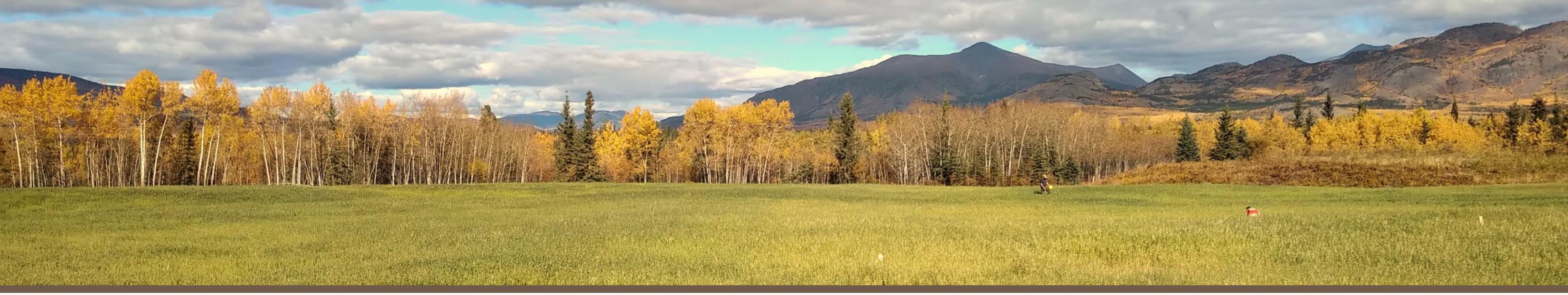

NORTHERN BOREAL FOREST CONVERSION TO AGRICULTURAL LANDSCAPES ALTERS SOIL MICROBIAL CARBON AND NITROGEN CYCLING POTENTIAL

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Government of Northwest Territories Gouvernement des Territoires du Nord-Ouest

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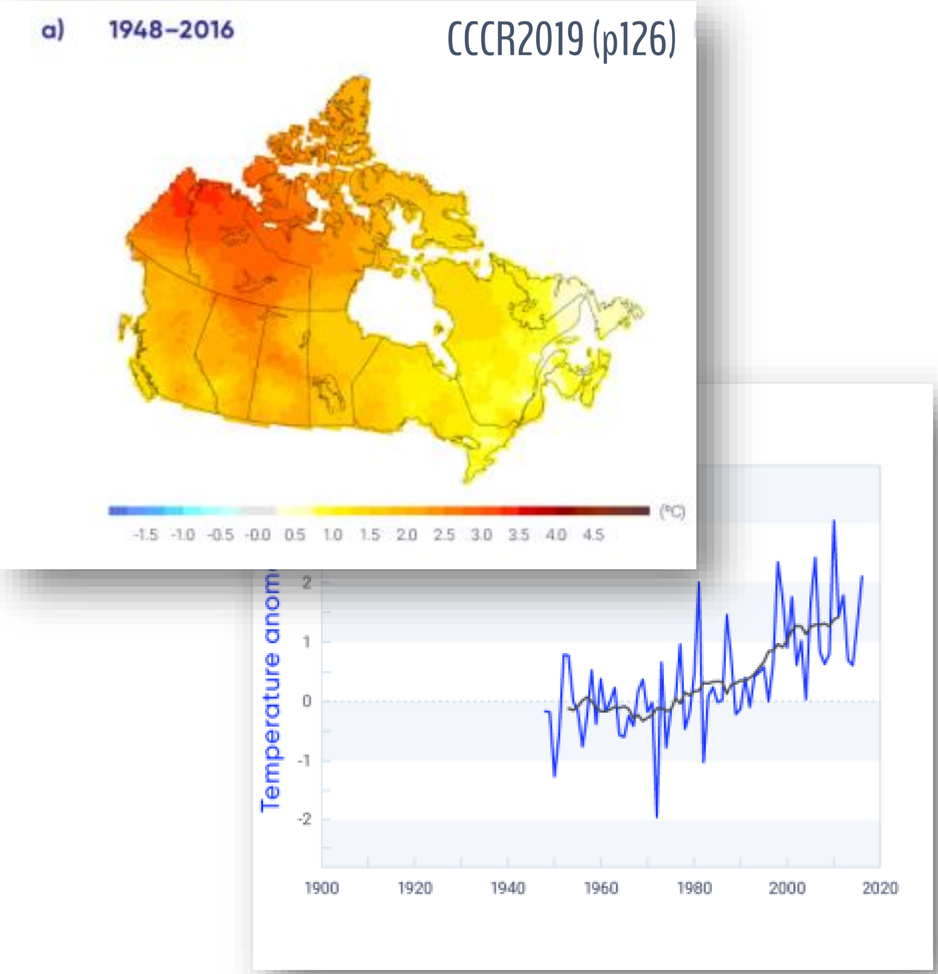
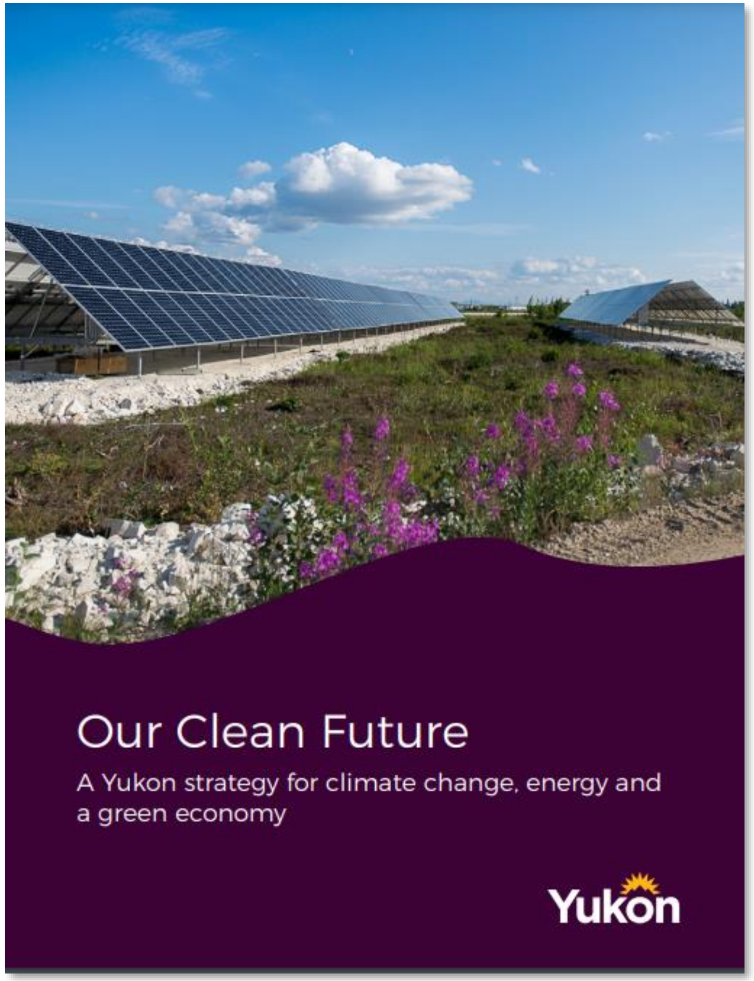
NORTHERN CANADA & CLIMATE CHANGE

- Warming due to Climate Change is occurring rapidly in Boreal and Arctic regions in Canada
- Growing interest and capacity to convert land to agriculture as warming continues
- Potential contributors to food supplies[2]



[1]King M et al. *Sci Rep* 8, 1904 (2018)

