-ended questions (where you can provide additional details). The multiple-choice type questions will be logged directly onto a laptop. The open-ended questions will be logged onto a recording device to obtain an accurate transcript of your answer. You will be invited to review the results at a presentation at your chapter house or community center when data has been analyzed. This will occur sometime in late 2026 or 2027.

WHAT ARE THE BENEFITS AND RISKS OF PARTICIPATION?

The potential benefits of participating are that your responses will help us work with your community and your leaders to develop a greater understanding of year-round farming and Controlled Environment Agriculture needs of your community.

The potential risks: There could be minimal risks of discomfort for participating in this study. You may not be knowledgeable about certain controlled environment agriculture types and may feel uncomfortable not responding. The interviewer will respect your knowledge as a respondent. Further clarification has been provided in VOLUNTARY NATURE sections to skip questions or stop at any time.

If you believe you are hurt, distressed, or if you get sick because of something that is due to the study, you should immediately contact the Researcher(s) and the Navajo Nation Human Research Review Board: Jonathan Hale, Board Chair, Navajo IRB Office, Navajo Division of Health, P. O. Box 1390, Window Rock, AZ 86515. Telephone number is (928) 729-4415. Fax number is (928) 729-4488 and the Office of Research Integrity and Compliance at New Mexico State University 575-646-7177 ric_admin@nmsu.edu. If you are experiencing any general stress or discomfort and need to talk to someone, please call the Navajo Nation Division of Behavioral and Mental Health Services Shiprock office at (505) 368-1438 or after hours at (928) 551-0566.



CONFIDENTIALITY

Everything you say is private and will not be shared with anyone. To protect your privacy, we ask that no one share what was talked about during survey sessions with people outside of this project. A report will be written at the end of the project. The report will not refer to you, your organization, or anyone else by name. Only information about the group as a whole will be reported. It will be impossible to identify individual answers and comments.

To protect your privacy, you will be given an identification (ID) number. We will keep all data gathered confidential. But we cannot guarantee total confidentiality. Some organizations like the Navajo Nation Human Research Review Board, New Mexico State University Institutional Review Board other federal, state, or tribal regulatory agencies; or the sponsor of this study (National Science Foundation), may review the research records for quality assurance purposes. We will only use the ID number and not any identifiable information so that no one can see what you have said.

The results of this study may be published as policy papers to the Navajo Nation, in scientific literature and the local media, but only in summary form so that no individual information can be identified with any participant or organization. The consent form that you provide will remain confidential. The consent form will be kept in a locked file cabinet. All digital records from completed surveys including voice recordings will be kept on a password protected computer in the investigator's locked office. All paper-based consent forms will be kept in a separate locked file cabinet in the investigators locked office.

Three years after the de-identified surveys have been compiled, all materials will be erased and destroyed. This includes shredding the paper-based signed consent forms.

IF YOU HAVE QUESTIONS OR CONCERNS OR WANT TO WITHDRAW:

Voluntary participation in this survey is entirely up to you. You both are free to make your own choice about being in the study. You may choose to answer specific questions. You may refuse to answer certain questions. You may stop participating at any time. There is no penalty for you if you choose not to respond to certain questions or stop your participation. Your participation will not interfere with services available to the rest of the Navajo people.

A copy of this form is available for you to keep.



**INFORMED CONSENT SIGNATURE PAGE: Tribal Community Resilience under Climate Change:
Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth
(Tri-CEA)**

If you have any questions, suggestions or concerns about your rights as a participant in this research, contact the Navajo Nation Human Research Review Board: Jonathan Hale, Board Chair, Navajo IRB Office, Navajo Division of Health, P. O. Box 1390, Window Rock, AZ 86515. Telephone number is (928) 729-4415. Fax number is (928) 729-4488 email is jonzcomet@yahoo.com and the office of Research Integrity and Compliance at the New Mexico State University 575-646-7177, or ric_admin@nmsu.edu.

