Microbial functional diversity – its importance to ecosystem function, and choice as a mine soil restoration objective

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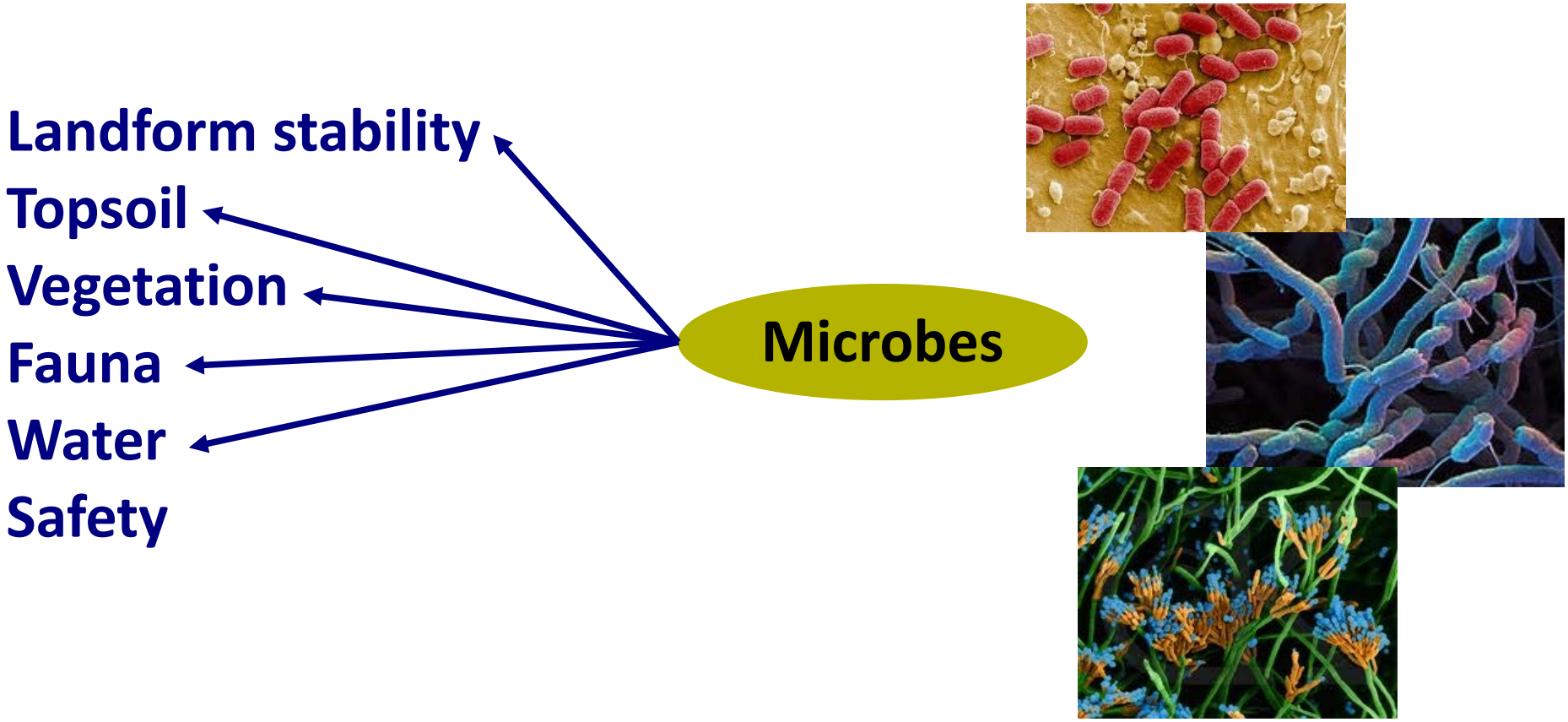
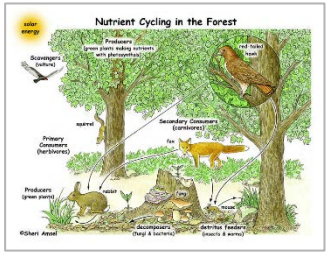
Mining companies are required to provide regulators with evidence that they are meeting obligations for rehabilitation of mined areas



