# Synthesis of Bio-regenerative Food Systems on Martian Regolith using assorted Inoculum, Hydrogel Netting and Phytoremediation Techniques

Proof of concept for foundational habitats and sustainable anthropogenic practices in extreme and non-terrestrial environments through novel methods of in-situ resource utilization.

*In line with contemporary research conducted in the field of* **astrobiology** *and* **biogeochemistry** *by NASA's Perseverance Rover, CheMin, MSL Analyses,* **applied microbiology in histosols** *by ETH Zürich (in conjunction with the USDA) and* **micro-biopolymer** *design and synthesis by Stanford's Doerr School of Sustainability.*

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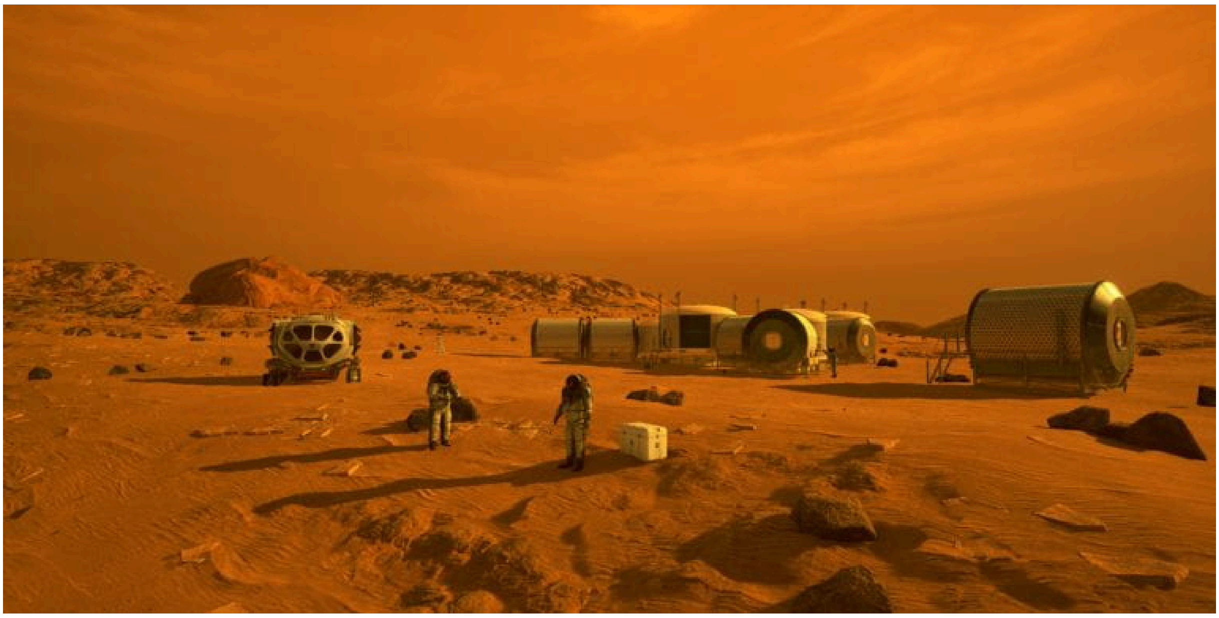
## Introduction

With the advent of an impending space race (concerning habitability of Mars) between private corporations such as SpaceX and subsidized space forces of various governments, a chief concern is that of food for the astronauts and consequently the production en masse for future habitants. With implications that are equally applicable to extreme environments here on Earth and incoming climate crises, **bioremediation practices** are more important than they ever were in the anthropocene.

On a more focused note, it serves common sense that terrestrial input towards bioregenerative systems on site is simply not economically viable with current rocketry or even foreseeable technological advancements. Thus, crewed missions and habitat onsets in the future will both require **in situ resource utilization (ISRU)** to establish sustainability. Bioregenerative food systems or their applications in the context of "astro farming" is the second most important tenet of **bioregenerative life support systems (BLSS)**, the first being air quality control.

The use of native Martian surface strata materials is of utmost importance in the procedures required to establish sustainable bioregenerative food systems. They fare better than current approaches to grow food such as **hydroponics, aquaculture** and **mineral loading in artificial growth beds**, in terms of initial input, sustainability and yield. However, extensive studies in this field are few and far between and consist of many technical liberties taken in experimental design.

