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SPACE BIOLOGY IN PHILIPPINE EDUCATION: CATALYZING CLIMATE-RESILIENT AGRICULTURE AND BIODIVERSITY CONSERVATION

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ABSTRACT – This paper is a concept and course proposal examining the feasibility of introducing space biology concepts and methodologies at the graduate level in the resource constrained Philippine educational system amidst prevailing opinion that it is a luxury for wealthy nations only. The rationale is to spur local and practical innovation and functional breakthroughs in climate-resilient agriculture, agroforestry, ecosystem biodiversity and environmental health. Selected literature, course outlines and syllabi relevant to the topic were reviewed using Safari and Google Chrome search engines. Key words include space biology, space science and space biology course outlines. Websites of the National Aeronautics and Space Administration (NASA) and the Philippine Space Agency (PhilSA) were visited to see current activities. Only selected literature essential to the writing of the course proposal were handpicked from the outputs generated. Results revealed that contrary to the belief that space biology is tailored fit for rich countries only, it has shown highly practical or functional utility and is a crucial strategic catalyst in coping with agriculture, forestry and ecosystem biodiversity conservation and environmental health vulnerabilities in developing economies. This is particularly useful and empowering in the Philippines, being in the Yuxi Circle and the Pacific Ring of Fire, where scarcity of resources and uncertainties of climate change impacts are evident. Space biology principles offer critical insights on how to manage limited resources in a highly stressed space environment which can be translated into managing severely degraded and threatened landscapes in the Philippines experiencing triple planetary crisis by embarking on biotechnological innovations like plant root and microbe symbioses, biofertilizers and biopesticides. The proposed course outline on space biology demonstrates the application of the field in agriculture, biodiversity conservation and environmental health. The strategic integration of space biology into the Philippine universities and hence, Science and Technology (S&T) would transform our country's position as mere observer and consumer of global space technology into a self-supporting visionary and trailblazer in today's space-based economy.

Keywords: Pacific Ring of Fire, Space-based economy, Space Science, Triple Planetary Crisis, Yuxi Circle

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INTRODUCTION

The world's quest to explore the space has been believed to be unrealistic and/or a second priority for the poverty-stricken countries (TWAS 2026) like the Philippines. Public perception seems to suggest that only wealthy nations need to embark on luxurious space explorations as they have the resources needed to finance the expensive space travels and explorations. But, integrating space science, particularly, space biology into the graduate level of the Philippine educational system may provide useful scientific approaches for addressing environmental and agricultural challenges, thus enabling us to survive amidst environmental crises, the triple planetary crisis, brought about by climate change anomalies, environmental pollution and biodiversity loss (Echoes et al. 2024) which started at the onset of the Anthropocene (Ellis 2018).

Different specialized fields of space science will have specific focus. Space biology investigates responses of plants, animals or microbes to spaceflight conditions. Space biomedicine is concerned of human health in space. Space ecology focuses on ecosystems, biodiversity and conservation. And space agriculture examines crop production and food systems under space or space-like conditions. Learning space biology enables students to recognize the endangerment of human life due to loss of life support system caused by environmental degradation (Karieva 2012 and 2014, Karieva and Marvier 2012, Ong et al. 2002), hence, quest for better alternatives and fundamental mechanics to enhance and sustain biological resilience should be a crucial priority. In a country like ours, situated within the Pacific Ring of Fire (Ramos 2021) and within the Yuxi Circle (Rae 2022), where anthropogenic pressures, typhoons, earthquakes and other disturbances aggravating climate anomalies and vulnerabilities, space biology class integration would train the next generation of Filipino researchers with both practical and radical problem-solving scheme (Alindayu 2026, Halos et al. 2025).

There is a need to study how life responds and survives with microgravity and cosmic radiation, two dominant conditions in space (Clement 2006, Kern and Siew 2026). Programs organized by the National Aeronautics and Space Administration or NASA (NASA 2024), show discoveries and innovations in hyper-resilient crop engineering and closed-loop resource management. The Philippine Space Agency or PhilSA, (PhilSA 2024) has been engaging young students in space biology studies such as "Herb in Space" initiative, investigating how seeds respond in the presence of cosmic microgravity. Moreover, PhilSA started developing cost-effective Random Positioning Machines (Cac et al. 2024) proving that microgravity experiments can be simulated in resource-controlled university laboratories. Integrating space biology in the Philippine university curricula can transform classrooms, into a springboard for urgent, immensely useful and highly practical solutions customized for the marginalized Filipino society.