Microorganisms affect most of the criteria used to determine rehabilitation success, yet they are not specifically included in any of them

Soil microorganisms are vital to ecosystem health and can improve rehabilitation success



Nutrient cycling

Organic matter decomposition

Microbes

Soil formation & aggregation

Food source for micro- & macro-fauna

Disease & pest suppression

Plant symbioses

“I make no apologies for putting microorganisms on a pedestal above all other living things. For if the last blue whale choked to death on the last panda, it would be disastrous but not the end of the world. But if we accidentally poisoned the last two species of ammonia-oxidizers, that would be another matter. It could be happening now and we wouldn’t even know...”

(Tom Curtis, University of Newcastle upon Tyne, in Nature, July 2006)

SER SOCIETY FOR ECOLOGICAL RESTORATION AUSTRALASIA

NATIONAL STANDARDS FOR THE PRACTICE OF ECOLOGICAL RESTORATION IN AUSTRALIA

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INTERNATIONAL STANDARDS FOR THE PRACTICE OF ECOLOGICAL RESTORATION – INCLUDING PRINCIPLES AND KEY CONCEPTS

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Tein McDonald, George D. Gann, Justin Jonson, Kingsley W. Dixon

SER SOCIETY FOR ECOLOGICAL RESTORATION

SER in collaboration with SER Australasia

Restoring microbial functionality is listed as a detailed ecosystem function objective

“Positive change in microbial functionality parameter xx”

“One or more quantitative determinants are used consistently throughout the life of the restoration project to ensure that the functional diversity of soil microbial communities is restored”

Why not choose a positive change in microbial biodiversity as in "Microbiological indicator genera xxx and yyy are present on zz zones"?

The usual macro-organism ecological parameters and indices often do not work with microbes

11km^2 area of the Reserva Biológica San Francisco, Ecuador

227 birds

21 bats

2,639 butterflies & moths

Photo © Göttingen Centre for Biodiversity and Ecology

1,300 plants

1,085 'lower' plants

Considered to be one of the most biodiversity habitats on earth, but ...

Microbial biodiversity is so vast it is almost meaningless in some environments

1 g of soil

100s of millions of bacterial cells

10K – 50K bacterial species

100m – 10km of fungal mycelium (up to 75% of microbial biomass)

= 2 – 45 t ha^{-1} of microbial biomass in forest soils

A significant functional redundancy means many of the major functions of the soil microbial biomass are unaffected by its exact species composition

Functional diversity is a better measure of the microbial status in soils

Various functional diversity measures include

- **Microbial activity**
- **Microbial biomass C & N**
- **Soil enzyme activities**

New whole microbial community analysis methods

- **Soil metagenomics**
- **Soil metaproteomics**

Functional diversity involves understanding communities and ecosystems based on what organisms do rather than on what they are

Simple and robust metrics provide summary information on the functional status of microbial populations of rehabilitating mine soils