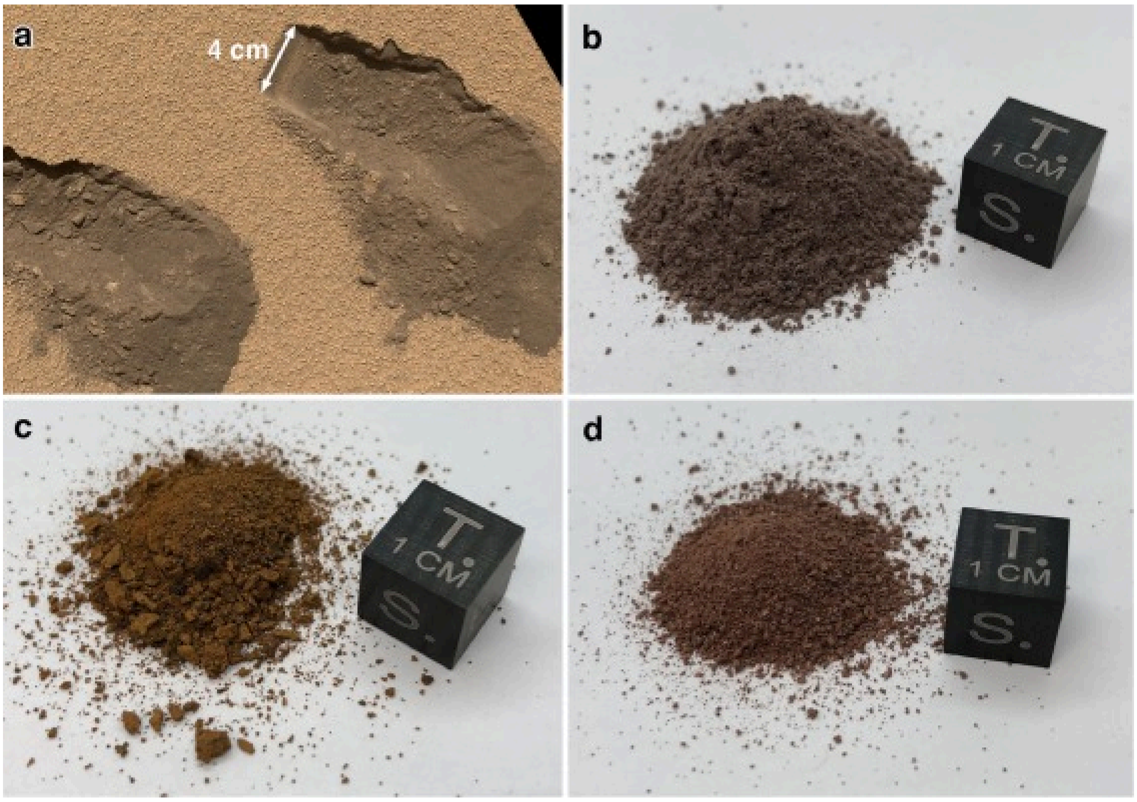


## Context

One of the main reasons for the lack of research is the multidisciplinary collaboration and interest regarding the matter. People often disregard soil if they even think about it in passing, not knowing how crucial it is to our current mode of existence.

On a more technical frame of reference, the hurdles to overcome in the experimental design such as but not limited to; the effects of partial gravity, simulating the limited availability of oxygen and water, particle size variation, sterility assurance (in the context of microorganisms tainting experiment outcomes) and most importantly - simulating a spectroscopically, dimensionally and physicochemically analogous regolith sample.

Martian regoliths are not available on Earth; therefore, space research studies are conducted on regolith simulants that replicate the physicochemical properties of these extra-terrestrial regoliths (as assessed in situ by previous and ongoing missions).




Commercially available Martian Regolith simulants

This study provides an overview of the physicochemical properties and mineralogical composition of commercially available Martian regolith simulants and how to utilize the novel in-house produced **MJA-1.**

Subsequently, it describes potential strategies and sustainable practices for treating the regolith simulant to be more akin to terrestrial soil, which is a highly dynamic environment where microbiota and humified organic matter interact with the mineral moiety.

These strategies include the amendment of simulants with assorted micro bacteria and composted bryophytes, which can turn nutrient-poor and alkaline crushed rocks into efficient life-sustaining substrates equipped with enhanced physical, hydraulic, and chemical properties. We also provide details on methods that involve the integration of chelating bioagents and artificial structures for water retention and distribution.

With more studies being conducted in the field of sustainable farming practices we can gain insight into our future on this planet and forecast the primary sector output. Research pertaining towards formulating an accurate regolith simulant and using a plethora of bioremediation and multidisciplinary engineering procedures will enable us to further advance the field of soil science in a global and terraforming contexts.