FOREST CONVERSION TO AGRICULTURE IN YUKON



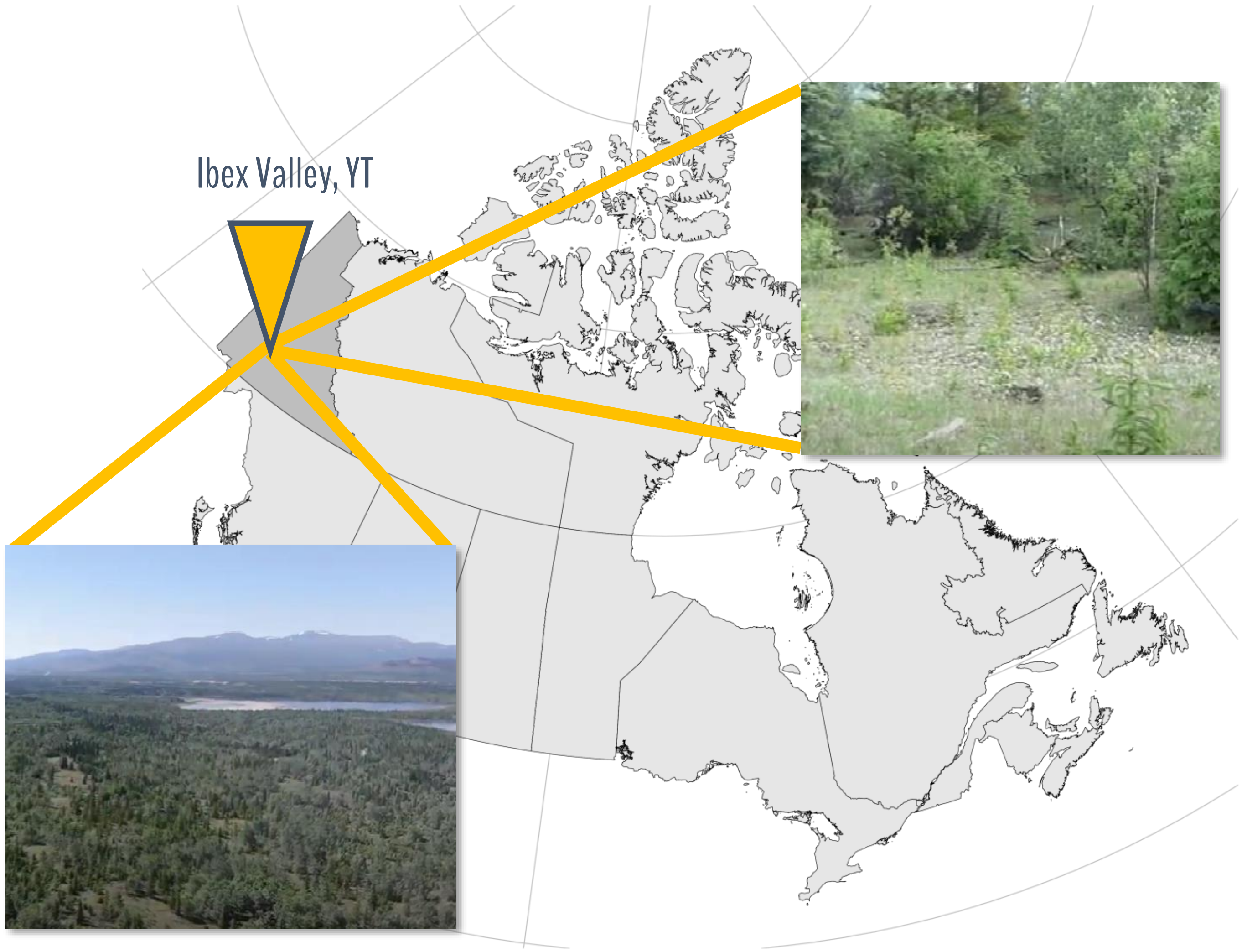
- Yukon Government's 2020 published policy on **Agriculture, Climate Change, Energy, and a Green Economy**
- Focus on agricultural intensification
- ↑ local food supplies and ↓ reliance on imports
- Assess forest removal strategies for land clearing

https://yukon.ca/sites/yukon.ca/files/env/env-our-clean-future.pdf

CONVENTIONAL METHODS

- Conventionally, forest clearing occurs in winter by bulldozing
- Top soil remains intact
- Windrows allowed to dry and then burned

EXPERIMENTAL TRIALS



- Land clearing/mulch experiment
- Ibex Valley, Yukon
- Assess how cleared forest material can be introduced back into the soil environment, improving soil health

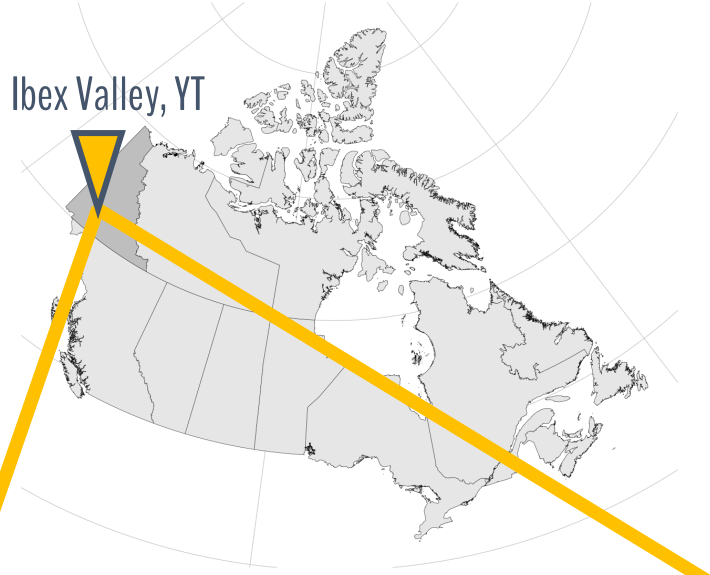
https://commons.wikimedia.org/wiki/File:Ibex_Valley_Yukon.jpg

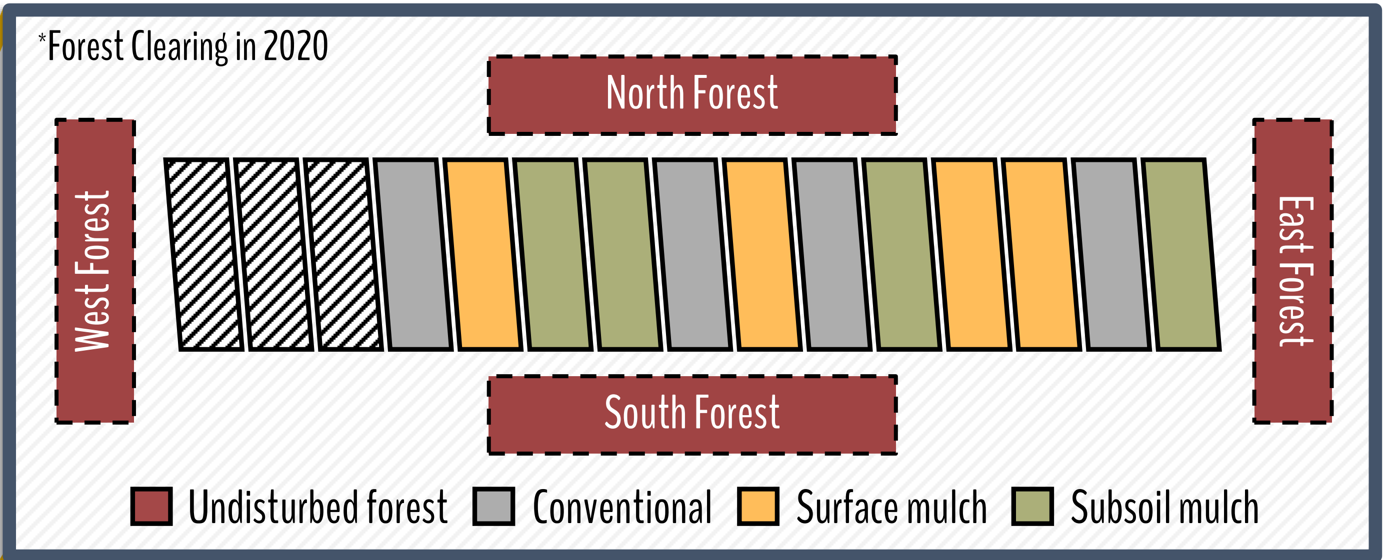
FIELD DESIGN

Undisturbed forest	Conventional	Surface Mulch	Subsoil Mulch
→ Mixed aspen, coniferous (pine, spruce), open woodland with some willow	→ Tree material completely NOT re-introduced into plots but burned (once dried)	→ Tree material mulched and applied at sowing (each year, starting 2021) to soil surface	→ Tree material mulched and incorporated into soil to a depth of 9-12"




FIELD DESIGN





- Samples taken from 0-15 cm
- Oats (*Avena sativa*)
- Fertilization (applied at the time of seeding each year):
  2021: ~175lb/ac 30-8-8-4
  2022: ~158lb/ac 30-8-8-4

FIELD DESIGN

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RESEARCH OBJECTIVES

Assess the impacts of different land conversion strategies (mulching techniques) from forest to agriculture on:

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Assess the impacts of different land conversion strategies (mulching techniques) from forest to agriculture on:

- The soil microbial (bacterial and fungal) community composition
- The soil microbial nutrient cycling potential

RESEARCH OBJECTIVES

Assess the impacts of different land conversion strategies (mulching techniques) from forest to agriculture on:

? Which processes are being activated/deactivated as a response to land conversion and what are the implications for GHG emissions and agricultural management?

