MICROBES IN MINE RECLAMATION:
BIOECOLOGY, BIOFERTILIZERS, BIOECONOMY

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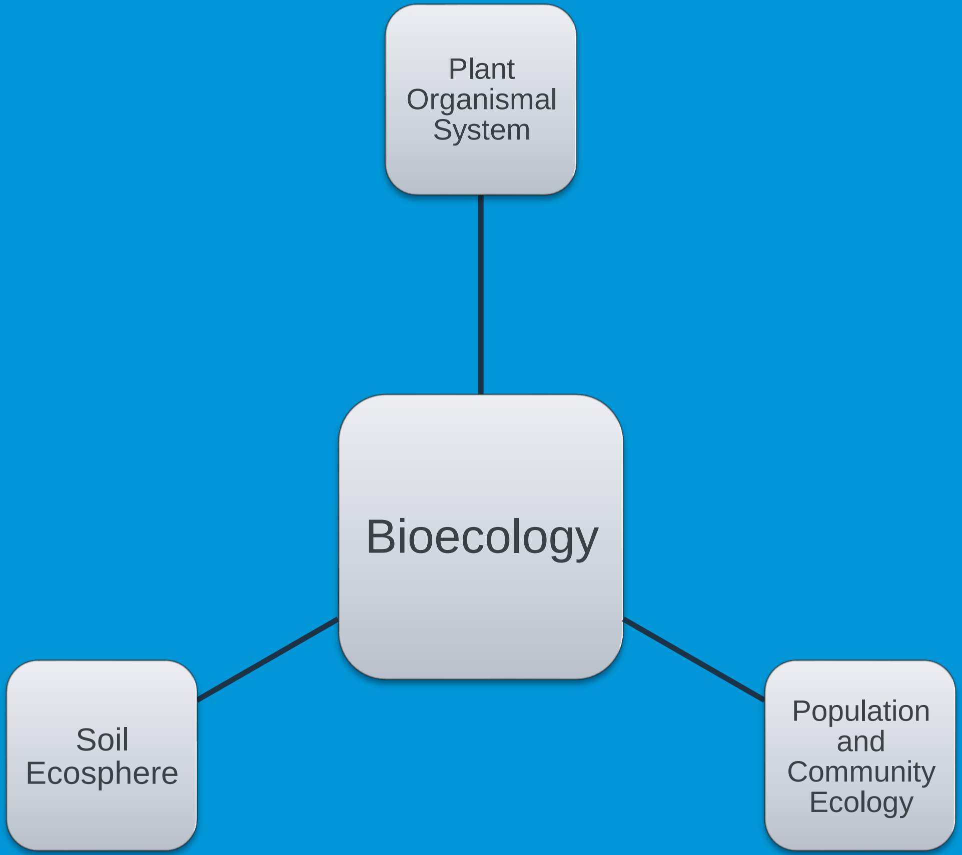
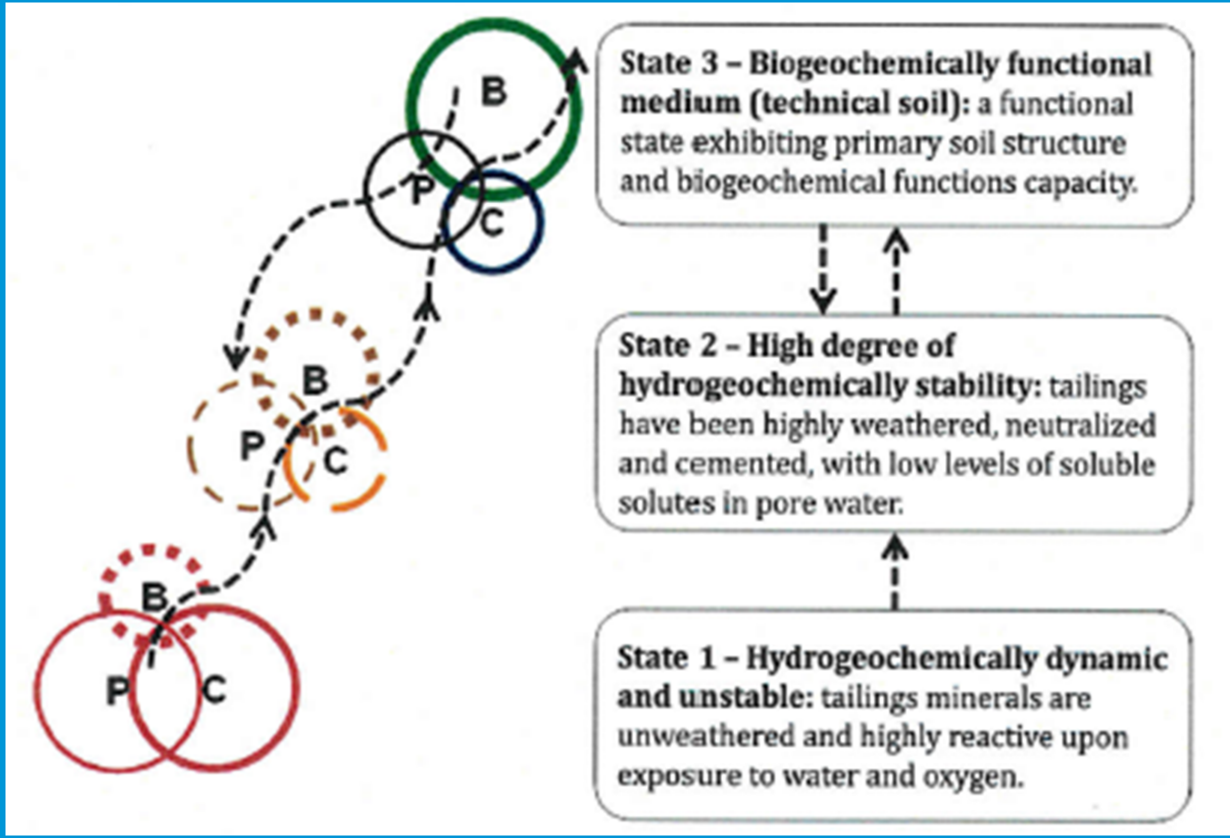
BIOECOLOGY