If you have any questions about this project, please contact Drs. Kevin Lombard Lois Stanford. Their contact information is listed below. To learn more about the NMSU Agricultural Science Center at Farmington for announcements or would like to reach out assistance on future grant writing, training events, and/or educational projects please visit our website: <https://farmingtonsc.nmsu.edu/> or reach out to the PIs directly.

Principal Investigator: Kevin Lombard, Ph.D.
Professor of Horticulture
New Mexico State University
Phone: (505) 960-7757
Email: klombard@nmsu.edu

Co-Investigator: Lois Stanford, Ph.D.
Academic Department Head
New Mexico State University
Phone: (575) 646-6092
Email: lstanford@nmsu.edu

Signature

Date

Printed Name

Subject's Statement: *The research study has been explained to me, and I agree to participate in this garden-based survey. I have had a chance to ask questions. I understand that I may answer some questions. I understand that I may refuse to answer certain questions. I understand that I may stop my participation at any time I understand that I may contact the Navajo Nation Human Research Review Board if I have questions about my rights as a research participant. I understand that I may contact either Kevin Lombard or Lois Stanford if I have questions about this project.*

APPROVED	NNHRRB	(NNR-XYZ [DATE] agenda)
until 2/17/2027		
		2/17/26
Signature NNHRRB Chair Jonathan Hale		Date Signed 4

participant's initials

Navajo Nation Human Research Review Board

February 18, 2026

Kevin A. Lombard PhD
NMSU Agricultural Science Center
300 Navajo Road 4063
PO Box 1018
Farmington NM 87499-1018

Dear Dr. Lombard:

This is to advise you that the **Study # NNR-26.574 "Tribal Community Resilience under Climate Change: Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth (Tri-CEA)"** has been presented to the Navajo Nation Human Research Review Board (NNHRRB) on **February 17, 2026**, and the following action taken subject to the conditions and explanation provided below.

Reasons: New Submission

Description: Request Review and Approval of New Submission

NNHRRB Action: Approved

The Navajo Nation Human Research Review Board has added a very important additional contingency regarding failure to comply with NNHRRB rules, regulations, and submittal of reports which could result in sanctions being placed against your project. This could also affect your funding source and the principal investigator. Under Part Five: Certification, please note paragraph five wherein it states: *"I agree not to proceed in the research until the problems have been resolved or the Navajo Nation Human Research Review Board has reviewed and approved the changes."* Therefore, it is very important to submit quarterly and annual reports on time and if continuation is warranted submit a letter of request sixty (60) days prior to the expiration date.

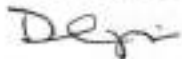
The following are requirements that apply to all research studies:

1. The Navajo Nation retains ownership of all data obtained within its territorial boundaries. The Principal Investigator shall submit to the NNHRRB a plan and timeline on how and when the data/statistics will be turned over to the Navajo Nation;
2. Only the approved informed consent document(s) will be used in the study;
3. Any proposed future changes to the protocol or the consent form(s) must again be submitted to the Board for review and approval prior to implementation of the proposed change;
4. If the results of the study will be published or used for oral presentations at professional conferences, the proposed publication, abstract and/or presentation materials must be submitted to the Navajo Research Program for Board review and prior approval;
5. Upon Board approval, three (3) copies of the final publication must be submitted to the Navajo Research Program;
6. All manuscripts must be submitted to the Navajo Research Program for Board Review and prior approval;

7. The Principal Investigator must submit a dissemination plan on how the results of the study and how these results will be reported back to the Navajo Nation;
8. The Principal Investigator must share specifically how these results will generally benefit or improve the health of the Navajo people. This can be completed by:
 - a. Conducting an educational in-service for the community people and health care providers on the Navajo Nation and present the findings. Provide documentation of these in-services presented.
 - b. Developing educational materials for use by the health care providers and the community people and providing the training on how to use the materials; and
 - c. Presenting and sharing the results of the study at a research conference sponsored by the Navajo Nation for its health care providers and the Navajo people.
9. The Principal Investigator is expected to submit documentation on 8a, b, & c;
10. The Principal Investigator must submit quarterly and annual reports as scheduled.