METHODS

Marker-gene amplicon sequencing

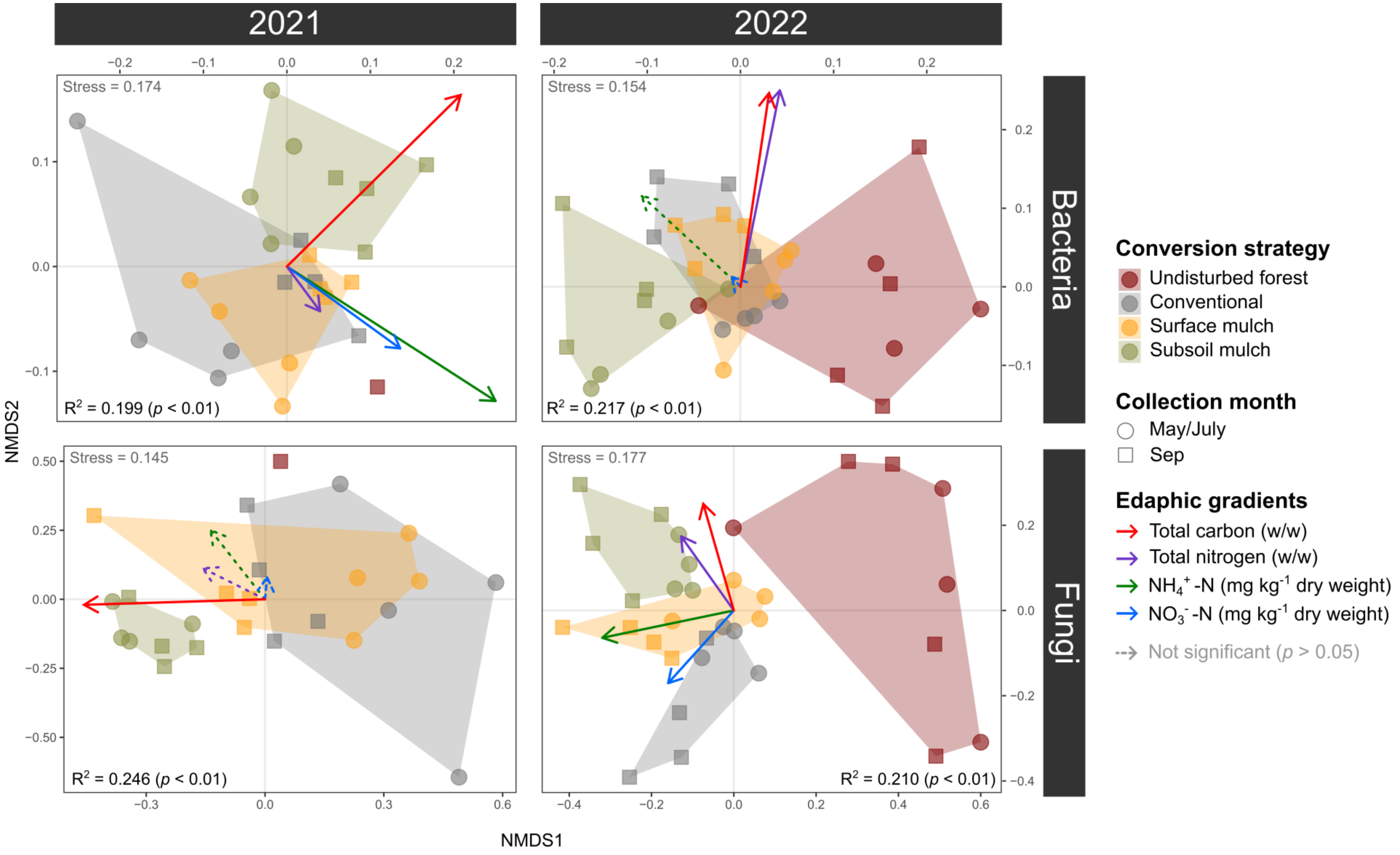
- 16S rRNA gene (bacteria)
- ITS2 (fungi)

Quantitative PCR

C-CYCLING	NITRIFICATION	DENITRIFICATION
Xylanse (CH11) Hemicelluose breakdown	Ammonia monooxygenase (amoA) NH_4^+ ▶ NO_2^-	Nitrite reductase (nirK) NO_2^- ▶ NO
Cellobiohydrolase (CBH) Cellulose breakdown	Nitrite oxidoreductase (nxrA) NO_2^- ▶ NO_3^-	Nitrous oxide reductase (nosZ) N_2O ▶ N_2

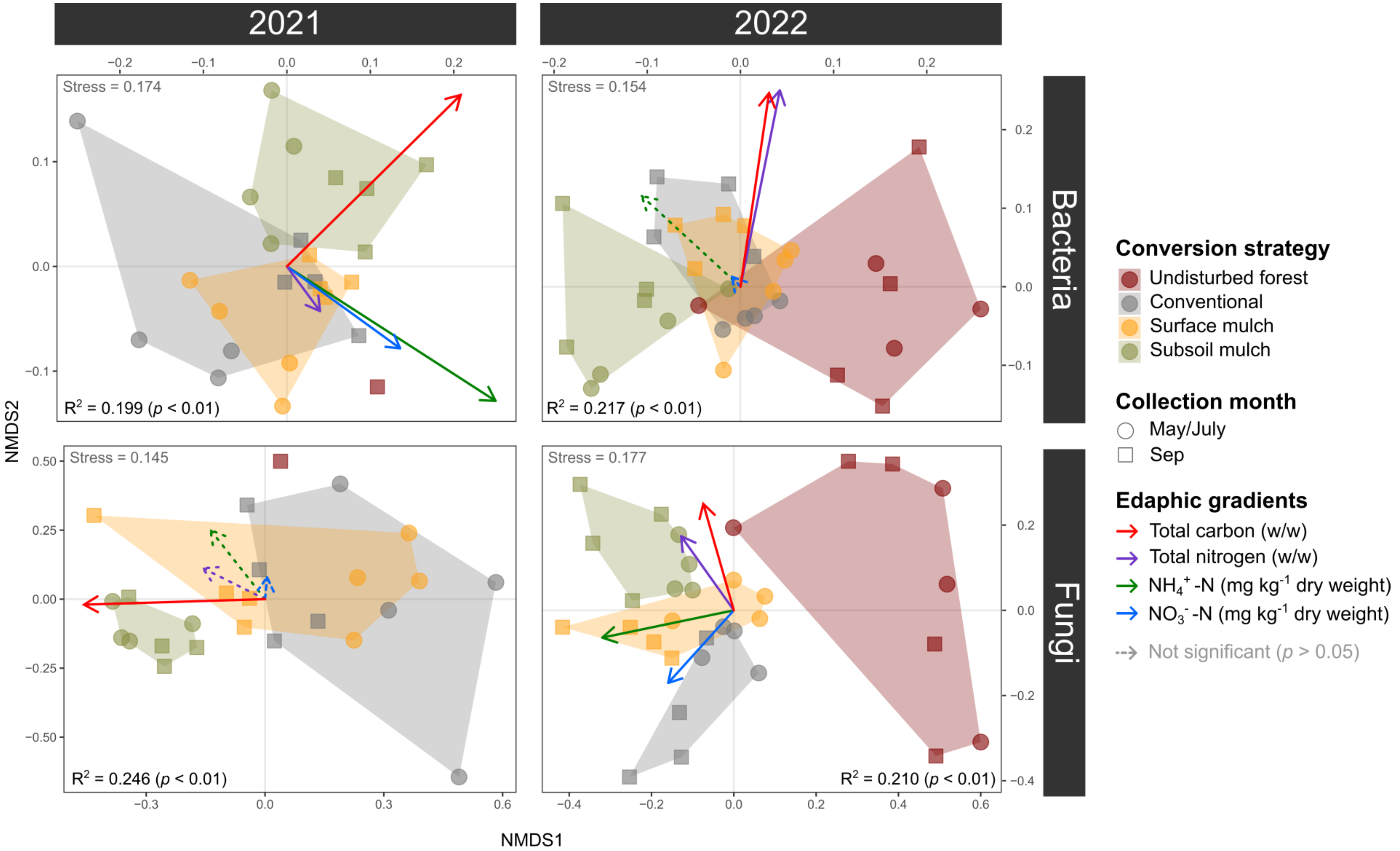
WHAT DID WE FIND?