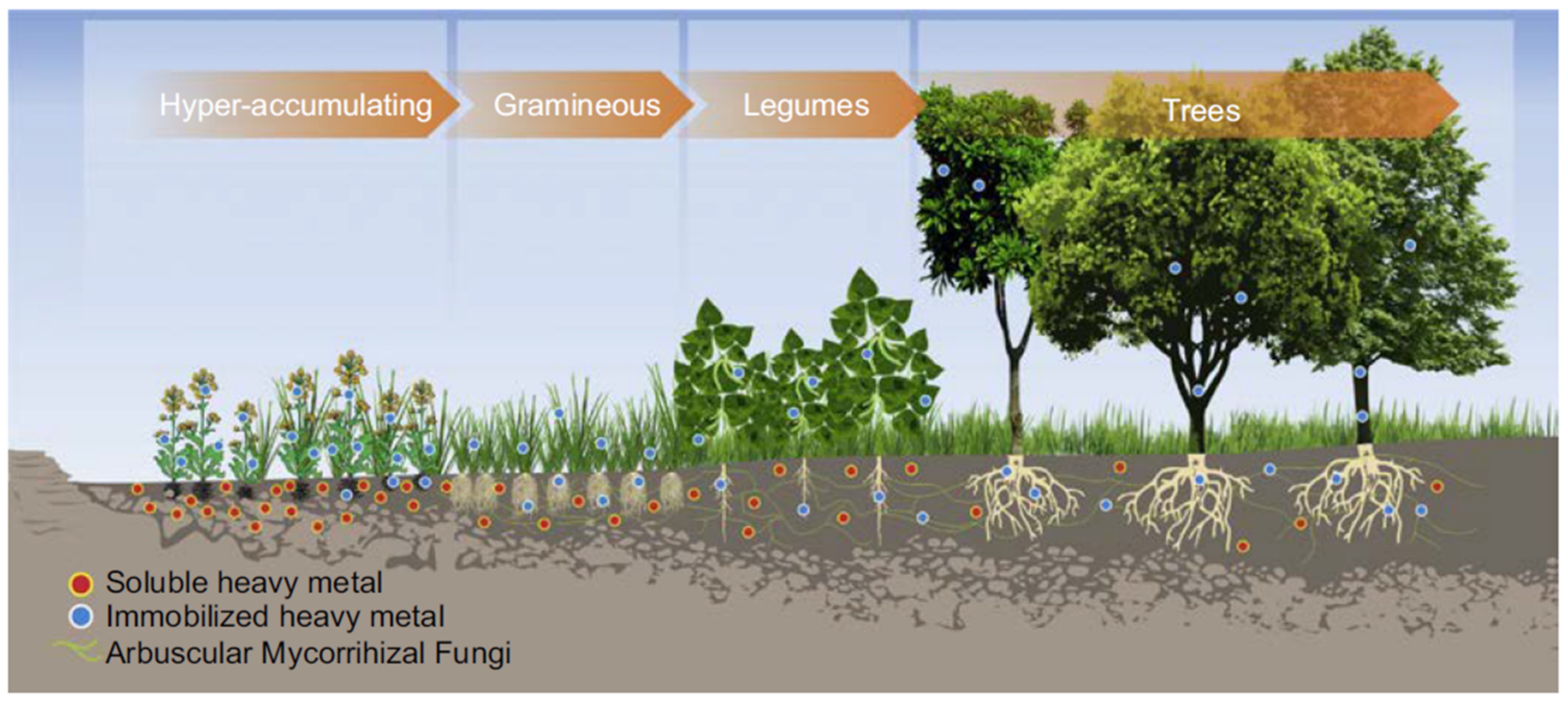

Plant Organismal System
Bioecology
Soil Ecosphere
Population and Community Ecology