The primary objective of this paper is to examine the feasibility of introducing space biology concepts and methodologies and how this can be incorporated at the graduate level of the Philippine educational system to spur local and customized practical innovation and functional breakthroughs in climate-resilient agroforestry, ecosystem biodiversity, environmental health or mere space exploration initiatives. Specifically, it aims to: 1) discuss the relevance of space biology education in a developing country like the Philippines, 2) explain space botanical insights to Philippine climate resilient agroforestry and ecosystem biodiversity, and 3) propose a curricular outline for space Biology as an elective course at the graduate level.

This paper provides insightful applicability of space biology for multiple sectors such as socio-economics and education, arguing the traditional perspective that space biology or space science for that matter, is for the developed countries only (TWAS 2026). Space biology indeed is an urgent practical need for everybody.

METHODOLOGY

The paper is basically a proposal for the institution of a course on Space Biology in a graduate biology program or related disciplines in the Philippines. Relevant literature and course outlines/syllabi on space biology, were generated from the internet using Safari and Google Chrome search engines. Key words such as space biology, space science and space biology course outlines/syllabi were used. Websites of relevant agencies like PhilSA, NASA and TWAS had been consulted regarding current initiatives and activities. Since the paper is mainly a course proposal for Space Biology, only essential and highly relevant papers crucial and indispensable for the document, were handpicked. In case of articles and books, the abstracts were first read and if the contents were highly relevant, the entire paper was examined. For the course outlines and syllabi, the entire content was examined and critically studied if applicable in Philippine setting. Selected literature on the overview of the state of the Philippine environment, biodiversity and agriculture during the Anthropocene were reviewed as well, and tried to relate how space biology can address the current challenges. The final course proposal had been presented during the First Space Biology Forum held at the Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Banos on December 18, 2024. It was critiqued by the participants and comments were taken into account. The current course outline incorporated the comments by the participants in that said forum.

RESULTS AND DISCUSSION

Relevance of Space Biology Course in Philippine Education

Studying space biology in the Philippine context where S&T budget is rather spent in the uplifting of the poverty-stricken population, is always met with ridicule, basically because of the serious rivalry and conflict with the immediate socioeconomic demands (TWAS 2026). But if you are to argue space biology as a science with high practical or functional utility (Kern and Siew 2026), everyone would realize that it can serve as a crucial strategic catalyst in coping with agroforestry and ecosystem vulnerabilities and environmental health issues (Laserna 2025). Being situated in the Pacific Ring of Fire as mentioned earlier (Ramos 2021), the Philippines is fundamentally prone to disasters, worsening climate anomalies, destructive typhoons, and environmental oscillations and instabilities that jeopardize food productivity as staples like rice and corn or livestock and poultry as well (Halos et al. 2025). This is alarming since as part of the Yuxi Circle (Rae 2022), its human population is burgeoning year after year. However, space biology concepts would force plants and agroforestry systems to adjust to worst stressors such as microgravity and cosmic radiation (Cac et al. 2024, NASA 2024).

Investigating how prime agricultural crops and representative species from various ecosystem types cope with cellular, subcellular and phenotypic stress dynamics with artificial gravity would allow researchers to pinpoint and isolate precise genetic or metabolic pathways that enhance survival amidst stressful environmental conditions (PhilSA 2024). Series of experiments (PhilSA 2025) can be launched to explore and examine the physiological adaptations of various plant propagules (seeds, spores, cuttings, suckers, rhizomes, corms or plantlets) under stressed conditions simulating space environment. Investigations of PhilSA (2024, 2025) using mung bean germination under stressful saline conditions offer important insights in saving crops under degraded, flooded, or arid and barren soils. This study can be replicated in many universities and research institutes using other crops, ecosystem markers as mosses, lichens, liverworts, or animals too (Hernandez 2026). The more diverse species tested, the better and more informative as to the mechanism of survival in harsh environs, including how animals and particularly human sustain public health amidst ongoing triple planetary crisis.

Contrary to common beliefs, these explorations do not necessitate prohibitive space missions (PhilSA 2025). This is the reason why many think that space biology is for well-off countries only. But, knowing how organisms respond to stressful space conditions can be done on earth by simple space simulation techniques as clinostats and Random Positioning Machines (RPMs) (Cac et al. 2024).