If you have any questions on this subject, please call the Navajo Research Program at (928) 871-6929.

Sincerely Yours,



Mr. Jonathan Hale, Chairperson
Navajo Nation Human Research Review Board

cc: NNR-26.574 file



Consent to Participate in a Research Study

KEY INFORMATION

You are being invited to take part in the following research study: **Tribal Community Resilience under Climate Change: Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth (Tri CEA)**

Researcher(s):

The person(s) conducting this study is(are) Kevin A. Lombard and Lois Stanford

Principal Investigator: Dr. Kevin Lombard, Ph.D.
Ph.D.
Professor of Horticulture
New Mexico State University
Phone: (505) 960-7757
Email: klombard@nmsu.edu

Co-Investigator: Dr. Lois Stanford,
Academic Department Head
New Mexico State University
Phone: (575) 648-6092
Email: lstanfor@nmsu.edu

WHAT ARE THE PURPOSES AND PROCEDURES OF THIS STUDY?

There has been limited investment in relevant research, community engagement, and workforce development, especially on the Navajo Nation underpinning year-round food production in, for example, greenhouses and hydroponics, commonly referred to as controlled environment agriculture or CEA for short.

By doing this study, the researchers hope to determine best practices for food production and to build a better understanding of the social and economic impacts related to year-round food production in CEA systems. The outcomes will appear as a policy report to the Navajo Nation leaders and may also appear as articles, presentations and creative or digital works.

WHAT WILL HAPPEN TO YOU IF YOU ARE IN THIS STUDY?

- We would like to offer seed packets of commonly grown vegetables in gratitude for your participation and time.
- You will be asked to complete one of three surveys depending on if you identify yourself as a fruit and vegetable consumer (e.g. purchase food from a grocery store), community leader (for example a school or senior citizen center), or agricultural producer (for example a farmer).
- The producer and community leader surveys include a combination of multiple-choice type questions and open-ended questions where you can provide additional details.
- Data collection will be face to face by _____ (identify self).
- For the multiple-choice type questions, we will log your responses directly into a tablet

1 _____ participant's initials



or laptop.

- For open-ended questions, we will use a hand-held recorder to log your responses to obtain an accurate transcript of your responses.
- The survey will take anywhere from 20 minutes to 1 hour.

WHY ARE WE ASKING YOU TO PARTICIPATE IN THIS STUDY?

You are being asked to participate in this study because we are seeking feedback about year-round farming from grocery store consumers of produce (fruits and vegetables), community leaders, and farmers to better understand where technical service providers can focus efforts regarding things like greenhouse and hydroponic production.

WHAT IS THE DURATION OF THIS STUDY?

Your participation in this research will last 20 minutes to 1 hour. It will involve a survey with multiple choice type questions and open-ended questions (where you can provide additional details). The multiple-choice type questions will be logged directly onto a laptop. The open-ended questions will be logged onto a recording device to obtain an accurate transcript of your answer. You will be invited to review the results at a presentation at your chapter house or community center when data has been analyzed. This will occur sometime in late 2026 or 2027.

WHAT ARE THE BENEFITS AND RISKS OF PARTICIPATION?

The potential benefits of participating are that your responses will help us work with your community and your leaders to develop a greater understanding of year-round farming and Controlled Environment Agriculture needs of your community.

The potential risks: There could be minimal risks of discomfort for participating in this study. You may not be knowledgeable about certain controlled environment agriculture types and may feel uncomfortable not responding. The interviewer will respect your knowledge as a respondent. Further clarification has been provided in VOLUNTARY NATURE sections to skip questions or stop at any time.