PHYTOSTABILISATION



Huang et al (2014) Life-Of-Mine Conference, Brisbane, QLD pp 663 - 674

SUCCESSION

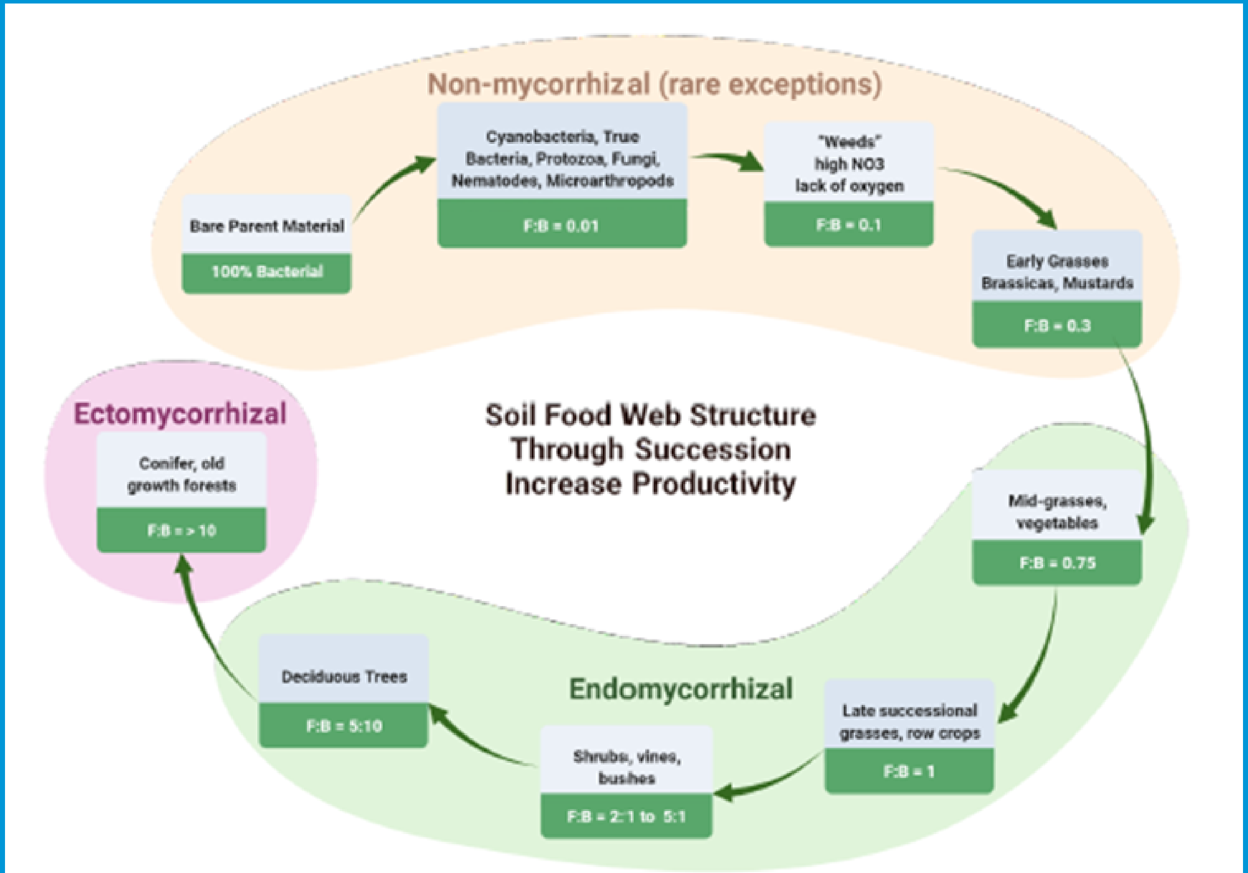


Carrenho et al. (2021), IN Bio-Geotechnologies for Mine Site Rehabilitation pp 261 - 279

SOIL FOOD WEB

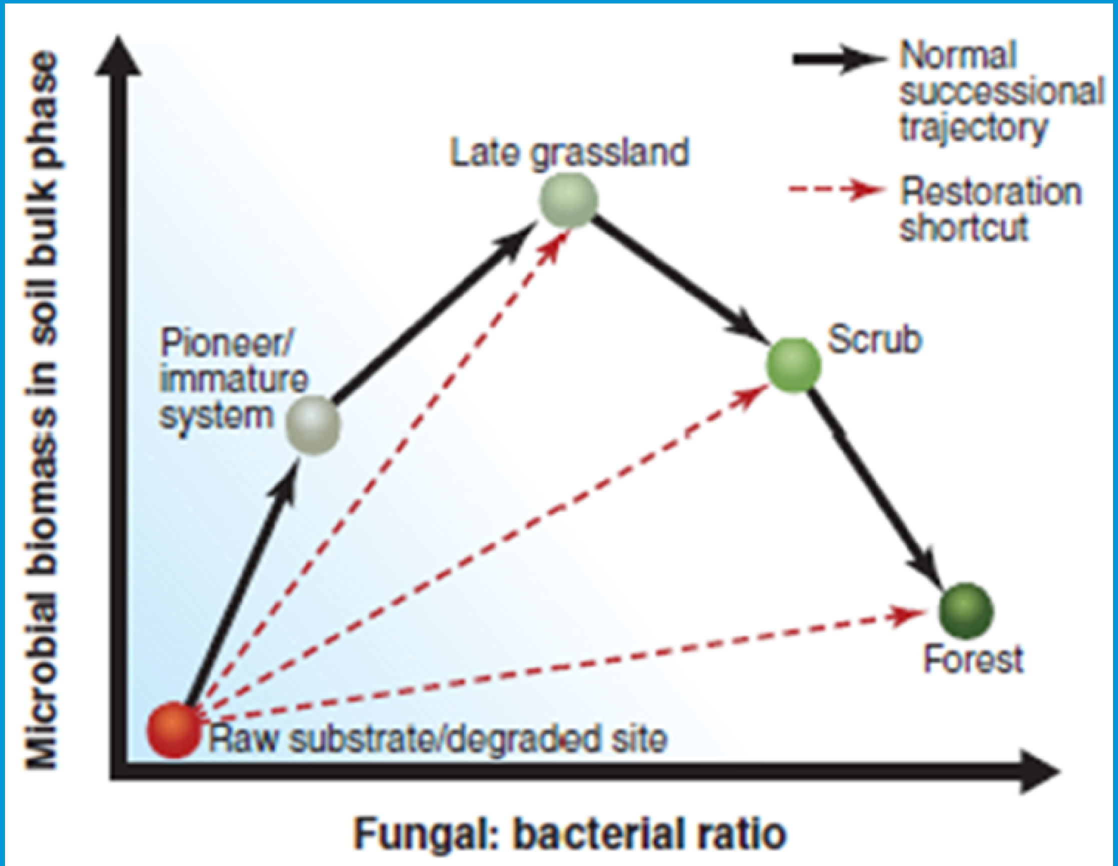
- Decomposers
- Symbiotic Fungi
- Predators

- Soil Formation and Nutrient Cycling
- Plant-Microbe Interactions
- Soil Structure Formation
- Organic Matter Decomposition
- Bioremediation



Soil Food Web (2021)

