Contact Information

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Expected Graduation: May 2024

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Position: Professor Department: Biology

Project Name: Improving Agricultural Sustainability through Ecosystem Services at Local and Global Scales

Abstract

The agricultural revolution of the 1970's has allowed farmers to meet global food demands by intensifying agricultural inputs, like utilizing a greater amount of fertilizers and pesticides per unit area. These intensive inputs have also been associated with environmental deterioration and biodiversity loss, making these strategies unsustainable. The necessity to feed growing human populations will make agricultural ecosystems (e.g., agroecosystems) permanent landscape fixtures. It is imperative that we develop agricultural strategies that improve farming sustainability while also minimizing the environmental costs caused by human activities. Ecosystem services, or the natural services provided by species and ecosystems that benefit humans, has been proposed as one possible tool to sustainably improve agricultural yields. Among different staple food crops, rice is consumed by half the global population. Rice fields may also serve as surrogate wetlands and can provide ecosystem services including greenhouse gas regulation. I plan to test two main questions at NAU's experimental greenhouse: 1) Do rice plants inoculated with soil fungi have the potential to affect greenhouse gas emissions? and 2) Do rice plants inoculated with soil fungi produce higher overall yields? This research may serve as a model for investigating sustainable methods of agricultural crop production at NAU and also at regional and global scales.

Project Proposal

The necessity to feed growing human populations will make agroecosystems permanent landscape fixtures. It is imperative humans develop cultivation strategies that both support biodiversity within agroecosystems, while minimizing the environmental costs due to agricultural intensification (Phelps *et al.* 2013). Agricultural research merging conservation and sustainability is relatively new, but this merger of ideas has been emphasized within several of the United Nation's (UN) sustainable development goals (United Nations Department of Economic and Social Affairs – Sustainable Development, SDG 2: Achieve food security, SDG 15: Promote sustainable use of terrestrial ecosystems).

This project aims to address the UN's sustainable development goals by investigating approaches that improves rice farming sustainability by supporting rice field ecosystem services.

Over the past two summers, I have collected rice plants from commercially operating rice fields within the Sacramento Valley of California. We have preliminary data indicating a higher degree of arbuscular mycorrhizal fungal (AMF) root colonization between rice plants cultivated in under distinct farming practices (e.g., conventional or organic). We plan to test if these AMF colonization patterns have the potential to influence greenhouse gas emissions emanating from rice field soils. We will also determine if these AMF patterns can impact overall rice yields. There is a wealth of literature covering how to experimentally grow rice from initial germination through maturity (Eddy *et al.* 2016). In short, rice plants will be grown in hydroponic trays measuring 50cm X 25cm in media made from a 50/50 mix of garden soil and clay granules. Plants will be grown under natural lighting, unless supplemental light is necessary, and fertilized every other week. There will be a total of 20 trays filled with rice plants, 10 controls and 10 treatments. The treatment trays will be inoculated with commercial AMF (Rani, Bhatia & Kaushik 2021). Each tray will contain 3 separate plastic collars that will be placed within the media to collect the real-time gas fluxes of methane, carbon dioxide and nitrous oxide (Richardson *et al.* 2022). Gas flux measurements will be collected weekly from the initial germination phase through final harvest (~3 months).

Rice cultivation accounts for ~10% of global methane production and covers ~10% of the world's arable agricultural lands (The World Bank). Reducing greenhouse gas emissions caused by rice agriculture can combat some of the negative effects caused by climate change. This research can also elucidate additional ecosystem services that sustainably increase crop yields, reducing the negative environmental effects caused by human activities. Although NAU does not directly cultivate rice, NAU can be proud of supporting research that investigates methods to improves global sustainability, which will benefit both NAU's campus and the greater Flagstaff community.

Citations

Eddy, R., Acosta, K., Liu, Y. and Russell, M. (2016) Optimizing Greenhouse Rice Production: Materials, Methods, and References. *Purdue Methods for Rice Growth*. Paper 3.

Fukagawa, N. M. and Ziska, L. H. (2019) Rice: Importance for global nutrition. *Journal of Nutritional Science and Vitaminology,* 65.

Phelps, J., Carrasco, L. R., Webb, E. L., Koh, L. P., & Pascual, U. (2013). Agricultural intensification escalates future conservation costs. *Proceedings of the National Academy of Sciences of the United States of America*, 110, 7601–7606.

Rani, V., Bhatia, A., and Kaushik, R. (2021). Inoculation of plant growth promoting-methane utilizing bacteria in different N-fertilizer regime influences methane emission and crop growth of flooded paddy. *Science of The Total Environment*, 775, 145826.

Richardson, A. D., Kong, G. V, Taylor, K. M., Le Moine, J. M., Bowker, M. A., Barber, J. J., Basler, D., Carbone, M. S., Hayer, M., Koch, G. W., Salvatore, M. R., Sonnemaker, A. W., and Trilling, D. E. (2022). Soil-atmosphere fluxes of CO2, CH4, and N2O across an experimentally-grown, successional gradient of biocrust community types. *Frontiers in Microbiology*, 13.

Questionnaire

Please select the focus of your research project, then address the following questions.