If you believe you are hurt, distressed, or if you get sick because of something that is due to the study, you should immediately contact the Researcher(s) and the Navajo Nation Human Research Review Board: Jonathan Hale, Board Chair, Navajo IRB Office, Navajo Division of Health, P. O. Box 1390, Window Rock, AZ 86515. Telephone number is (928) 729-4415. Fax number is (928) 729-4488 and the Office of Research Integrity and Compliance at New Mexico State University 575-646-7177 ric_admin@nmsu.edu. If you are experiencing any general stress or discomfort and need to talk to someone, please call the Navajo Nation Division of Behavioral and Mental Health Services Shiprock office at (505) 368-1438 or after hours at (928) 551-0566.



CONFIDENTIALITY

Everything you say is private and will not be shared with anyone. To protect your privacy, we ask that no one share what was talked about during survey sessions with people outside of this project. A report will be written at the end of the project. The report will not refer to you, your organization, or anyone else by name. Only information about the group as a whole will be reported. It will be impossible to identify individual answers and comments.

To protect your privacy, you will be given an identification (ID) number. We will keep all data gathered confidential. But we cannot guarantee total confidentiality. Some organizations like the Navajo Nation Human Research Review Board, New Mexico State University Institutional Review Board other federal, state, or tribal regulatory agencies; or the sponsor of this study (National Science Foundation), may review the research records for quality assurance purposes. We will only use the ID number and not any identifiable information so that no one can see what you have said.

The results of this study may be published as policy papers to the Navajo Nation, in scientific literature and the local media, but only in summary form so that no individual information can be identified with any participant or organization. The consent form that you provide will remain confidential. The consent form will be kept in a locked file cabinet. All digital records from completed surveys including voice recordings will be kept on a password protected computer in the investigator's locked office. All paper-based consent forms will be kept in a separate locked file cabinet in the investigators locked office.

Three years after the de-identified surveys have been compiled, all materials will be erased and destroyed. This includes shredding the paper-based signed consent forms.

IF YOU HAVE QUESTIONS OR CONCERNS OR WANT TO WITHDRAW:

Voluntary participation in this survey is entirely up to you. You both are free to make your own choice about being in the study. You may choose to answer specific questions. You may refuse to answer certain questions. You may stop participating at any time. There is no penalty for you if you choose not to respond to certain questions or stop your participation. Your participation will not interfere with services available to the rest of the Navajo people.

A copy of this form is available for you to keep.



**INFORMED CONSENT SIGNATURE PAGE: Tribal Community Resilience under Climate Change:
Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth
(Tri-CEA)**

If you have any questions, suggestions or concerns about your rights as a participant in this research, contact the Navajo Nation Human Research Review Board: Jonathan Hale, Board Chair, Navajo IRB Office, Navajo Division of Health, P. O. Box 1390, Window Rock, AZ 86515. Telephone number is (928) 729-4415. Fax number is (928) 729-4488 email is jonzcomet@yahoo.com and the office of Research Integrity and Compliance at the New Mexico State University 575-646-7177, or ric_admin@nmsu.edu.

If you have any questions about this project, please contact Drs. Kevin Lombard Lois Stanford. Their contact information is listed below. To learn more about the NMSU Agricultural Science Center at Farmington for announcements or would like to reach out assistance on future grant writing, training events, and/or educational projects please visit our website: <https://farmingtonsc.nmsu.edu/> or reach out to the PIs directly.

Principal Investigator: Kevin Lombard, Ph.D.
Professor of Horticulture
New Mexico State University
Phone: (505) 960-7757
Email: klombard@nmsu.edu

Co-Investigator: Lois Stanford, Ph.D.
Academic Department Head
New Mexico State University
Phone: (575) 646-6092
Email: lstanford@nmsu.edu

Signature

Date

Printed Name

Subject's Statement: *The research study has been explained to me, and I agree to participate in this garden-based survey. I have had a chance to ask questions. I understand that I may answer some questions. I understand that I may refuse to answer certain questions. I understand that I may stop my participation at any time I understand that I may contact the Navajo Nation Human Research Review Board if I have questions about my rights as a research participant. I understand that I may contact either Kevin Lombard or Lois Stanford if I have questions about this project.*