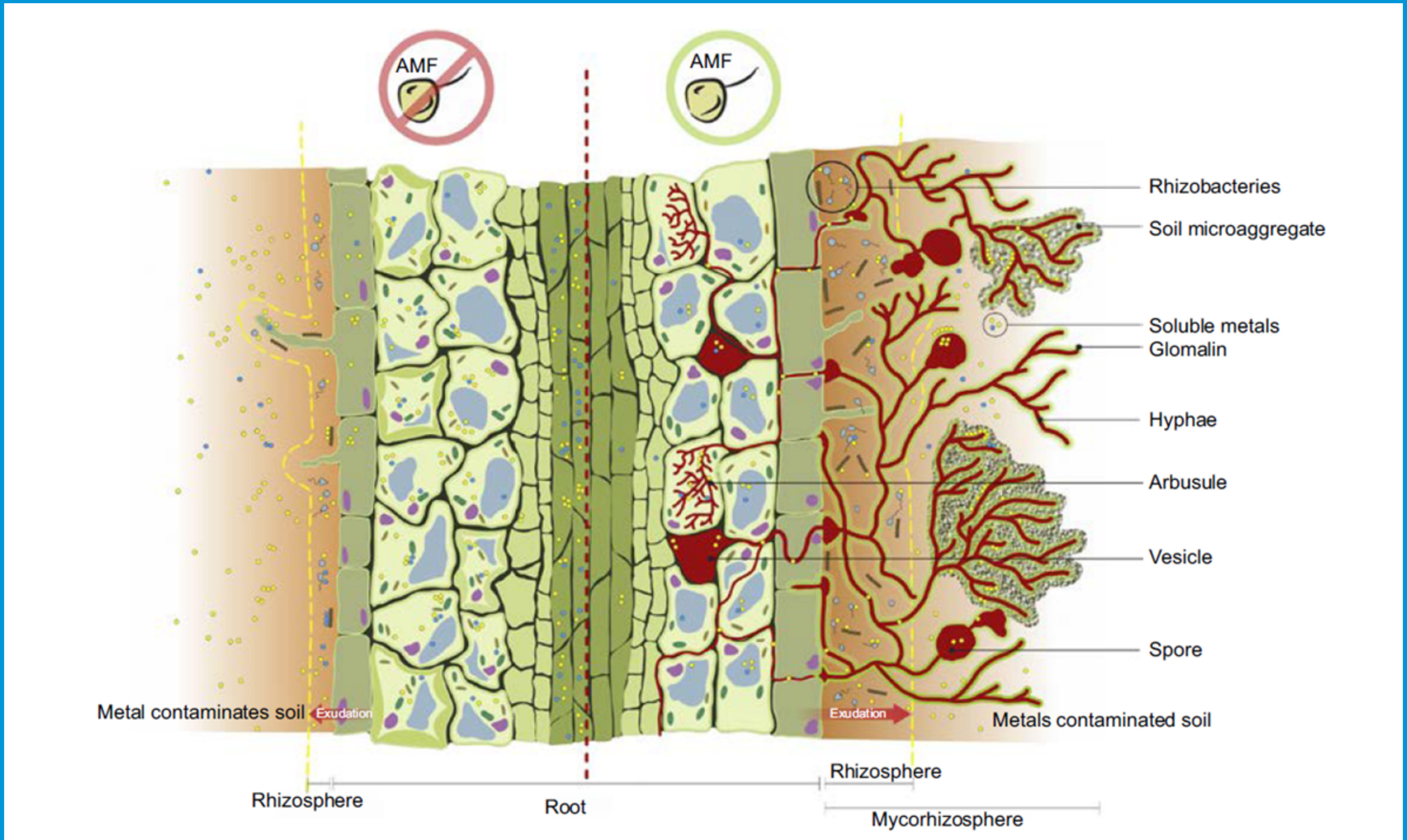
SFW/SUCCESSION INTEGRATION

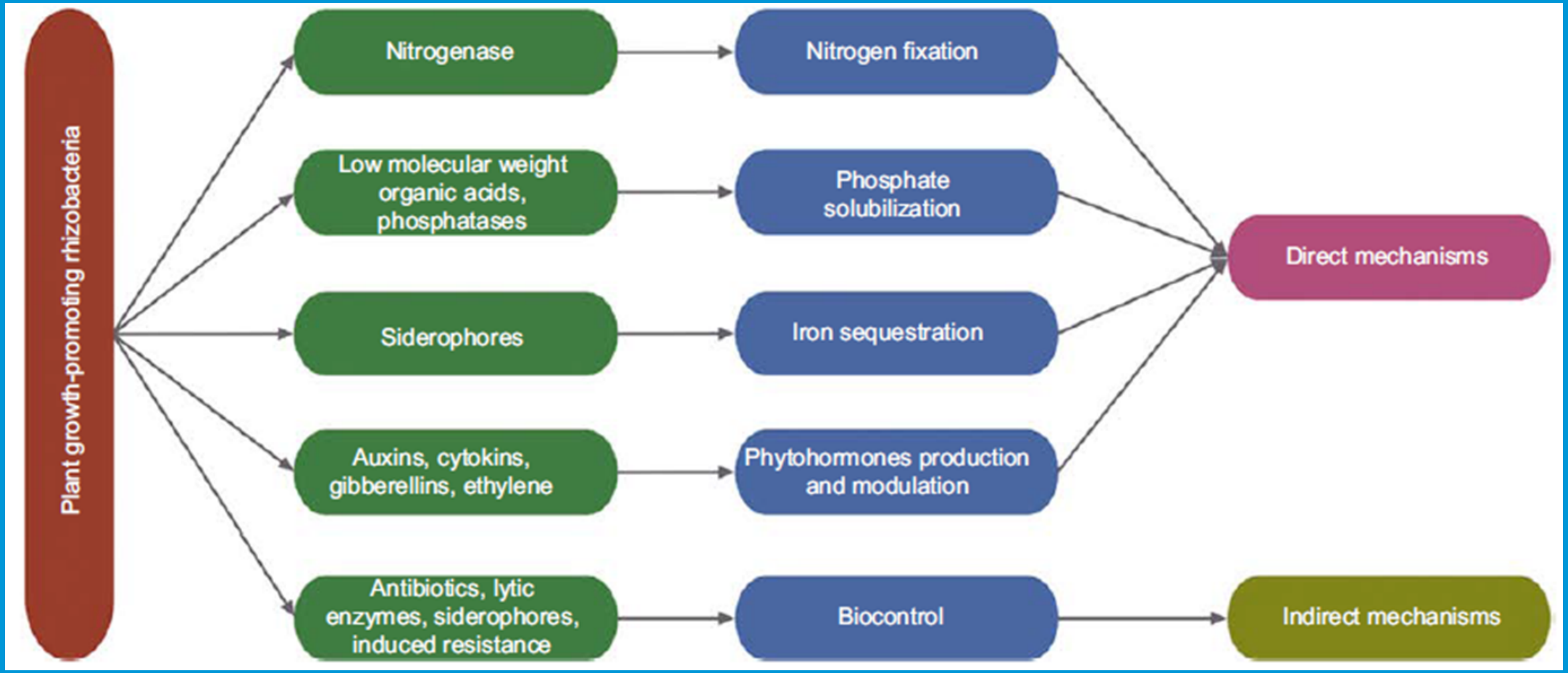


Harris, J. (2003). European Journal of Soil Science, 54, 801-808

BIOFERTILIZERS

- Microbial Inoculants to enhance soil fertility
  - Fix Atmospheric N
  - Solubilize P
  - Produce Growth Producing Hormones
  - Biostimulants e.g. humic acids
  - Mycorrhizal fungi


AMF
AMF
Rhizobacteries
Soil microaggregate
Soluble metals
Glomalin
Hyphae
Arbusule
Vesicle
Spore
Metal contaminates soil
Exudation
Exudation
Metals contaminated soil
Rhizosphere
Root
Rhizosphere
Mycorhizosphere


Plant growth-promoting rhizobacteria
Nitrogenase
Low molecular weight organic acids, phosphatases
Siderophores
Auxins, cytokins, gibberellins, ethylene
Antibiotics, lytic enzymes, siderophores, induced resistance
Nitrogen fixation
Phosphate solubilization
Iron sequestration
Phytohormones production and modulation
Biocontrol
Direct mechanisms