RAPID FUNDAMENTAL SHIFTS IN MICROBIAL COMMUNITIES

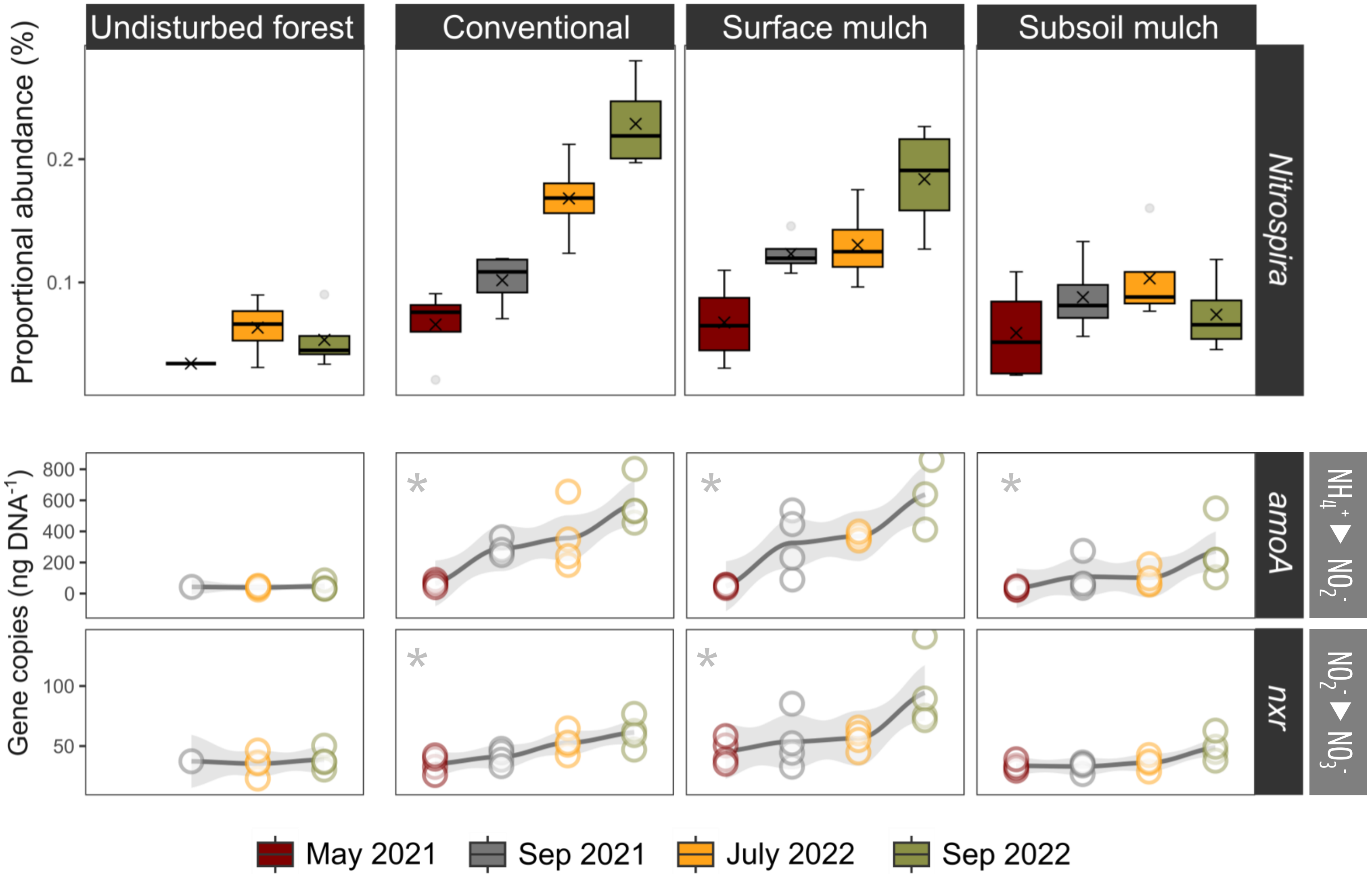


RAPID FUNDAMENTAL SHIFTS IN MICROBIAL COMMUNITIES

- Conventional and Surface mulch treatments showed more similar responses
- Subsoil treatments showed the greatest shift from the undisturbed systems
- Very strong shifts in key taxa

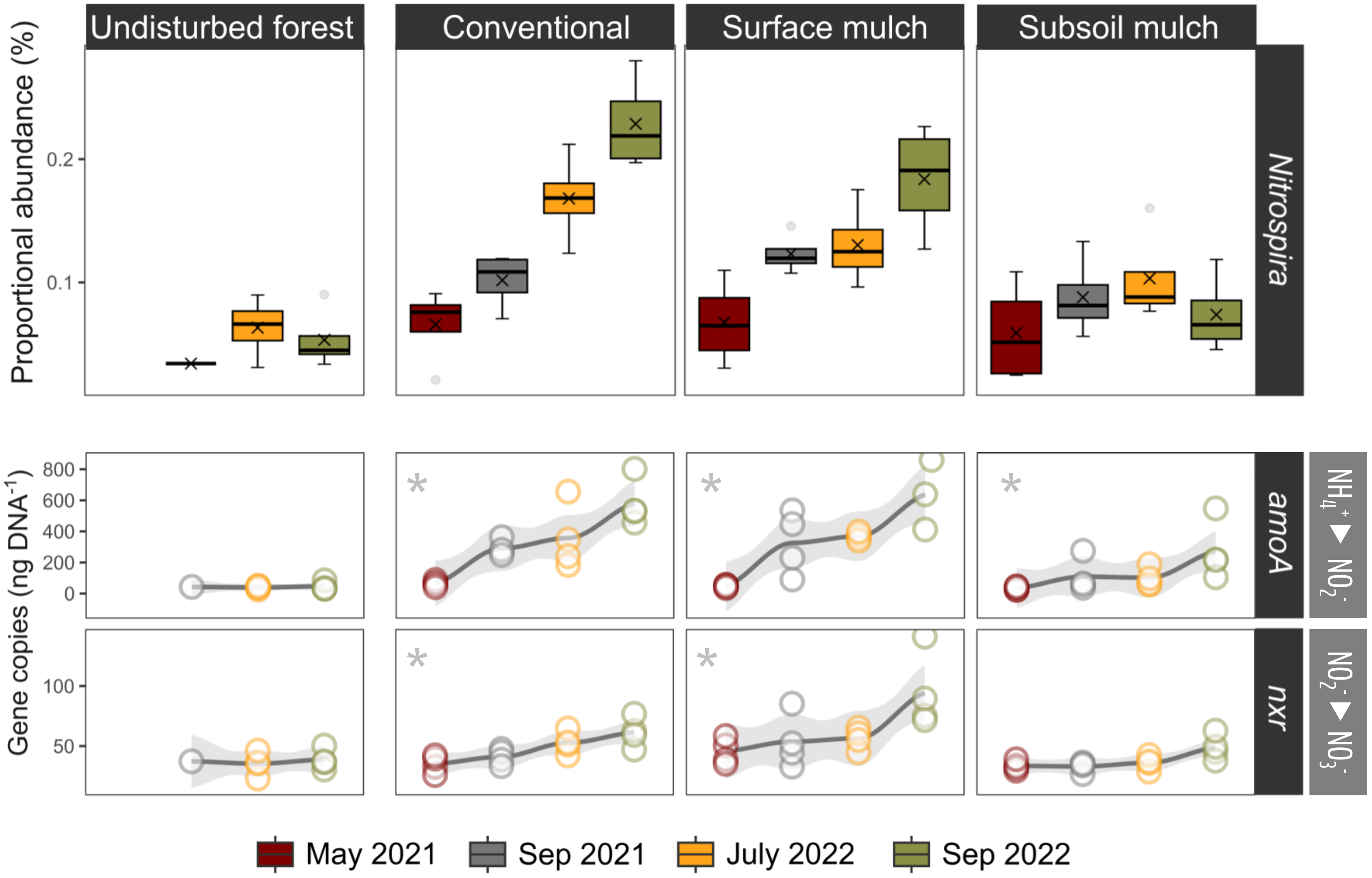


SHIFTS IN FUNCTIONAL POTENTIAL – NITROGEN CYCLING



$^* p < 0.05$

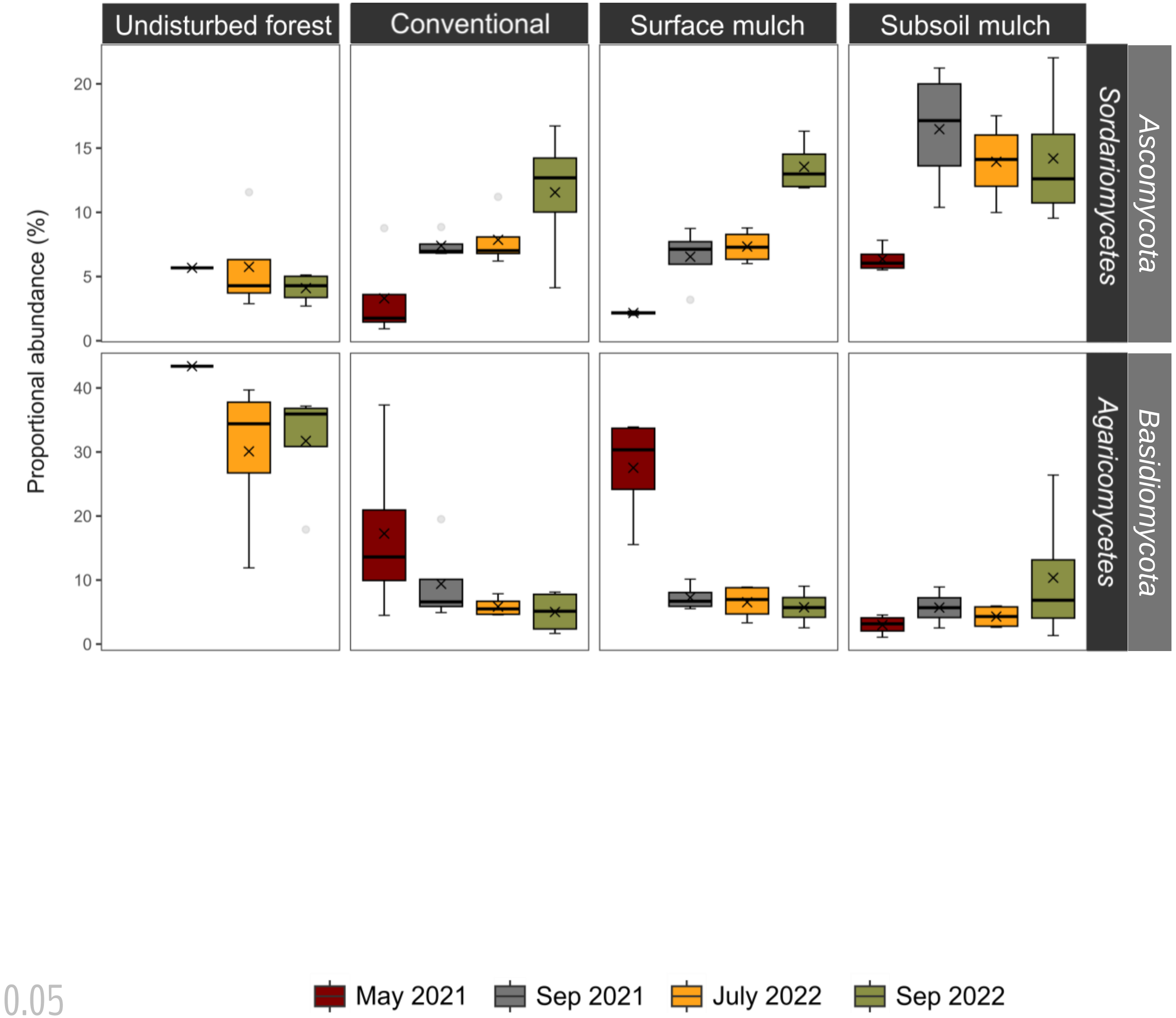
SHIFTS IN FUNCTIONAL POTENTIAL – NITROGEN CYCLING



- Strong shifts in key N-Cycling bacteria in the Conventional and Surface Mulch systems
- Consistent relationship in genes associated with nitrification
- Effect less pronounced in the Subsoil Mulch

