Seeding of Large Areas with Biological Soil Crust Starter Culture Formulations

Using an Aircraft Disbursable Granulate to Increase Stability, Fertility and CO_2 Sequestration on a Landscape Scale

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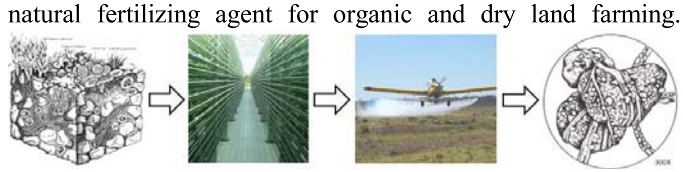
Abstract: ***Microbial consortia found in biological soil crusts can mitigate climate change and assist agriculture. Cyanobacteria and other biological soil crust (BSC) microorganisms have fulfilled essential roles in the global ecosystem by fertilizing arid soils and stabilizing them from wind and water erosion. Using only photosynthesis, ambient minerals and water, these microorganisms directly capture atmospheric carbon dioxide and nitrogen. As the crust matures, sugars and nutrients biologically manufactured by the crust infuse down into the soil for the benefit of other plants and microorganisms. The development of aircraft and GPS based technology to selectively seed starter cultures of BSCs across large landscapes will enable the resultant colonies to become a highly scalable agent that naturally mitigates the effects of climate change and can find application both in arid or desert lands and for agriculture. This paper will present the case for scaling up the research, development and application of a cyanobacteria based soil crust inoculant called TerraDerm when it is applied to arid land ecosystems and AgriDerm when it is formulated for agricultural ecosystems.***

Keywords: Biological Soil Crusts; Cyanobacteria; TerraDerm; AgriDerm; Photobioreactors; Carbon sequestration; Net Primary Productivity.

INTRODUCTION: Global climate change, ground surface anthropogenic activity and livestock grazing have destroyed significant amounts of established soil crusts that normally would take decades or even centuries to naturally reestablish. The resulting erosion, dust generation and lack of natural fertilization have decreased the soil's net primary productivity (NPP) and decreased the atmospheric CO_2 sequestering capabilities of affected lands. Global conversion of historically vegetated landscapes to agriculture, use of factory fertilizer and watershed mismanagement has resulted in soil being periodically exposed to wind and water erosion. In each case reestablishment of historical Biological Soil Crusts (BSC's) or establish native cyanobacteria colonization will increase soil stability, fertility and ability to sequester atmospheric carbon dioxide.

This paper discusses the prospective requirements, development, use and impact of a low-cost BSC inoculant designed to be capable of distribution in crop duster fashion over large scale landscapes where it would naturally propagate microbial consortia into stable crusts and create a positive environmental and economic result. Starter cultures made from indigenous microorganisms and formulated for agriculture will enable their use for soil erosion control and as a sustainable natural fertilizing agent for organic and dry land farming.



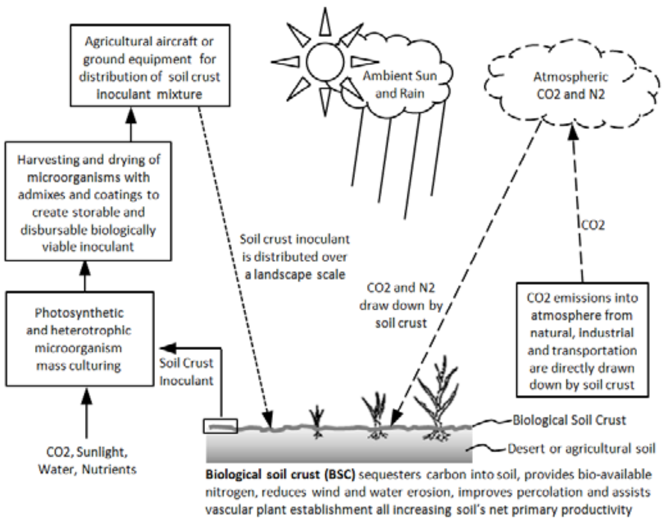
Suitability Parameters for Establishing or Re-Establishing Cyanobacteria in Soil

Cyanobacteria utilize solar energy to sequester atmospheric carbon into plant sugars, glue together soil grains and fix nitrogen for the benefit of other plant growth. In order to propagate the photosynthetic microorganisms must be seeded onto, and remain on, the top illuminated skin of unshaded soil. With respect to hydration, soil cyanobacteria can be found surviving in some of the driest, hottest, and most inhospitable locations on the planet. However, the rate of colony establishment, soil stabilization and fertilization is dominantly throttled by the duration of illuminated hydration at moderate temperatures.