Indirect mechanisms

CASE STUDY – WALDORF MINE

CASE STUDY – WALDORF MINE

Parameter	Units	DTA1-2	DTA3
pH	S.U.	3.5	5.5
Organic Matter	%	2.1	0.9
Organic Carbon	%	1.2	0.5
Nitrate	mg/kg	1.6	1.8
Phosphate	mg/kg	0.1	0.2
Potassium	mg/kg	5.3	6.8
Calcium	mg/kg	60	179
Magnesium	mg/kg	13	14
Zinc	mg/kg	15	19
Manganese	mg/kg	26	49
Copper	mg/kg	20	8.3
Iron	mg/kg	211	66
Boron	mg/kg	0.25	0.10
Sulfate	mg/kg	230	237

Amendment	Rate
Lime	40ton/acre
Biochar	5 tone/acre
Wood Straw/Straw	Crimped to Cover
Richlawn 3-6-3	1.3 ton/acre
Total Nitrogen	3.0%
Water Insoluble Organic Nitrogen	2.9%
Water Soluble Organic Nitrogen	0.1%
Available Phosphate	6.0%
Soluble Potash	3.0%
Calcium	11.0%
Humates	15.0%
Endo Mycorrhizae	
Glomus mosseae	7,500 Propagules
Glomus entunicatum	7,500 Propagules
Glomus intradices	7,500 Propagules
Glomus aggregatum	7,500 Propagules

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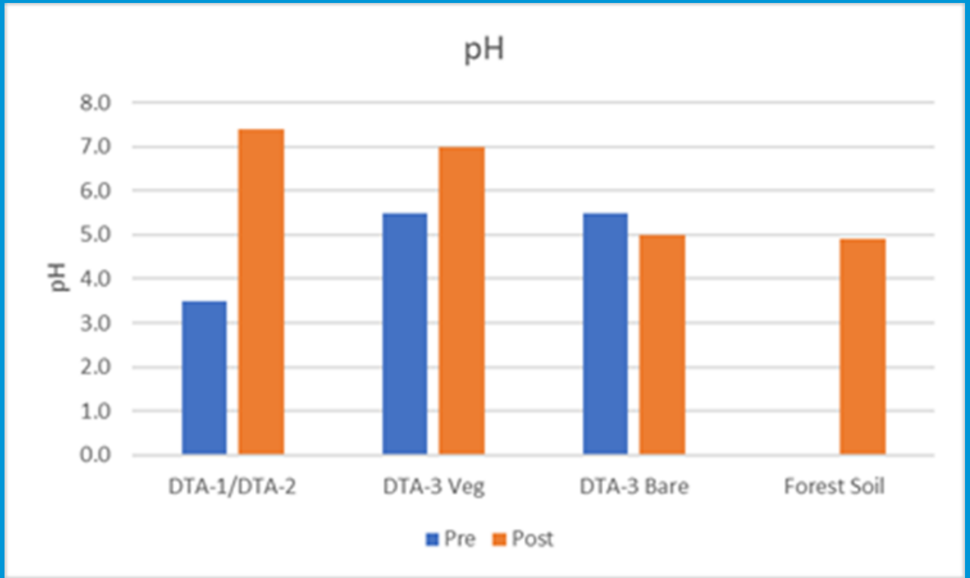