*$p < 0.05$

SHIFTS IN FUNCTIONAL POTENTIAL – CARBON CYCLING



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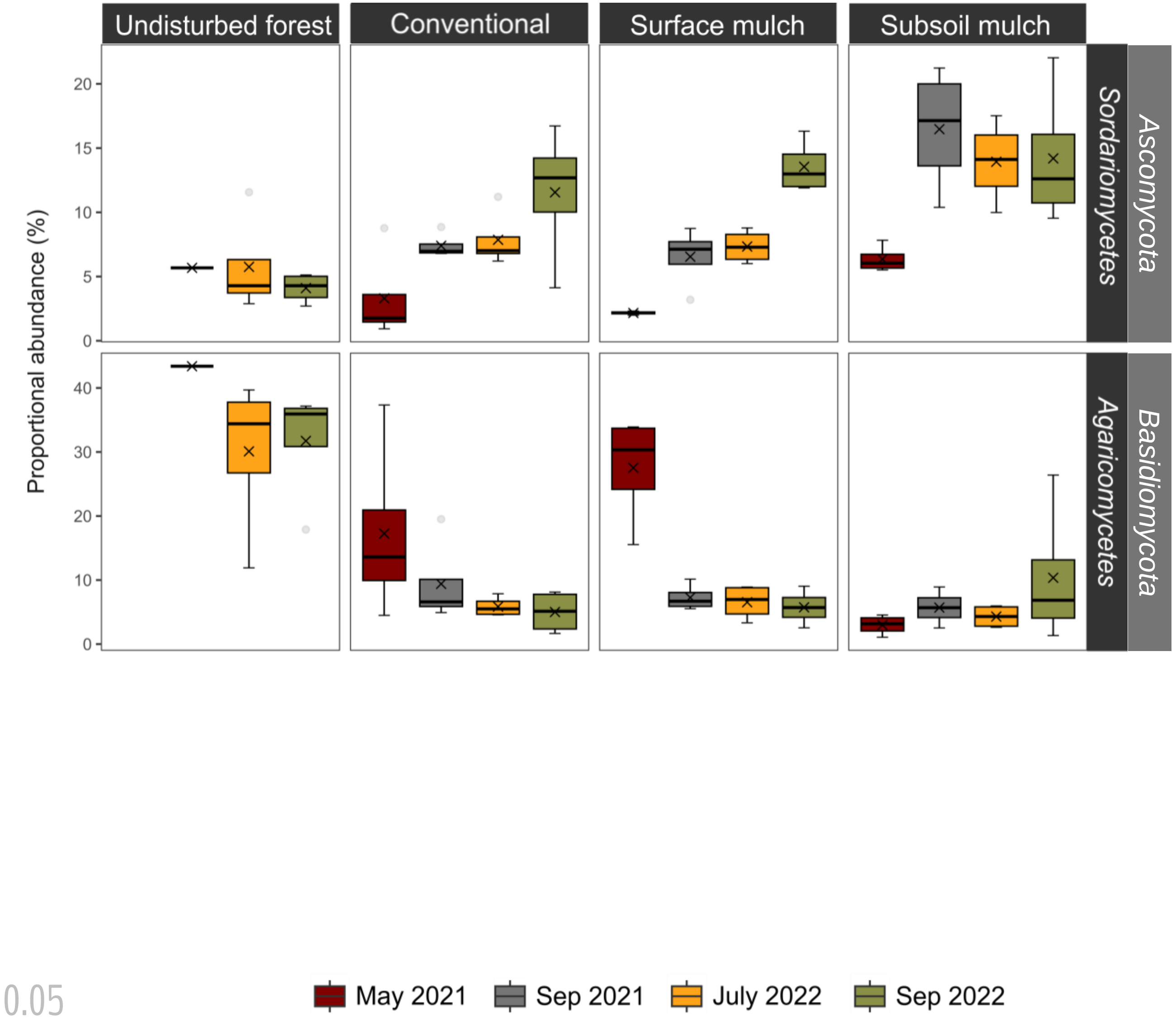
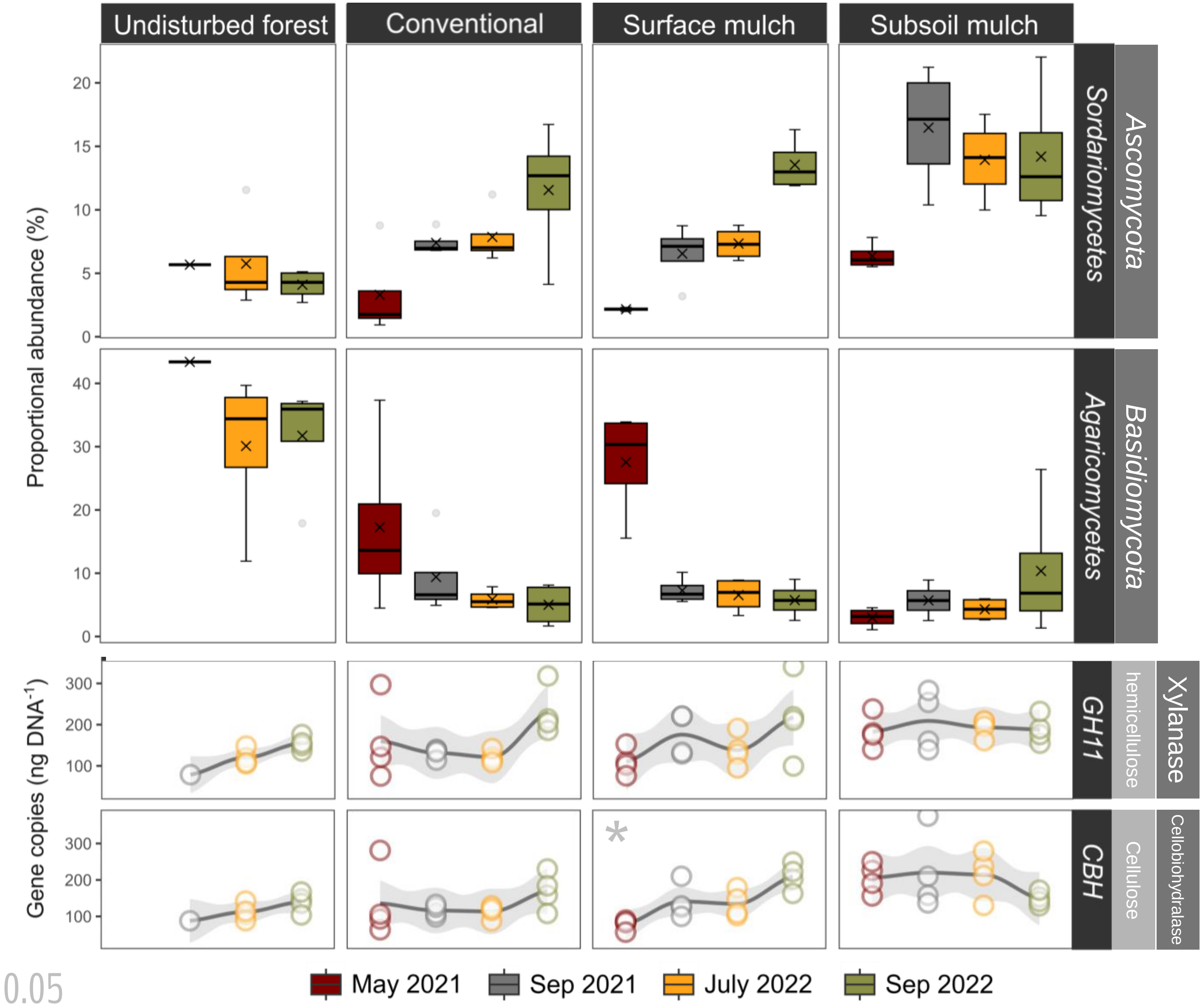
SHIFTS IN FUNCTIONAL POTENTIAL – CARBON CYCLING



- Dominant fungal taxa:
  - Ascomycota (~50-90%)
  - Basidiomycota (~15-45%)
- Shift from Basidiomycota to Ascomycota when forest was converted to agriculture