Ratio of actinomycetes to non-filamentous bacterial colonies

0 ← 1

Increasing soil disturbance

Proportion of copiotrophic (fast-growing) bacteria

0 → 1

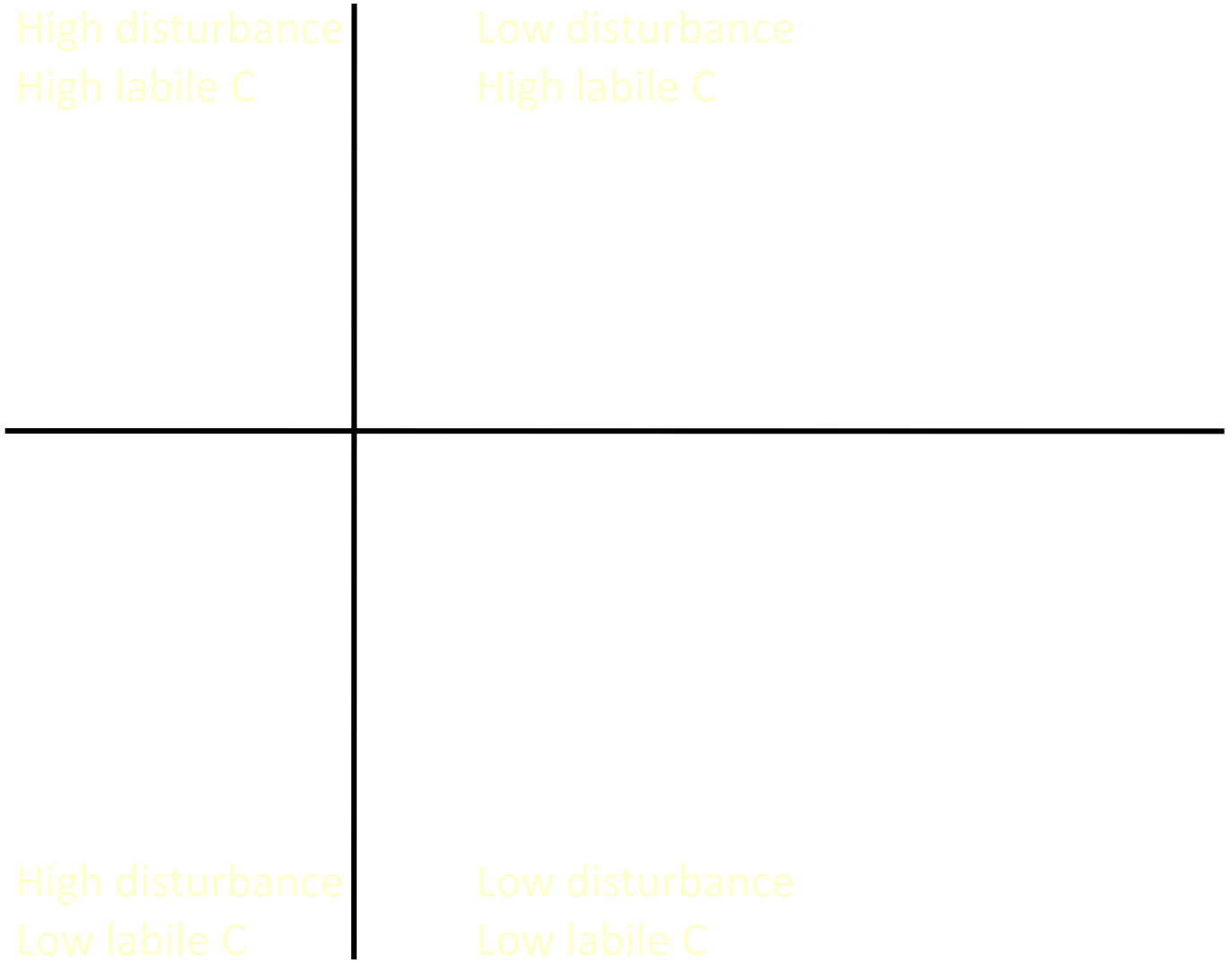
Increasing labile soil organic carbon

Presence/absence of the fungus *Trichoderma*

Rare → Common

Increasing plant cellulosic substrates in soils

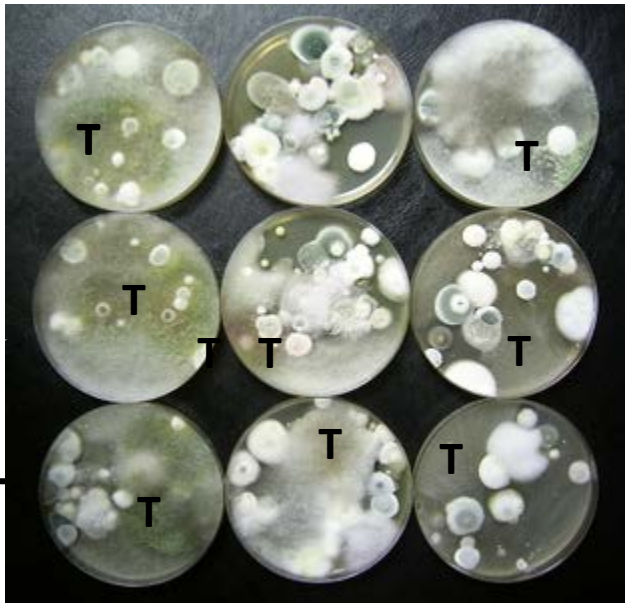
Results for a number of mine and grazing sites