APPROVED	NNHRRB	(NNR-XYZ [DATE] agenda)
until 2/17/2027		
		2/17/26
Signature NNHRRB Chair Jonathan Hale		Date Signed 4

participant's initials

IRB-24-264 - Initial: Exempt Approval

Download Save to OneDrive

Show email

IRB-24-264 - Initial: Exempt Approval

do-not-reply@cayuse.com
To: Wergin, Rand

Tue 2/25/2025 12:37 PM



Date: February 25, 2025

University of South Dakota
414 E. Clark Street
Vermillion, SD 57069

PI: Rand Wergin
Student Investigator(s): Glen Marshall
Re: Initial - IRB-24-264 Sustainable Marketing in Resource-Limited Communities

The University of South Dakota Institutional Review Board has rendered the decision below for this study. Because this study is exempt, its approval does not expire. Please submit a closure form to the IRB when this study is complete.

Decision: Exempt
Category: Category 2.(ii). Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:
Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

Research Notes: Interview study; date-stamped consent with no signature; consent form emailed during scheduling; oral consent at beginning of interview; recruiting email.

Dear Rand Wergin,

The proposal referenced above has received an exempt review and is approved according to the procedures of the University of South Dakota Institutional Review Board.

Please make sure to use the date-stamped consent form when emailing copies to potential participants. You can find the date-stamped version in the "Attachments" tab of your initial application.

Annual continuing review is not required for this exempt study. However, two years after this approval is issued, on about February 24, 2027, we will contact you to request an update on the status of this study.

When the study is complete, you must submit a closure form to the IRB. You may close your study when you are finished collecting data, no longer have contact with the subjects, and the data have been de-identified. You may continue to analyze the existing data on the closed project.

Please promptly report to the IRB any proposed changes or additions (e.g., protocol amendments/revised informed consents, site changes, etc.) in previously approved human subjects research activities BEFORE you put those changes into place.

Any modifications to the approved study must be submitted for review through Cayuse IRB. All approval letters and study documents are located within the study details in Cayuse IRB.

If you have any questions, please contact: irb@usd.edu or (605) 658-3743.

Sincerely,
University of South Dakota Institutional Review Board

Marc Guilford, J.D.
Director, Office of Human Subjects
University of South Dakota
(605) 658-3767

Reply Forward

Checklist for Final Approval

This Checklist lays out the necessary pieces for a research proposal to the Rosebud Higher Education Research Review Board. After completing the HERRB Questionnaire, prospective researchers should gather these pieces and submit them to the Chairperson for review.

Your Name	Glen Marshall
Your Home Institution	University of South Dakota (and SGU)

Name	Description	Mark when finalized in PDF
Copy of IRB	Provide a copy of your completed and approved IRB from your home institution	☒
Human Subject Certification	Provide a copy of the Certificate of Completion for a “Human Subject Certification” training (you may have completed this as part of your home institution’s IRB process).	☒
Preliminary Approval from Partner Organization	Provide a copy of the approval documentation you have from participating organizations on/near the Rosebud Reservation N/A - Sinte Gleska University only	☐ N/A
Tribal Data Sovereignty Essay and Assurance	Provide an essay and a signed and dated copy of the Tribal Data Sovereignty Assurance Agreement: https://www.sintegleska.edu/uploads/1/1/3/8/11384118/tribal_data_sovereignty.pdf	☒
Cultural Context and Meaning	Create a short vignette describing a researcher who displays cultural understanding or who fails to do so: https://www.sintegleska.edu/uploads/1/1/3/8/11384118/cultural_context_and_meaning.pdf	☒

You may compile the documents above into a single PDF file and title your document as follows: Last Name/First Name/Date of Submission. (If you prefer, you may request that a Google folder be set up for you on the HERRB server. On the server you may complete the *Tribal Data Sovereignty Essay* and the *Cultural Context and Meaning Vignette*.)