*$p < 0.05$

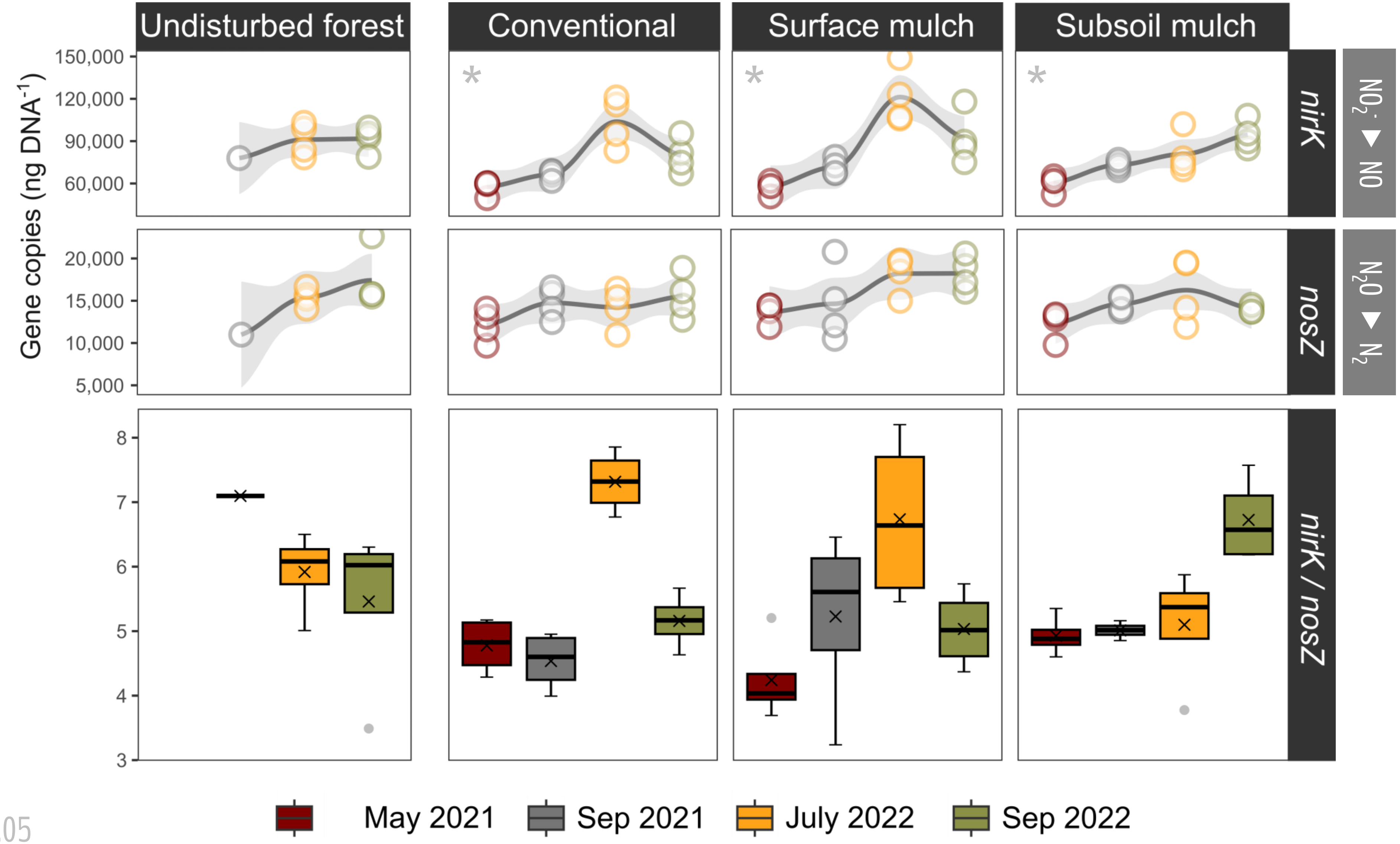
SHIFTS IN FUNCTIONAL POTENTIAL – CARBON CYCLING



- Dominant fungal taxa:
  - Ascomycota (~50-90%)
  - Basidiomycota (~15-45%)
- Shift from Basidiomycota to Ascomycota when forest was converted to agriculture
- C-Cycling genes associated with hemicellulose and cellulose showed most variation across treatments
- More pronounced effects in the Conventional and Surface Mulch treatments

*$p < 0.05$

HIGHER POTENTIAL FOR INCOMPLETE DENITRIFICATION



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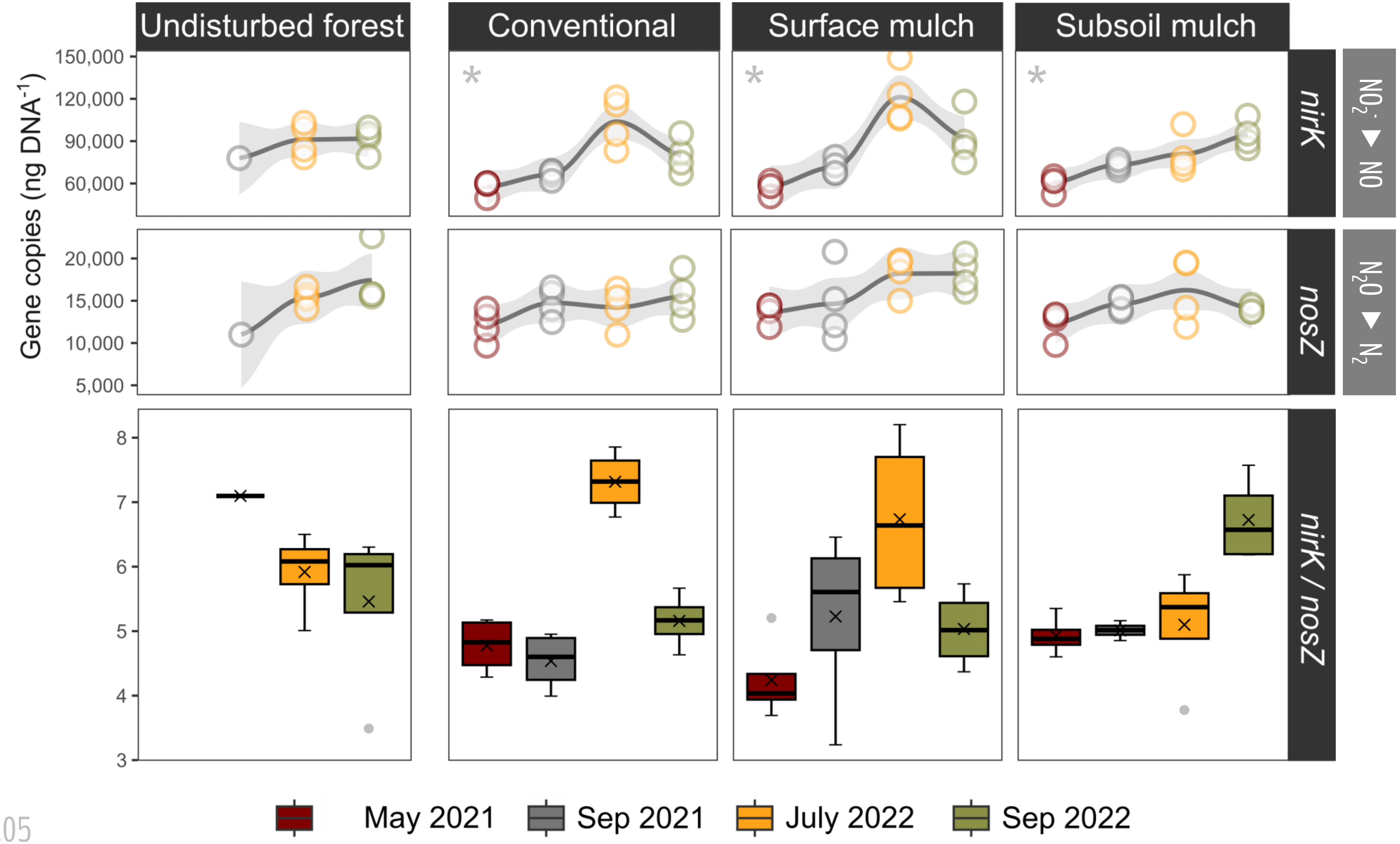

* $p < 0.05$

Spikes in genes associated with production of N_2O but the agricultural treatments are similar (if not less) to the undisturbed forests in terms of denitrification potential

CONCLUSIONS

- Forest clearing and Mulching techniques fundamentally shifted microbial community composition and C & N Cycling potential
- Subsoiling appears to moderate the microbial community response of forest conversion
  - More stable "slow release" of nutrients without completely removed C from the system
- Microbial potential to release N_2O

FUTURE DIRECTIONS

- Longer term tracking of how this system evolves (agronomy, nutrient pools, microbial ecology)
- Implementing direct measures of greenhouse gas emissions in-situ