In this regard, we provide a comprehensive analysis of recent scientific works focusing on the exploitation of regolith simulant-based substrates as plant growth media. The literature discussion helps identify the main critical aspects and future challenges related to sustainable space farming by the in situ use and enhancement of Lunar and Martian resources.

## Problem Statement

The main question we are trying to answer revolves around the viability of extraterrestrial strata materials being transformed into fertile soil and the efficacy of the "soil" in question, thereafter. Some key elements that this research problem will address are:

1. **The formation of a dimensional, physicochemical, mineralogically and spectrographically similar regolith profile** of the Martian surface (Jezero Crater in particular). The clay minerals abundant in this region as observed through the sedimentation present on rock samples shows promise for a heterogeneous soil body fit for agronomical practices. The addition of sulfates, ferrihydrite, anhydrous salts and perchlorates with trace amounts of heavy metals also provides a hurdle as commercially available simulants are not accurate in recreation. Crushed mafic material may present advantages towards recreation.
2. **The formation of the hydrogel net structure we propose to infiltrate the substrata**, and its effects on *soil water retention*, *soil temperature* and *void content analysis* (with the effects of Martian gravity of 0.34g taken into account).
3. **The effects of phytoremediation techniques we employ and their efficacy** compared to the control soils. The use of *phytostabilization*, *phytovolatilization*, *rhizofiltration*, *phenol removal through phytoextraction* and an *array of assorted inoculum* working to simulate earth biogeochemical cycles (**N, P, S, O, oC, Mg, B**) and form analogous conditions akin to *mollisols from aridisols (implementation of histosol quanta).*
4. **The utilization of all these processes ultimately leads to the measurement of selected crops and their growth, dry mass per unit, useful yield** *in* MJA-1 as compared to a highly productive terrestrial control soil. The results and data collected will be put through two way ANOVA and specialized $\chi 2$ analysis.

Current research lacks the multidisciplinary approach towards the creation of a BLSS through phytoremediation techniques, the use of hydrogel netting in a shallow regolith bed and specialized research methodology with precise conformations. The research to be conducted would answer questions the field of extraterrestrial soil science didn't know it had; - phytoremediation of arid, sterile soils for comparable plant growth and useful yield. The implications will come in handy for generations to come with the impending climate crisis and arid zones of the world affected with saline soils.

## Research Queries and Scope

1. Whether the untreated regolith produces yields similar to control soil.
   - Limiting factors of the regolith to be noted
2. The different factors of the ameliorated regolith -
   - OC, *Metal availability*, *moisture availability*, *particle size and compaction factors*, *salinity amelioration*, *inoculum culture growth*, *active* OC *sequestration*, *peat availability window*,

*seepage of minerals, leeching factors, N-fix bacteria culture,* CEC, *pH amelioration in accordance to the genus of crop in study.*

3. Whether the ameliorated regolith produces yields similar to control soil.
4. An outline for agronomical scaling policies for a foundational community.
   - A temporal outline, potential budgeting and sustainability analysis to be undergone

## Relevance and Importance of the Research

Make it clear what new insights you will contribute, who they are relevant to, and why the research is worth doing.

Literature review

The literature review summarizes, compares and critiques the most relevant scholarly sources on the topic. There are many different ways to structure a literature review, but it should explore:

Key Concepts, Theories and Studies

Compare, contrast, and establish the theories and concepts that will be most important for your project.

Key Debates and Controversies

Identify points of conflict and situate your own position.

Gaps in Existing Knowledge

Show what is missing and how your project will fit in.

Research design and methods

Here you should explain your approach to the research and describe exactly what steps you will take to answer your questions.

Research design

Explain how you will design the research. Qualitative or quantitative? Original data collection or primary/secondary sources? Descriptive, correlational or experimental?

Methods and Sources

Describe the tools, procedures, participants and sources of the research. When, where and how will you collect, select and analyze data?

Practical Considerations

Address any potential obstacles, limitations and ethical or practical issues. How will you plan for and deal with problems?

Implications and contributions to knowledge

Finish the proposal by emphasizing why your proposed project is important and what it will contribute to practice or theory.

Practical Implications

Will your findings help improve a process, inform policy, or make a case for concrete change?

Theoretical Implications

Will your work help strengthen a theory or model, challenge current assumptions, or create a basis for further research?

Research schedule

| Research phase | Objectives | Deadline |
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