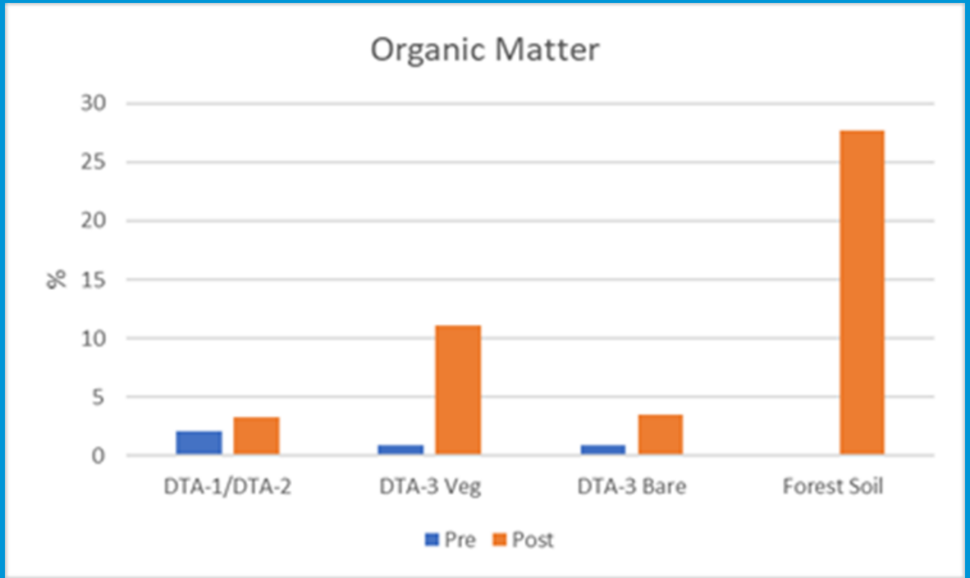

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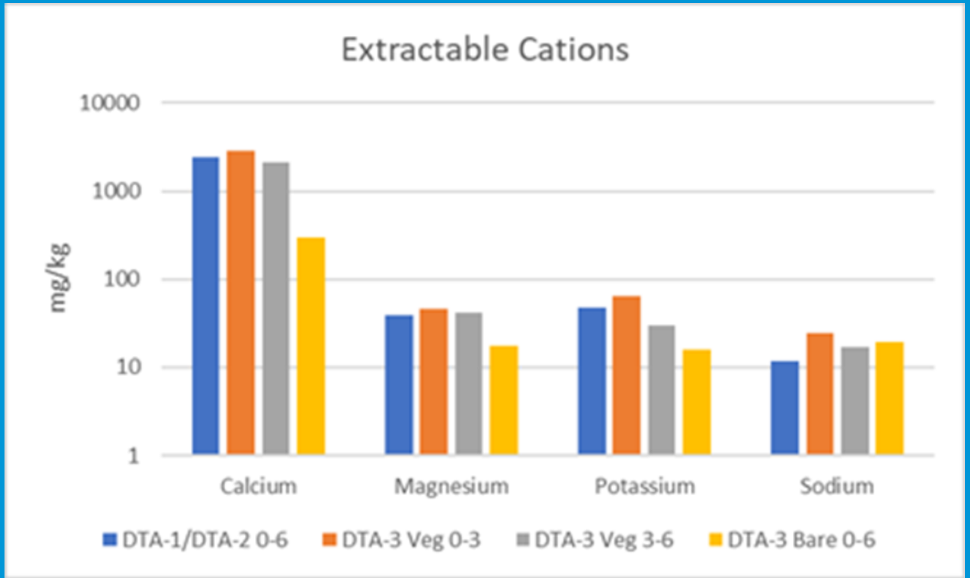
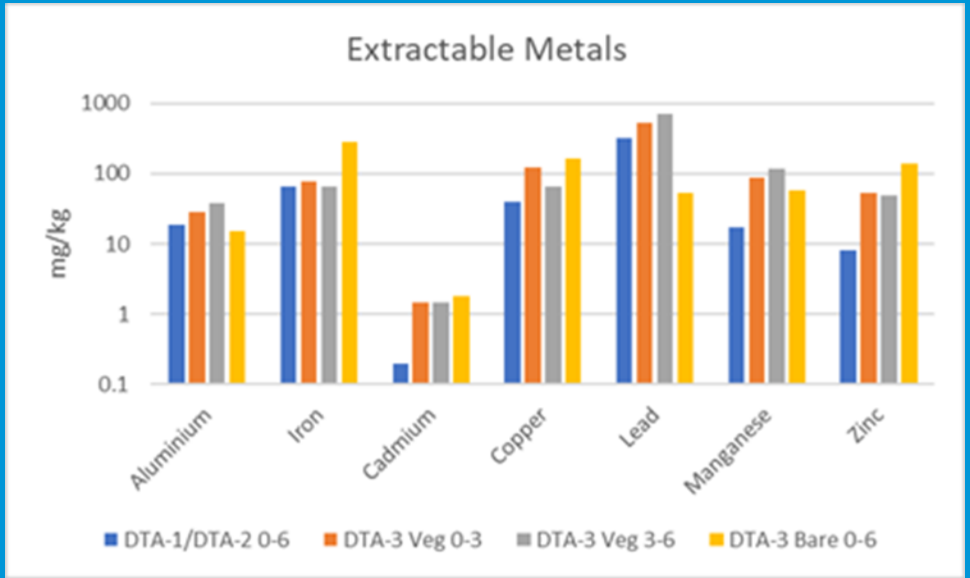