THANKS

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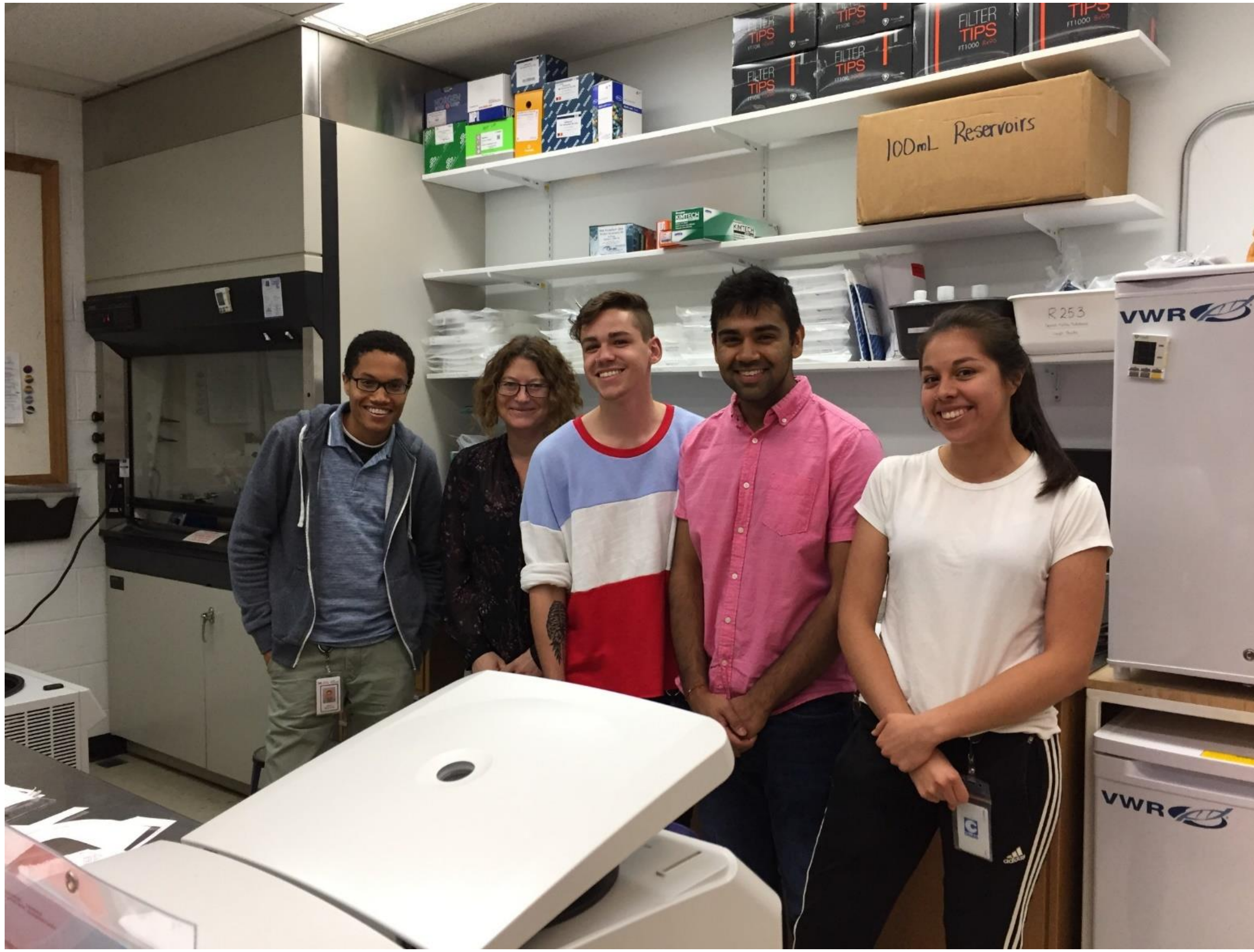
Canada

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada



HOW DO WE APPROACH THIS?

It's complicated...

- Emphasize adapting to regional agricultural practices currently being used by communities in Northern regions

- **Long term research** is required to assess impacts on nutrient cycling potential and biological communities

"UNTAPPED" POTENTIAL?

BENEFICIAL

- Estimates of up to 1 billion people can be fed by 2100 by a 10-20% expansion of agriculture into northern regions[2]
- Potential to ↑ autonomy in Northern communities
- ↑ local food supply & ↓ the necessity to import foods

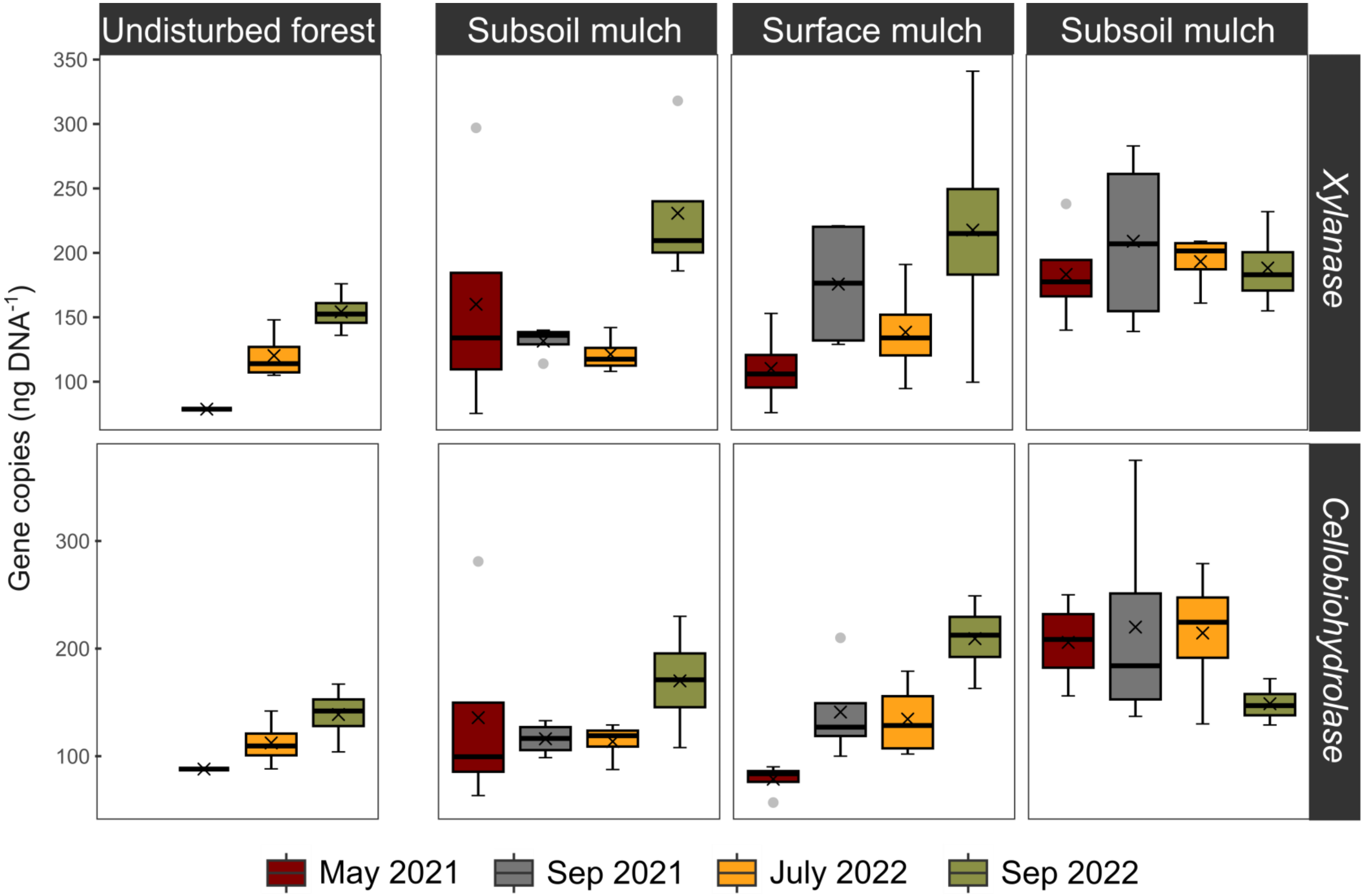
ADVERSE

- Boreal forests stores ~32% of the global forest carbon stocks[1]
- Agricultural conversion may cause upwards of a 76% loss of carbon stored in plants and soils
- Potential increasing GHG emissions?[1]

[1]Unc et al. *Front. Sustain. Food Syst.* 5:663448 (2021); [2]Cassidy et al. *Environ. Res. Lett.* 8:034015 (2013)