☐ Renewable energy/ Energy efficiency/
☒ Emissions reduction
☐ Environmental justice/ Intersectionality
☐ Waste Minimization
☐ Understanding sustainability behavior/perspectives of NAU students
☐ Transportation
☒ Other: Sustainable food production

1. How will your research benefit the mission statement of the Green Fund and improve sustainability on NAU's campus?

Through the promotion of ecosystem services, this solution-orientated research is focused on developing sustainable agricultural methods that will benefit NAU's campus. Specifically, we plan to test if rice plants inoculated with Arbuscular Mycorrhizal Fungi (AMF) can decrease methane, carbon dioxide and nitrous oxide emissions in addition to improving rice plant size and yields. These findings will enable rice farmers to implement strategies that reduces humanities negative impact on the environment. This ecosystem service-based experimentation may also serve as model for future sustainability studies conducted at NAU's campus.

2. Will your research require the utilization of any spaces or infrastructure on campus? If so, identify the specific locations and/or infrastructure, how much of the space you require, and what each space will be used for.

We will need to use NAU's experimental greenhouse to grow rice plants for approximately 3 months. There will be a total of ten trays per treatment and each treatment will take up approximately 25 m^2. We are also collaborating with the Terrestrial Ecosystem Carbon Cycling lab, directed by Mariah Carbone, who has granted us access to use their infrared gas analyzers to determine real-time soil gas fluxes. This equipment will also take up 10 m^2 of space.

3. Will other departments on campus (other than your own) be needed to assist in this project (i.e. Facility Services, Campus Transit)? If so, identify department partnerships.

We are collaborating with the Terrestrial Ecosystem Carbon Cycling lab to use their infrared gas analyzers and NAU's experimental greenhouse staff.

Project Budget

Please respond to the following funding question, and complete a thorough breakdown of all project costs in the provided. Include a 5% line item for contingency.

1. Does this project have any other sources of funding, and/or have you applied for other sources of funding? If so, list all additional sources of funding, both confirmed and potential, outside of the funds being requested from the Green Fund.

NA

Line-Item Budget:

Item	Justification	Quantity	Price per Unit	Total
PVC S&D Coupling, 4 in. Hub X Hub	Placed in media to allow for gas flux measurement	65	$4	$260
4 in. x 10 ft. PVC D2729 Sewer and Drain Pipe	Seal for PVC coupling to allow for gas flux measurement	2	$34	$68
PVC S&D Cap, 4 in.	Cap for above seal	4	$4	$16
PEEK Natural tubing: 1.8mm	Allows for gas collection chambers to release pressure	1	$30	$30
1/4OD Bulkhead	Connection between cap and tubing – allows chamber to relieve pressure	1	$24	$24
Panel-Mount Thermometer	Takes precise temperature measurements within collection chamber – required for gas flux calculation	1	$36	$36
Waterproof Cable Connectors	Connection seals between caps, tubes and bulkheads	2	$17	$34
Hydroponic Grow Trays	Trays where plants will be grown	20	$10	$200
Grow light (optional)	Used to provide supplemental light.	2	$210	$420
Greenhouse space rental	Cost of rental space at greenhouse (3 months)	1	$350	$350
Commercial AMF	Study treatment	1	$100	$100
Rice growing media	Needed to grow rice	5	$50	$250

Water soluble fertilizer	Needed to grow rice	2	$25	$50
Student Wages	Money to support undergraduate work	3hrs/week + 3 months	$15.25	$550

Total Funding Requested: $2388+ $120 (**5% contingency**) = **~$2500**

Project Timeline

Please provide an expected timeline for your research in the template below. The Green Fund recognizes that complex projects of this nature should have flexible, adaptable schedules, and the timeline provided will be treated as such. However, it is expected that you strive to adhere to this schedule as much as possible.

Expected Timeline:

Action	Parties Involved	Month/Year
Pilot study	Research team/Carbone lab	January/2023
Soil preparation and seed planting	Research team/NAU greenhouse	May/2023
Plant fertilization	Research team/NAU greenhouse	May/June/July/2023
Weekly flux measurements	Research team/Carbone lab	May/June/July/2023
Removal of “sacrifice” plants to quantify root colonization efficacy	Research team	June/2023
Drying of soil and collection of mature plants	Research team	July/2023
Quantification of plant size and yield per treatment	Research team	August/2023

Expected Project Completion Date: **August 2023**

Commitment to Present Research

Please read and sign the statement below, acknowledging your commitment to present the findings of your research.

If selected as a recipient of the 2022 Green Fund Student Research Grant, regardless of the outcome of my research project, I **Alejandro Grajal-Puche** commit to presenting the status of my research described in this application in the form of both an oral presentation to the Green Fund Committee and a poster/exhibit presentation at the Undergraduate or Graduate Symposium, no more than 1 year after receiving notification of funding.

The oral presentation to the Green Fund Committee will consist of an approximately 10 minute long PowerPoint that includes the following aspects of your project:

- Original goal and purpose of research
- Conflicts or changes to the original purpose
- Results/Conclusion
- All relevant graphical displays of data

Project Leader Signature: *Alejandro Grajal-Puche* *8Nov2022*