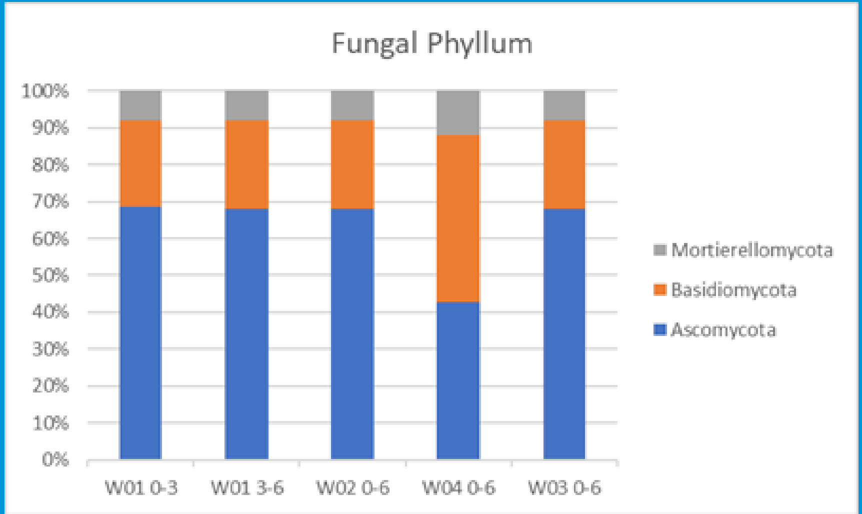


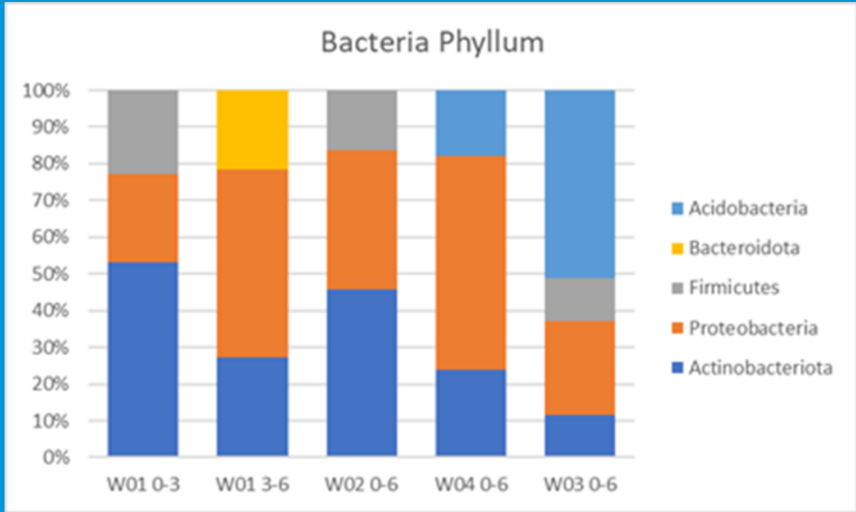
CASE STUDY – WALDORF MINE

Biomass	Units	DTA-3			DTA-1/DTA-2	Forest Soil
		W01 0-3	W01 3-6	W02 0-6	W04 0-6	W03 0-6
Beneficial Microorganisms						
Bacterial Biomass	µg/g	101	626	751	816	945
Actinobacterial Biomass	µg/g	6	23	0	0	0
Fungal Biomass	µg/g	0	0	0	0	0
Fungal:Bacteria	Ratio	0	0	0	0	0
Total Beneficial Protozoa	number/g	34,646	207,876	586,944	2,425,220	762,212
Flagellates	number/g	34,646	207,876	586,944	2,425,220	762,212
Amoebae	number/g	0	0	0	0	0
Bacterial-feeding Nematodes	number/g	0	0	0	0	0
Fungal-feeding Nematodes	number/g	0	0	0	0	0
Predatory Nematodes	number/g	0	0	0	0	0
Detrimental Microorganisms						
Oomycetes Biomass	µg/g	0	0	0	0	0
Ciliates	number/g	0	0	0	0	69,292
Root-feeding Nematodes	number/g	0	0	0	0	0

CASE STUDY – WALDORF MINE

Species	Units	DTA-3			DTA-1/DTA-2	Forest Soil
		W01 0-3	W01 3-6	W02 0-6	W04 0-6	W03 0-6
Total Bacteria	gene units/g	1E+09	1E+09	1E+09	1E+10	1E+09
Total Fungi	gene units/g	1E+08	1E+07	1E+08	1E+09	1E+08
Fungi:Bacteria	Ratio	0.06	0.03	0.05	0.11	0.09
Arbuscular:Ectomycorrhizal	Ratio	Ectomycorrhizal Only	Ectomycorrhizal Only	Ectomycorrhizal Only	Ectomycorrhizal Only	Ectomycorrhizal Only





CASE STUDY – WALDORF MINE

Soil Quality

	DTA-3			DTA-1/DTA-2	Forest Soil
	W01 0-3	W01 3-6	W02 0-6	W04 0-6	W03 0-6
Soil Quality Value	Medium	Medium	Low	Medium	Low
Biodiversity	Low	Very Low	Very Low	Very Low	Very Low
Functionality	Medium	High	Medium	Medium	Very Low
Resistance	Medium	Low	Very Low	Very High	High

Soil Health

	DTA-3			DTA-1/DTA-2	Forest Soil
	W01 0-3	W01 3-6	W02 0-6	W04 0-6	W03 0-6
Soil Health Index	Medium	Medium	Medium	Medium	Medium
Hormone Production	High	High	Very High	High	Very Low
Stress Adaption	Medium	High	Very High	High	Very Low

CASE STUDY – WALDORF MINE

	DTA-3			DTA-1/DTA-2	Forest Soil
	W01 0-3	W01 3-6	W02 0-6	W04 0-6	W03 0-6
C Nutritional Status	Medium	Medium	Medium	High	Very High
N Nutritional Status	High	Very Low	Very Low	Low	Very Low
P Nutritional Status	Medium	High	High	High	Very High
K Nutritional Status	High	High	High	High	Very High
Fe Assimilation	Low	High	Very High	Medium	Very Low
Zn Transport Assimilation	High	Low	Low	Very Low	Very Low
Mn Transport Equilibration	High	Medium	Very Low	Medium	Very Low
S Cycle Equilibrium	Medium	High	High	Very Low	Low
Ca Transport	High	Low	Low	Very Low	Very Low
Cu Export	Low	High	Very High	Low	Very Low
Mg Transport	Low	High	High	Medium	Medium
Cl Transport	Low	Low	Low	Medium	Medium

BIOECONOMY

An economy based on the sustainable and circular use of biological resources and processes to produce food, feed, bio-based products and services.

Untapped potential to support both climate change mitigation and adaptation.

Approx 1/3 of global greenhouse gas (GHG) emissions currently come from agrifood systems

Offers opportunities to reduce GHG emissions along the agrifood system replacing fossil-based resources and processes with biological ones, including the adoption of biofertilizers.