Space Botanical Insights to Philippine Climate-Resilient Agroforestry and Ecosystem Biodiversity

Space biology (botany) would normally bypass the slow timeline required to subject organisms in natural stressors as extreme temperature, dry spell, waterlogged conditions, earthquake, etc. (Laserna 2025). You have to wait for long seasons to do these experimentations. However, space biology would use microgravity and simulate space conditions to attain the same goal (Cac et al. 2024). This is very relevant in agroforestry where trees are intercropped with root vegetables (sweet potato, taro), plantation crops (coffee, cacao, coconut) and are subjected under multi-stress conditions as rapid soil erosion, extended droughts or waterlogged state in order to select the most fit. This would usually take several years. However, with space biology, plants in simulated space conditions (Cac et al. 2024, Gamana et al. 2026) undergo severe mechanical, cellular and subcellular stress, which spark conserved evolutionary pathways and primordial stress response networks, enabling the species to stay alive under harsh environmental conditions.

Results of spaceflight experiments of NASA (2024) explained changes of the cell-wall composition of plants, particularly the regulation of the synthesis of lignin and cellulosic molecules and boosting specific heat-shock proteins and antioxidants, helping preserve cellular soundness and viability under cosmic stress. Filipino biotechnologists may contemplate on these trait manifestations both genetic and phenotypic, to bioengineer specific gene mechanisms responsible for resiliency despite environmental stressors (natural and man-made as mining) in agriculture, agroforestry systems and plantations (Cac et al. 2024, Halos et al. 2025, PhilSA 2024, 2025). Likewise, biotechnologists specializing on natural ecosystems may explore similar initiatives. In mangroves and sea coasts, this may boost coastal biodiversity against salinity crises. These ecosystems are protective barriers, the country's main frontliner or bioshield against rising sea levels, common during tsunamis and destructive super typhoon. Space biology studies can investigate how the plant system can manage overwhelming nutrient and moisture restrictions. Studies conducted by PhilSA (2024, 2025) and Gamana et al. (2026) under hypergravity and salinity stresses, revealed data on how plants exclude sodium and retain vital nutrients under damaging conditions. Examining these spaceflight matches and parallels, local ecosystem conservationists and biologists can contemplate and design techniques in plant propagation for native mangroves, beach plants and other coastal species that can enhance restoration of degraded coastal buffer zones. In turn this will ensure survival of native biodiversity amidst worsening marine water encroachment and soil/water salinization.

In the same manner, it is good to map and contemplate on the role of space biology on how to rehabilitate degraded forest landscapes (PhilSA 2024, 2025, Cac et al. 2024, Gamana et al. 2026). These are those landscapes damaged by irresponsible mining, indiscriminate logging and extensive quarrying. In these utterly ripped landscapes, every milliliter of liquid water, molecule of carbon dioxide, and milligram of nutrient must be superbly salvaged and reused to help existing organisms survive. In a spacecraft, resources are critically scarce, matching with the resources of a heavily degraded landscape described above (Hernandez 2026). Therefore, applying space derived knowledge on plant root-microbe mutualistic relationship—specifically how mycorrhizal fungi and nitrogen-fixing bacteria adapt and enhance uptake of nutrient in unfriendly, soil-free, or nutrient-starved environments (Kern and Siew 2026, PhilSA 2025, Sato 2016), Filipino ecologists and biotechnologists can innovate and continue to boost high-efficiency bio-fertilizers as is done in the University of the Philippines Los Banos BIOTECH laboratories (UPLB-BIOTECH 2026). Specialized microbial inoculants like UPLB BIOTECH NitroLink, Nutrio, NitroPlus, MYCOVAM, Oryzinc, PhosphoLink and many others can enhance growth of crops and endangered native trees for quicker reestablishment in heavy destroyed ecosystems and landscapes.

Proposed Outline of a Space Biology Course in the Philippines

Having known the relevance of space biology not only in developed countries, but more so in developing economies as well, where anthropogenic activities swiftly degrade resources, aggravating triple planetary crisis, an elective course may be launched at the graduate level. Several course outlines were studied (Venkateswaran 2025, The University of Arizona 2026, The University of Edinburgh 2026, UCD 2026). A tentative course outline was drafted and customized for the Philippine setting and is presented in this section.