The timing of inoculant application to correspond with surface stability and high moisture conditions is important to enable it to begin binding the soil grains before it itself is buried by adjacent windblown soil. Cyanobacteria fix their own nitrogen from the atmosphere and so in combination with ambient water and carbon dioxide they have over 97% of the elements needed to accumulate biomass. However, in areas that are undisturbed yet historically have never been colonized by soil crust then it is possible, if not likely, that there are missing micronutrients. In this case, it may be practical to combine the addition of these missing micronutrients during airborne re-inoculation.

CYANOBACTERIAL USE, FORMULATION AND APPLICATION

The focus of this paper is the aerial seeding of a viable inoculant to affect atmospheric carbon capture although erosion control, dust abatement and natural fertilization are equally important. Experimental rates of application as small as 0.2 Kg per hectare of the active cyanobacteria component have increased the nitrogen and carbon uptake of soils. However, considerably higher quantities of inoculant plus additional components such as soil tackifiers, water storage polymers, additional nutrients, vascular plant seeds, and distribution agents would all be combined in the design of an application-specific mix. We are proposing as much as 10 Kg/hectare of the active microorganism components that in addition to cyanobacteria would contain fungi, lichens, other bacteria. These would be combined with approximately 10 Kg/hectare of the non-biologic support components.



TerraDerm and AgriDerm processing will consist of four steps. First, soil crust microorganisms found in the sunlit skin of indigenous soils are mass cultured in liquid growth media using a combination of light fed photobioreactors and sugar fed bioreactors. The microorganisms are strained from the media using a capillary belt arrangement that harvests various sizes and types of microorganisms equally onto a thin damp mat of undamaged living biomass. To the damp mat are added a variety of 1) Anti-oxidants such as beta carotene 2) Xeri-protectants such as trehalose and other sugars to prevent cell damage from rapid desiccation 3) Growth micro nutrients and sugars to feed the non-photosynthetic cohorts during initial establishment. 4) Quartz and clay fillers to facilitate mat granulation without cell damage. 5) Optional non-operational unique gene sequences to track growth propagation. 6) Vascular plant seeds like restorative grasses that may work in concert with the cyanobacteria. And 7) Facilitating microorganisms that increase the physical distribution, germination and survival of the cyanobacterial based inoculant. Once all these components are layered on the wet mat it is dried on a continuous low-temperature belt process then reduced to millimeter sized spheres without harm to the viability of the microorganisms. The spherical granules are then fed through a fluidized bed coating process to add functions of anti-caking, anti-friction, delayed-release, spread pattern tracers, and additional tackifiers or biologics that aid the viability and effectiveness of individual formulations.

While ground spreading equipment could be used for distribution, the prospect of spreading using agricultural aircraft permits the cost-effective application at the landscape scale without disrupting or further damaging the existing soil surface. As new soil crust matures, measuring the quantity of nitrogen and carbon found in the soil surface indicates the crust's growth rate and its fertilizing and erosion stabilization influence.

Technological and IP Approach to Landscape Scale Cyanobacterial Seeding:

By enabling aircraft based soil crust inoculation projects from individual ranch to entire landscape scales can be considered. A cornerstone proposition of this paper is that an aircraft disbursable formulation of inoculant can be both effective on-the-ground and can be economically practical to produce and use. A proof of principle laboratory demonstration is getting underway at the University of Colorado as this paper is being written. Although considerable challenges remain, the environmental and economic benefits of successful commercial deployment are significant on a national and global scale. For this reason the author has published the following fundamental intellectual property (IP) into the public domain to enable unrestricted research and development improvements: "Production and Application of an Aircraft Spreadable, Cyanobacterial Based Biological Soil Crust Inoculant for Soil Fertilization, Soil Stabilization and Atmospheric CO_2 Drawdown and Sequestration". Information on this publication and others is provided at the end of this document.

Particle Design and Equipment for Aircraft distribution:

The use of agricultural aircraft to distribute inoculums enables large amounts of ground to be covered quickly without damaging existing ground flora by moving equipment across it. In example, the Air Tractor AT-802a, a 60 foot wingspan single engine agricultural aircraft, can carry 4000 Kg of agricultural dispersant. At an envisioned distribution rate of 20 Kg per hectare one flight would be able to inoculate 200 hectares of surface area. A review of literature on airborne distribution of particles suggests that a particle of approximately 0.8 mm diameter could be precisely laid upon the ground from a low flying aircraft. At a nominal weight of 0.2 milligram each, 20 Kg would yield 100 million particles sufficient to lay one particle on each square centimeter of a hectare. This density attempts to balance the aerodynamic needs of air dispersal with minimizing the microorganism's horizontal propagation distance required for infill.