Email the final PDF to herrb.chair@sintegleska.edu. (If you are completing *Tribal Data Sovereignty Essay* and the *Cultural Context and Meaning Vignette* in a Google folder that has been set up for you,

let the HERRB chair know when your documents in the Google folder are complete and ready for review.)

Please be aware that additional documentation may be required if the Board has further questions.

Pilamayayelo!

[Draft] Re: IRB-25-153 - Initial: Exempt Approval

From iolay@unm.edu
Draft saved Fri 05/29/2026 2:11 PM

From: do-not-reply@cayuse.com <do-not-reply@cayuse.com>
Sent: Monday, August 18, 2025 12:09 PM
To: Marshall, Glen <glen.marshall@coyotes.usd.edu>; Jarchow, Meghann <meghann.jarchow@usd.edu>
Subject: IRB-25-153 - Initial: Exempt Approval



Date: August 18, 2025

University of South Dakota
414 E. Clark Street
Vermillion, SD 57069

PI: Meghann Jarchow
Student Investigator(s): Glen Marshall
Re: Initial - IRB-25-153 *Growing Potential: Exploring Hydroponic Solutions for Food Access in Rural and Tribal Communities*

The University of South Dakota Institutional Review Board has rendered the decision below for this study. Because this study is exempt, its approval does not expire. Please submit a closure form to the IRB when this study is complete.

Decision: Exempt

Category: Category 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met: (i) The identifiable private information or identifiable biospecimens are publicly available; (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects; (iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or (iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Research Notes: Existing data study; data was collected as part of a class project (NHSR); data will be de-identified before use for this project; Exempt 4 study that does not require consent.

Dear Meghann Jarchow,

The proposal referenced above has received an exempt review and is approved according to the procedures of the University of South Dakota Institutional Review Board.

Annual continuing review is not required for this exempt study. However, two years after this approval is issued, on about August 17, 2027, we will contact you to request an update on the status of this study.

When the study is complete, you must submit a closure form to the IRB. You may close your study when you are finished collecting data, no longer have contact with the subjects, and the data have been de-identified. You may continue to analyze the existing data on the closed project.

Please promptly report to the IRB any proposed changes or additions (e.g., protocol amendments/revised informed consents, site changes, etc.) in previously approved human subjects research activities BEFORE you put those changes into place.

Any modifications to the approved study must be submitted for review through Cayuse IRB. All approval letters and study documents are located within the study details in Cayuse IRB.

If you have any questions, please contact: irb@usd.edu or (605) 658-3743.

Sincerely,

University of South Dakota Institutional Review Board

A handwritten signature in blue ink, appearing to read "Marc Guilford".

Marc Guilford, J.D.
Director, Office of Human Subjects
University of South Dakota
(605) 658-3767



IRB-2025-234 - Initial: Initial - Expedited Review Approval

From UW-IRB-do-not-reply@cayuse.com <UW-IRB-do-not-reply@cayuse.com>

Date Tue 2/3/2026 4:36 PM

To Jill Fabricius Keith <jkeith5@uwyo.edu>

◆ This message was sent from a non-UWYO address. Please exercise caution when clicking links or opening attachments from external sources.

Date: February 3, 2026

PI: Jill Keith

Re: Initial - IRB-2025-234

Tribal Community Resilience Under Climate Change: Harnessing Controlled Environment Agriculture to Secure Sustainability and Economic Growth

The University of Wyoming Institutional Review Board has reviewed the above-referenced submission and rendered the decision below. All approval letters and study documents are located in the tabs on the Submission Details page.

Decision: Approved

Decision Date: February 3, 2026

Study Admin Check-in Date: January 2, 2027

Study Expiration Date: February 2, 2027

Review Type: All reviewed research activities fall under 45 CFR 46.110.