Resource-efficient circular bioeconomy projected to reach a value of $US 7.7 trillion in 2030

IPCC MITIGATION OPTIONS AND CORRESPONDING BIOECONOMY INNOVATIONS

Macrosectors	IPCC Mitigation Options	Bioeconomy Innovation
Primary Production	Shift to balanced, sustainable healthy diets	New food sources, biofortification
	Carbon sequestration in agriculture	Microbiome innovations
	Reduce methane and nitrous oxide emissions	Biofertilizers and Biomineral fertilizers
Circularity and by-product use	Ecosystem restoration, afforestation, reforestation	Carbon and climate focused strategies
	Enhance recycling	Circular use of bioresources
	Reduce food loss and waste	Closed nutrient loops generating added value from waste and surplus materials.
Bio-based industries	Enhance use of wood products	Enhance use of wood products
	Feedstock decarbonization, process change	Natural organisms and enzymes in food production and processing
	Fuel Switching (Bioenergy)	Sustainable bioenergy from waste

INTEGRATION WITH SDGS

Facilitate conservation and restoration of ecosystems contributing to the achievement of SDGs 13 (Climate action), 14 (Life below water) and 15 (Life on land).

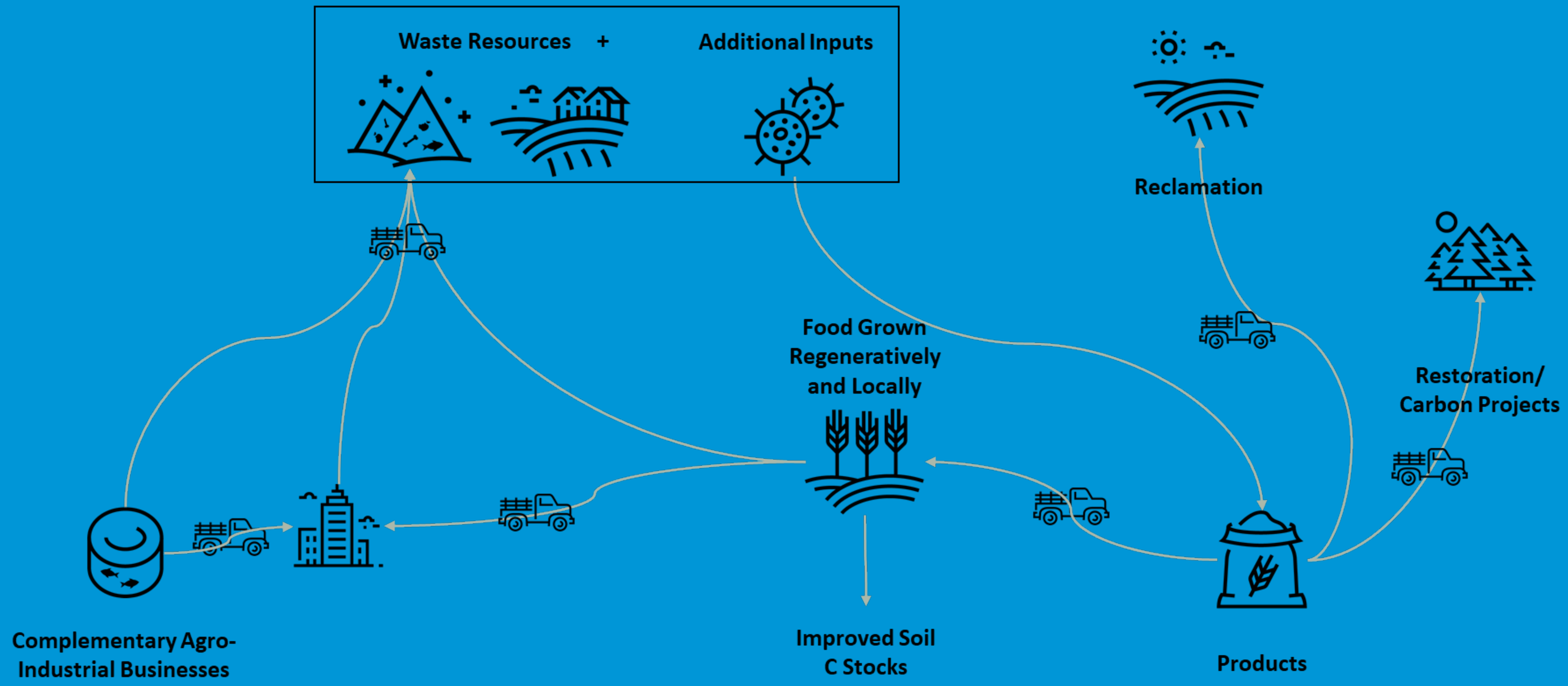
Promotion and implementation of practices, techniques and technology that preserves natural resources and biodiversity for food and livelihoods security (SDG 2: Zero hunger), provisioning clean water and air (SDG 6: Clean water and sanitation).

Recognizing the value of traditional and local practices thereby dignifying the work of smallholder farmers and reducing inequalities along the agrifood system (SDGs 5: Gender Equality and 10: Reduced Inequalities) and poverty (SDG 1: No poverty).

Steady supply of diversified and balanced diets, which is crucial for achieving SDG 3 (good health and well-being)

Apply at the landscape level, implying that enhanced local community partnerships, as outlined in SDG 17 (Partnerships for Goals)

BIOMINERAL FERTILIZER PRODUCTION



BIOMINERAL FERTILIZER PRODUCTION

BIOMINERAL FERTILIZER PRODUCTION

CHALLENGES AND LIMITATIONS

- Limited knowledge and research in reclamation settings
- Long-term Monitoring
- Regulatory Considerations
- Public Perceptions

FUTURE DIRECTION AND OPPORTUNITIES

- Building knowledge base
- Best practices
- Targeted species for reclamation
- Designing microbial based soil amendments
- Genetic engineering
- Bioleaching
- Bioremediation
- Phytoremediation

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