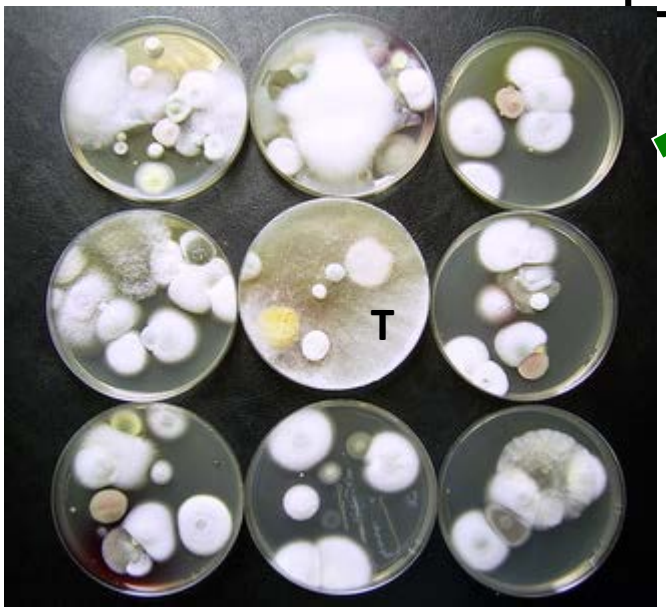


Results for a number of mine and grazing sites

High disturbance
High labile C

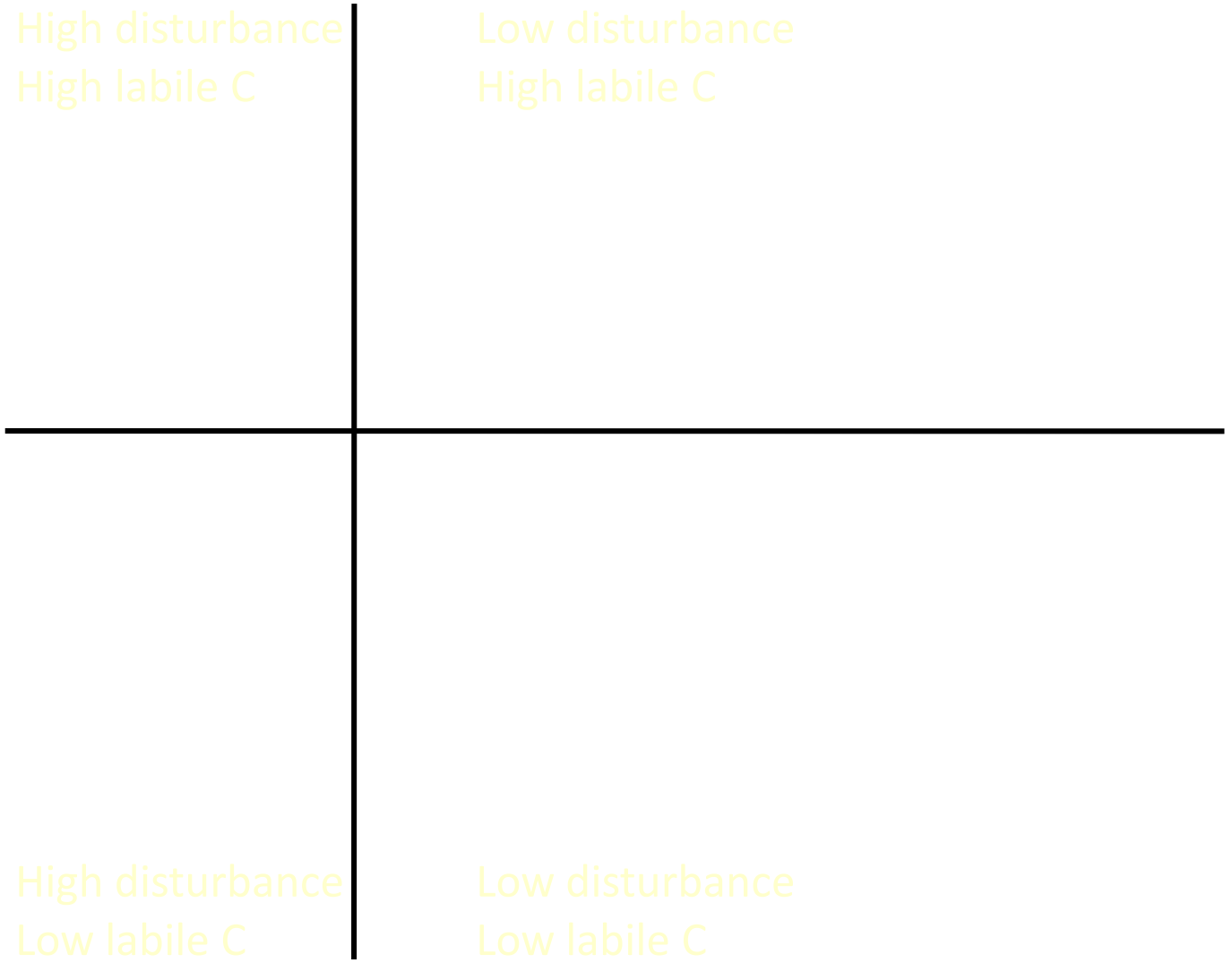
Low disturbance
High labile C





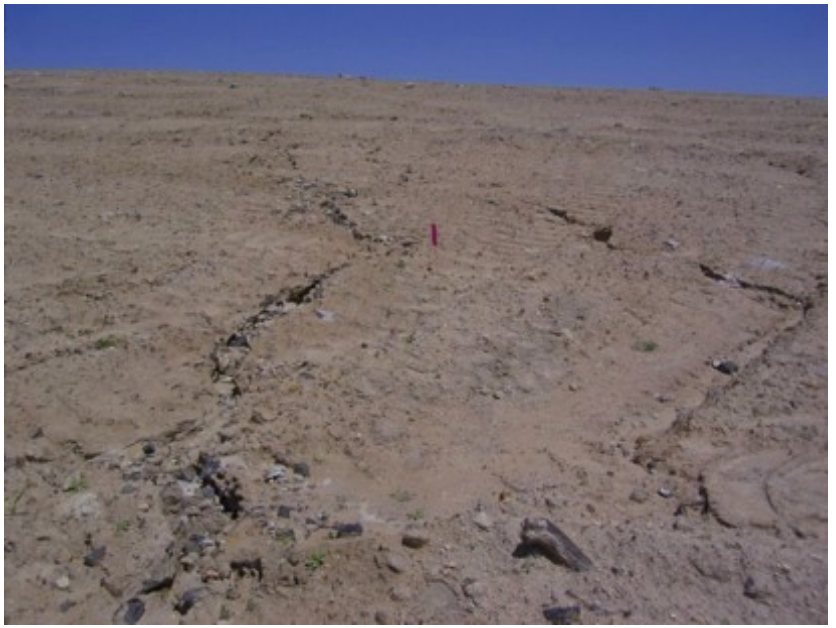
Low disturbance
Low labile C

Results for a number of mine and grazing sites



Topsoil is a valuable resource which needs to be kept alive and in place

Photo © Portand State University



The greatest soil erosion risk is before vegetation establishes and the window-of-erosion risk is greatest before the vegetation cover is above 50%

Changes in soil community structure and functioning are rarely considered in relation to nature restoration

Restoration targets focus on above-ground biodiversity and the presence of rare or red list species, but....

Below-ground networks are likely of greater importance

- **Fungi drive the development of new organism connectance, leading to more efficient nutrient cycling and C uptake**

  (E. Morriën *et al.* Nature Communications 8 Feb 2017)

Need to move beyond basing restoration success on simple biodiversity recovery and to look at the restoration of soil functionality

Soil functionality depends on the functional diversity of its resident microbial communities

Restoring microbial functional diversity and establishing filamentous networks of microorganisms in soils is essential to rehabilitation success