Findings:

Research Notes:**Key Principal Investigator Responsibilities:**

- **Submit any proposed changes to the Study prior to being implemented via a Modification submission for IRB review and approval.**
- **Promptly notify the IRB, via Incident submission, of any reportable events (adverse events/protocol deviations/unanticipated problems/subject complaints/etc.) that occur during the research, including any breach in confidentiality or data security that places participants or others at a greater risk of harm.**
- **Submit a Renewal Submission in advance month of Administrative Check-in or Study Expiration dates to allow for IRB review and approval to continue conducting study activities.**

If you have any questions, please contact the University of Wyoming Institutional Review Board. Please include the Study Title and Study Label (Study #) in all correspondence with the IRB.

Sincerely,

University of Wyoming Institutional Review Board



OFFICE MEMO - Wind River Inter-Tribal Council

Office of the WRITC Secretary



TO: Denyse Ute
DATE: November 13, 2025
FROM: Carolyn Shoyo, WRITC Executive Secretary *CS*
SUBJECT: 11/10/25 WRITC Action Item

On November 10, 2025 the WRITC through it's routing approval process, considered your request for a approval of your project, Year-Round Farming (a controlled environmental Agriculture Project), and a letter of support for your grant proposal.

The data is to be owned by the Shoshone and Arapaho Tribes and the research team, and only to be released to others with written permission from the WRITC.

This was approved by a vote of 4 ESBC members in favor and 3 NABC members in favor, the request was approved.

I have attached a copy of the items you submitted along with your request for your records. As well as a scanned copy of the signed letter of support (you may stop by my office at Room 108 at the Tribal Complex to pick up the original).

If you have any questions you may contact me at 307-332-6625 extension 2028.

cc: A. Pingree, Supt. BIA-WRA
File

November 5, 2025

RECEIVED

NOV 05 2025

WRITC Secretary's Office

Re: Letter of Support for the Year-Round Farming [Controlled Environment Agriculture] project

To Whom it May Concern,

This letter expresses our support for the Year-Round Farming [Controlled Environment Agriculture-CEA] collaborative project through the University of Wyoming. The goals of the project include gathering information about community attitudes, perceptions, and guidance related to food access, food security, food production, and year-round farming [CEA].

Many Tribal farmers have struggled with growing enough crops and food during the farming season due to the hot dry summers, cold winters, and insufficient amount of water. With these systems, they have the potential to increase food production while decreasing the amount of water usage throughout the growing season since the water only requires changing about every two to three weeks. Having more control over the growing environment could help expand the growing season to year-round and allow for better and faster plant growth. Year-round farming systems have a lot of benefits but do require some prior knowledge and training, but with a little teaching, anyone can do it and could result in more community involvement. Gathering community input related to year-round farming will support community members learning about CEA and provide insights about the food environment in the community.

As part of this project, data generated will be jointly owned by the Tribes and research team. We know that results and implications will be shared with the Tribal Councils, Tribal community members, and participants in the project. This letter serves as support for project team members to pursue IRB approvals through the University of Wyoming and Rocky Mountain Tribal review board.

We look forward to this project building knowledge in the community of food access, food security, food production, and year-round farming. If you have any questions, please contact our office at:

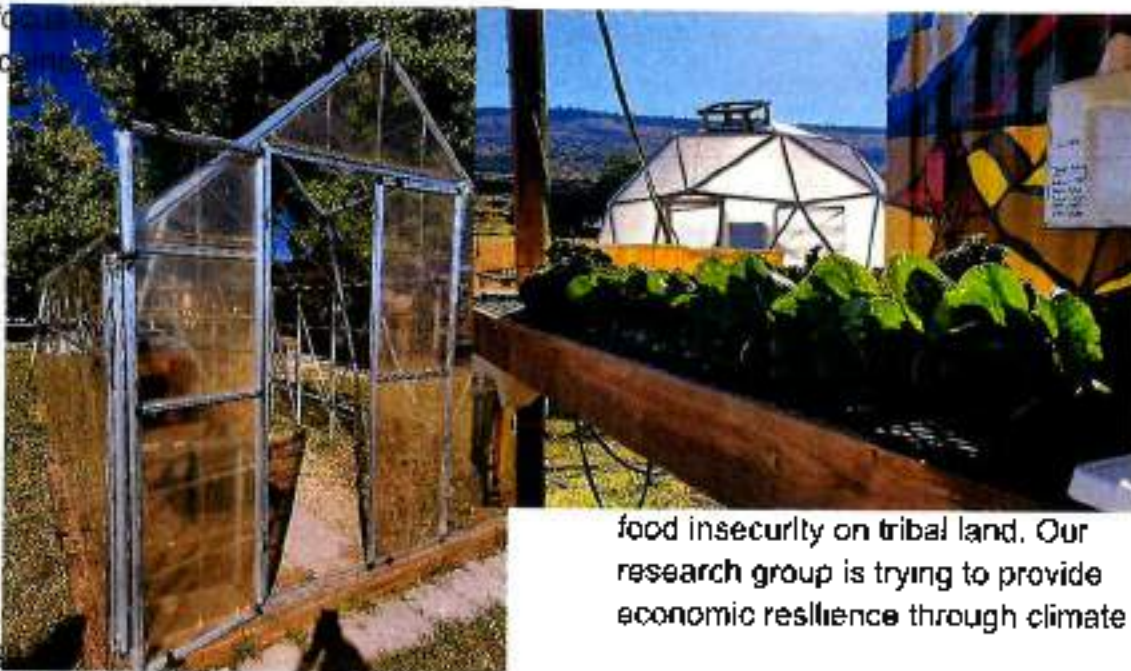
Sincerely,

Year-Round Farming [Controlled Environment Agriculture] project

Who is involved: collaborative project with University of Wyoming, New Mexico State University, University of New Mexico, University of South Dakota.

What the project is about: Our project is based on year-round farming, also called CEA, or Controlled Environment Agriculture. Examples of CEA include greenhouses, hoop houses, hydroponics, and aquaponics.

The focus is to
help communities



change

food insecurity on tribal land. Our research group is trying to provide economic resilience through climate



Step 1 - Advanced Fundamental Understanding of Year-Round Farming: Identify the interaction and affects between the hydroponic systems with the environment, plants and micro-organisms.

Step 2 - Assessing Social and Economic Impacts of Year-Round Farming: Connect the CEA impacts as well as the environmental, nutritional, and economical impacts to increase stability through climate change.

Step 3 - Workforce Development: Support tribal communities' priorities for opportunities and training for these Year-Round Farming systems.

Why it is important: Many tribal farmers have struggled with growing enough crops and food during the farming seasons due to the hot dry

summers, cold winters, and insufficient amount of water. With these systems, they have the potential to increase food production while decreasing the amount of water usage throughout the growing season since the water only requires changing about every two to three weeks. Having more control over your growing environment could help expand your growing season to year-round and allow for better and faster plant growth. Year-Round Farming systems have a lot of benefits but do require some prior knowledge and training, but with a little teaching, anyone can do it and could result in more community involvement.

Benefits vs Drawback of Year-Round Farming [CEA] methods like hydroponics

Benefits

Year-round Crop Production

Space Efficient

Reduced Water Usage

Faster Growth Rate

Control over Conditions

Reduce Risks (weeds, pests, disease)

Drawbacks

Can be Expensive

High Maintenance

Limited Plant Types

Technical Expertise

Vulnerable to some disease and pests

Gathering community input: we would like to 1) conduct listening sessions with community members and organizations working with food [e.g. Wind River Food Sovereignty, Wind River Tribal Buffalo Initiative] and 2) gather input through surveys to explore community attitudes, perceptions, and guidance related to food access, food security, food production, and CEA on the Wind River reservation.

How we would share the results:

- newsletters
- tribal websites
- posters at conferences
- open access journal articles

What we are requesting:

- Letter of support from the Wind River Intertribal Council