Tentative Course Outline on Space Biology

Botany 291: Special Topics on Space Biology

Course Credit: 3 hours lecture, 3 units

Prerequisite: None

Course Description: The course examines the physiological, cellular, and genetic responses of living organisms—with an emphasis on plant systems and micro-ecosystems—to the extreme environments of spaceflight such as microgravity, hypergravity, altered gas dynamics, and cosmic radiation. Students will analyze global space biology datasets and learn how to translate these insights into practical, earth-bound solutions to address triple planetary crisis, problems in tropical agriculture, agroforestry systems and conservation of threatened biodiversity. The course requires students to write review papers based on global databases and hands-on study using low-cost, practical microgravity simulators designed for the limited resources of Philippine universities.

Learning Outcomes

At the end of the semester, the students should be able to:

1. Assess the relevance of space biology in Philippine education and in the Philippine society;
2. Evaluate current advances of space biology literature in the context of the era of Society 5.0;
3. Develop a research proposal applying space biology concepts to a Philippine agro-environmental problem aggravated by the impacts of climate change.

1. Introduction
    - 1.1 What is space biology? (concepts, current trends)
    - 1.2 Importance in studying space biology (relevance to diverse organisms and to humanity)
2. Review of ecology theories, ecosystems and ecosystem types
    - 2.1 Ecology theories and principles
    - 2.2 Basic ecosystem structure, functions and processes
    - 2.3 Ecosystem types and their unique characteristics
    - 2.4 Ecosystem health and vulnerabilities
3. Planetary health
    - 3.1 The planet earth
    - 3.2 The Triple planetary crisis
        - 3.2.1 Climate change crisis
        - 3.2.2 Biodiversity loss
        - 3.2.3 Environmental pollution
4. Plant responses to stress and crisis
    - 4.1 Morpho-anatomical
    - 4.2 Physiological
    - 4.3 Cellular
    - 4.4 Molecular
5. Space as an ecosystem
    - 5.1 Structure and dynamics in space
    - 5.2 The harsh environmental conditions in space
    - 5.3 Effect of space environment on plants and other organisms
        - 5.3.1 Plant gravitropism and stress physiology
        - 5.3.2 Cellular and molecular mechanics under altered gravity
        - 5.3.3 Genomic adaptations to extreme cosmic stressors
6. Simulating life in space
    - 6.1 Designs for space simulation studies
    - 6.2 Remote sensing and bioinformatics for space simulation studies

6.3 Satellite technologies for space simulation studies

6.4 AI for space simulation studies

7. Applications of space biology studies

7.1 Translating data to tropical agriculture & agroforestry

7.2 Breeding stress tolerant varieties of farm crops and native tree diversity

7.3 Root-microbes symbioses (N_2 fixation, mycorrhizal association, etc.)

7.4 Ecosystem and landscape rehabilitation

7.5 Public health and policy amidst climate crisis

8. Space biology colloquium

Special lecture, laboratory demonstration, seminar, workshop will be conducted by invited space biology experts

9. Prospects for life elsewhere in the solar system

Assessment strategies and required outputs:

1. Examinations
2. Publishable review paper about space biology research applications to address climate change impacts, biodiversity loss and environmental pollution
3. Scientific paper on independent laboratory simulation studies

This tentative course outline can be enhanced and evolve through time. To start with, the course can be offered as an elective special topic course. After sometime, as the course content and pedagogy improve, it can be formalized as a regular offering.

CONCLUSION

Having space biology integrated into the university curricula of developing nations like the Philippines, is a bold attempt to change traditional perspective considering advanced science as luxury for developed economies only. Indeed, it is urgently needed regardless of the economic status of any country. Its concepts help address current pressing issues in agriculture, forestry, environment, public health and policy amidst worsening climate anomalies during the Anthropocene, particularly, in the Yuxi Circle. Space biology has a practical answer and solution to address triple planetary crisis arming next generation of Filipino researchers and inventors with biotechnological knowledge and skills, opening local opportunities in bioregenerative systems and realistic research innovations and development initiatives. In the near future, embarking on space biology will enable the Philippines to evolve from a mere spectator or observer and consumer of global technology advances into a groundbreaker, trailblazer and self-supporting visionary in today's space-based economy.

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