With electronically actuated drop systems having GPS controls the aircraft can be used somewhat like a giant ink-jet printer to lay inoculant precisely onto the GPS defined patches of landscape or fields. The technology being proposed largely encases the inoculant components in a sugar matrix that when dissolved diffuses the microbes and other non-soluble components directly into the soil grain matrix.

Healthy Soil Crust Impact on Increasing Terrestrial Carbon Sequestration:

The presence of a healthy soil crust increases terrestrial carbon storage via four mechanisms: a) A mature crust may uptake up to 30 gms C/m^2-year; b) Cyanobacterial crust may accelerate the growth or establishment of vascular plants such as grasses that, even in arid lands, may sequester up to 100 GmsC/m^2-year in combined above ground and below ground stores; c) Crusts improve soil resistance to wind/water erosion and improve water retention which can reduce soil carbon uptake loss due to spreading desertification, and; d) Healthy crusts reduce landscape dust generation that can cause premature melting of mountain snowpack and diminished overall plant drawdown. It can be provisionally estimated that by appropriately re-inoculating damaged soils they may have an increased aggregate terrestrial carbon sequestration and mitigation potential from all mechanisms totaling up to 100gmsC/m2-year averaged across applicable lands. This would be equivalent to one ton of increased yearly carbon uptake or mitigation per treated hectare of land that is further equivalent to the drawdown or mitigation of 3.6 tons of atmospheric carbon dioxide from each hectare each year.

It is within reason that previously barren but receptive soils could amass a total of up to 1 Kg of additional carbon per square meter of soil in combined aboveground and belowground biomass over the decades following inoculation. How many decades this would require or whether an entire Kg of carbon or more could be amassed will be dependent on ambient nutrients, water, climate and the degree the land is protected from recurring damage as from over grazing. However, if each square meter were to ultimately draw down 1 Kg of carbon then this would amount to 36 tons per hectare (15 tons per acre) of CO_2 being removed from the atmosphere over that time.

Discussion:

Depending on the quantity of applicable soils, globally significant carbon sequestration is possible. Of the world's 13 billion hectares of land mass, almost 2 billion hectares have been degraded by human activity including 1.1 billion suffering from water erosion, 0.5 billion from wind erosion, and 0.14 billion from nutrient decline. An additional 1.4 billion global hectares are considered non-used wastelands. In agricultural lands, a portion of the 1.4 billion hectares of annual crops and 3 billion hectares of grazing lands could benefit from periodic inoculation with a fast growing formulation of crust designed for higher moisture soils that increased soil stability and fertilization.

Considering the sum of the above lands, it seems reasonable to propose as many as 1 billion hectares of combined agricultural and arid lands may be receptive and could significantly benefit from re-inoculation or new inoculation. Conceptually, if this much land was treated over a decade or longer treatment plan then the aggregate long-term CO_2 drawdown would be highly significant from a climate change mitigation perspective. For example if, on average, each treated square meter's ability to sequester carbon was ultimately increased at maturity by 100 grams/year then this would enable the transfer of 1 billion tons per year of atmospheric carbon into terrestrial soil and plant life.

This would constitute 1 climate stabilization wedge, as defined by Socolow *et al* 2004, of reduced atmospheric carbon loading and is 1/8th of the global GHG mitigation goal. In addition to massive reductions in atmospheric carbon, potential improvements in organic agricultural, grazing yields and reductions in global dust, erosion, and fossil fuel-based fertilizer use would also ensue. Certainly a key aspect of a calculation like this is how much land would be applicable, how much would actually be seeded and what would the actual carbon mitigation effect be over time. The referenced round number of 1 billion hectares and 100 grams of carbon/m2-year are meant to illustrate the general magnitude of a global inoculation program's benefit and not exact expectations which would vary widely between regions.

Production of Soil Inoculant Is Enabled by Algal Biomass Industry Innovations:

The algal biomass industry has produced important innovations in the areas of closed photobioreactors and algal harvesting technology applicable to producing a soil crust inoculant. Closed algal photobioreactors enable the production if pure strains of soil cyanobacteria in precise growing conditions. New disbursed air flotation and belt harvesting technology allows the live harvesting, compounding and drying of microorganisms without loss of viability.

Work to be done:

Demonstration of a mass producible inoculation particle across a variety or outdoor environments, development of a stable mass production process, permitting and evaluation of scaled field trials, and attracting funding attention to this relatively new but important field of research.

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