IMPACTS OF LAND CONVERSION

Community composition



IMPACTS OF LAND CONVERSION

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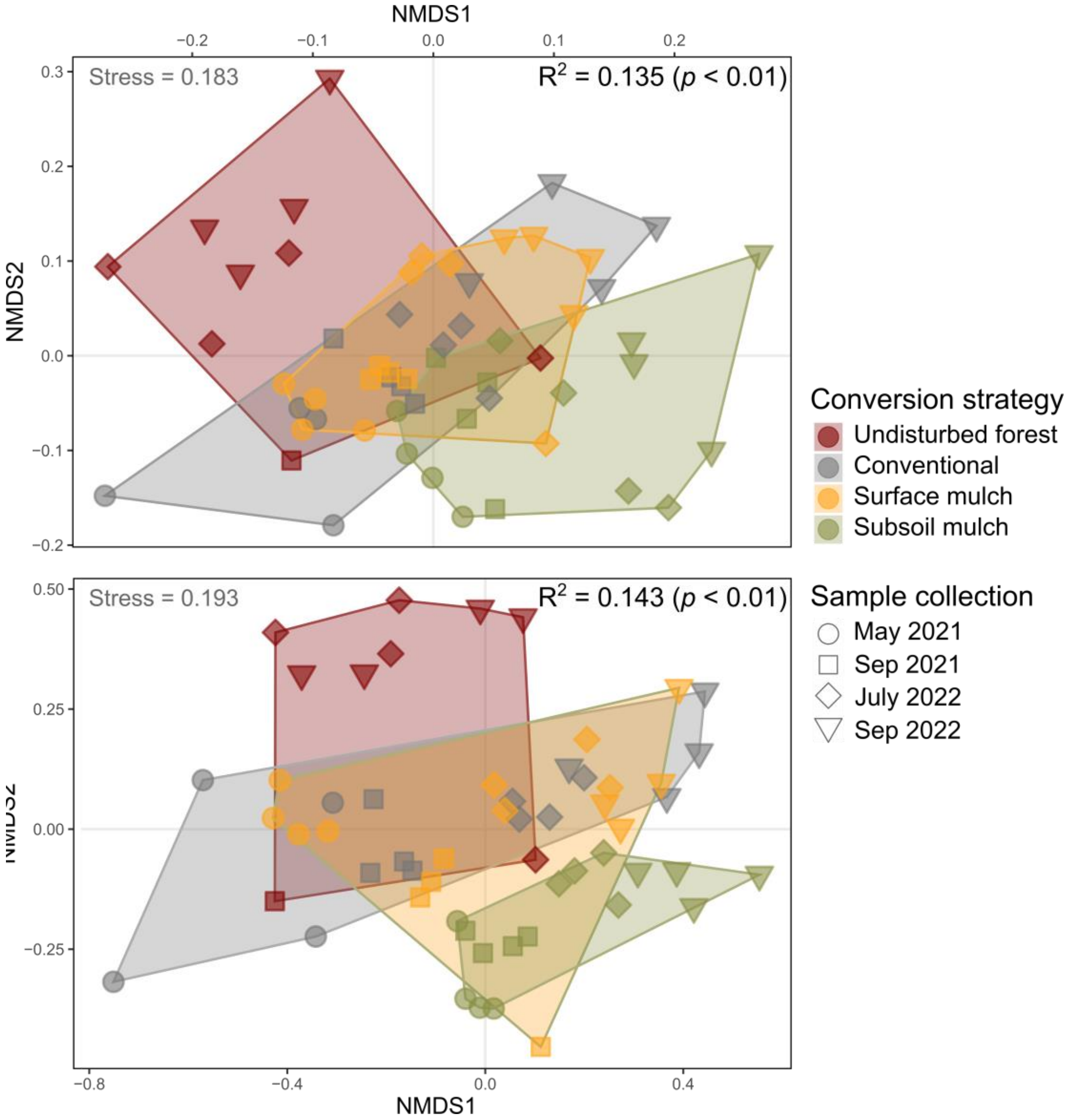
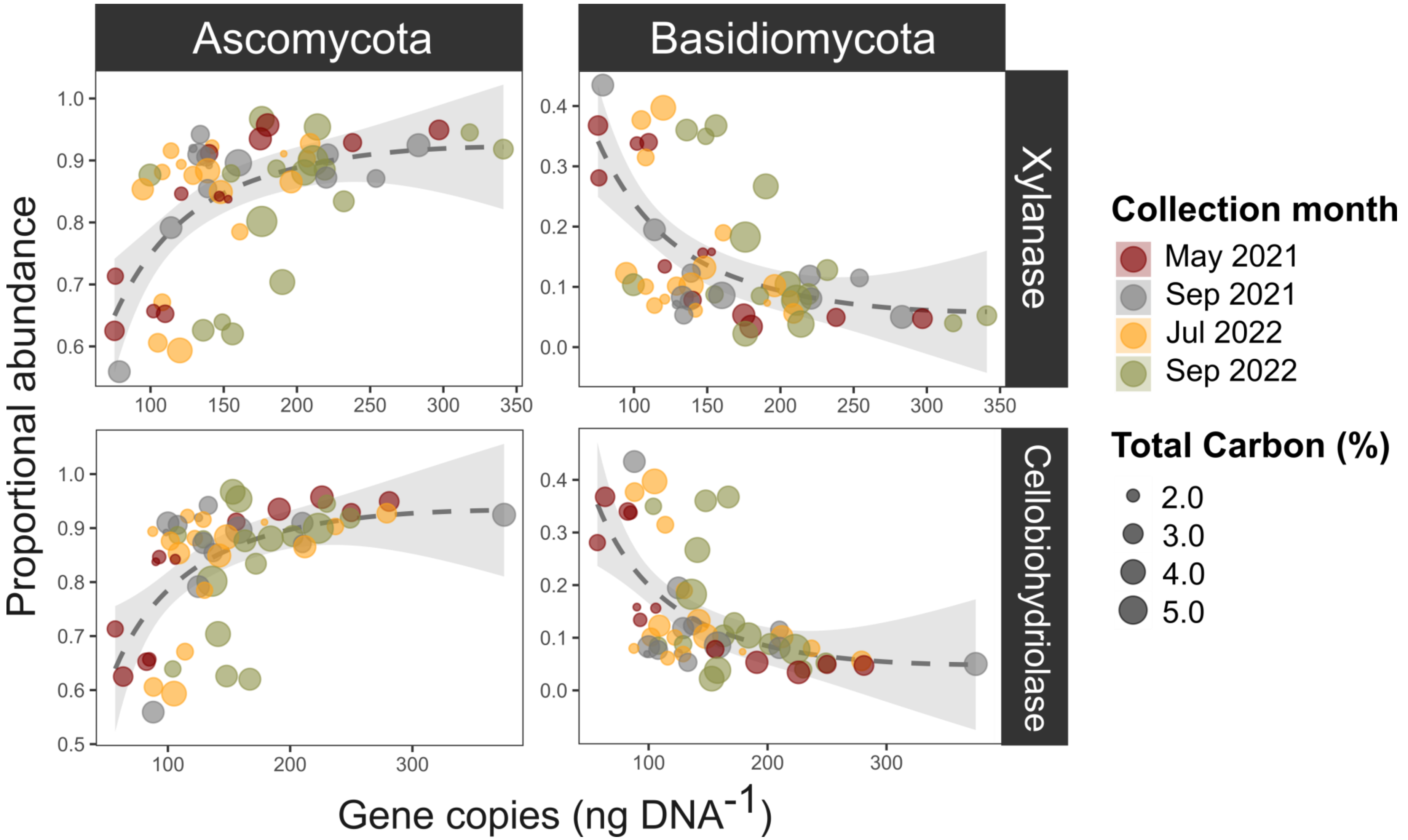


SHIFTS IN FUNCTIONAL POTENTIAL – CARBON CYCLING



SOILS ARE IMPORTANT

SOILS ARE IMPORTANT

Nutrient Cycling / Fertility
C, N, P, S

Soil Formation & Weathering

Plant / Crop Health

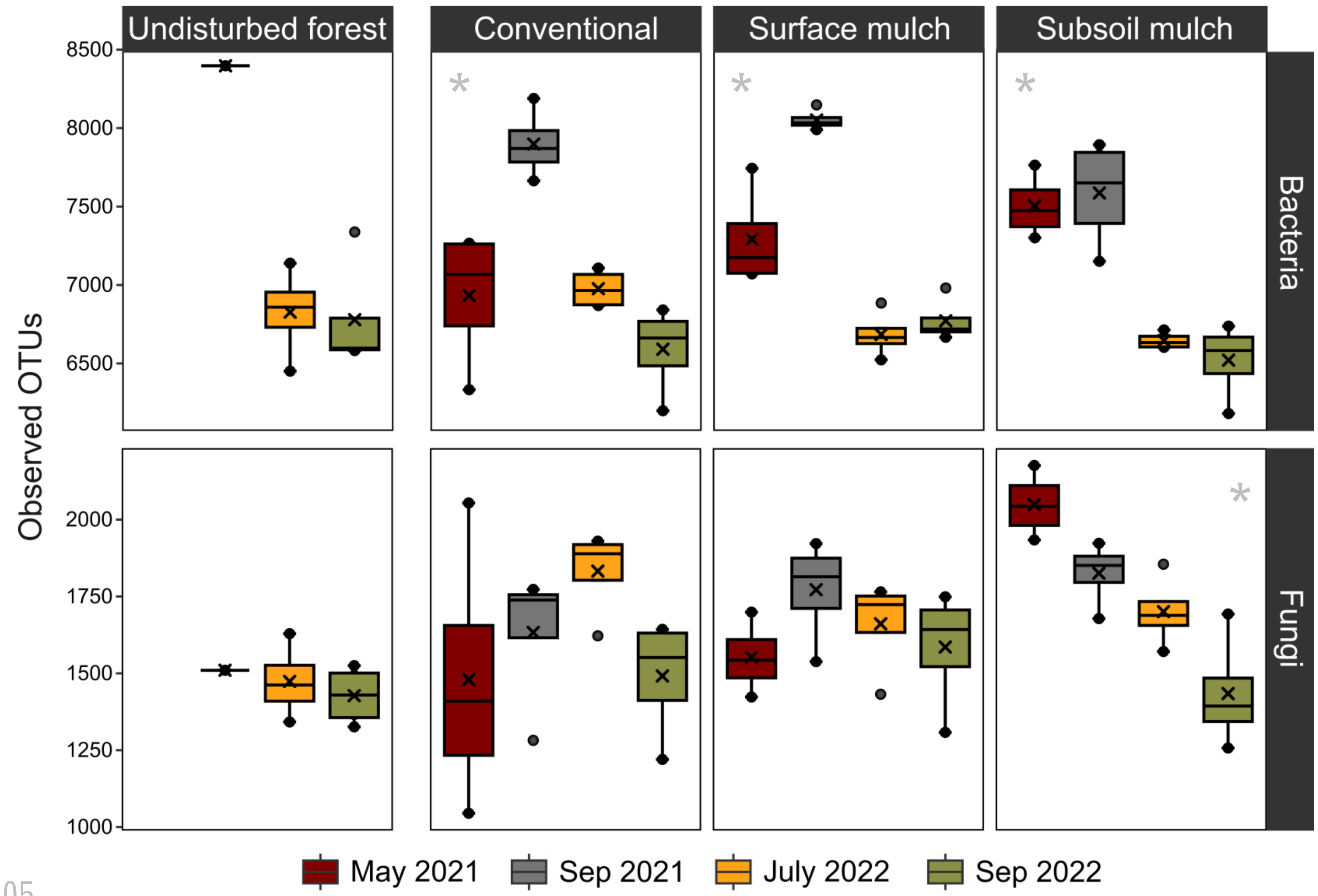
Pollutant degradation

Carbon Sequestration

Soil Resiliency

Human Health

IMPACTS OF LAND CONVERSION



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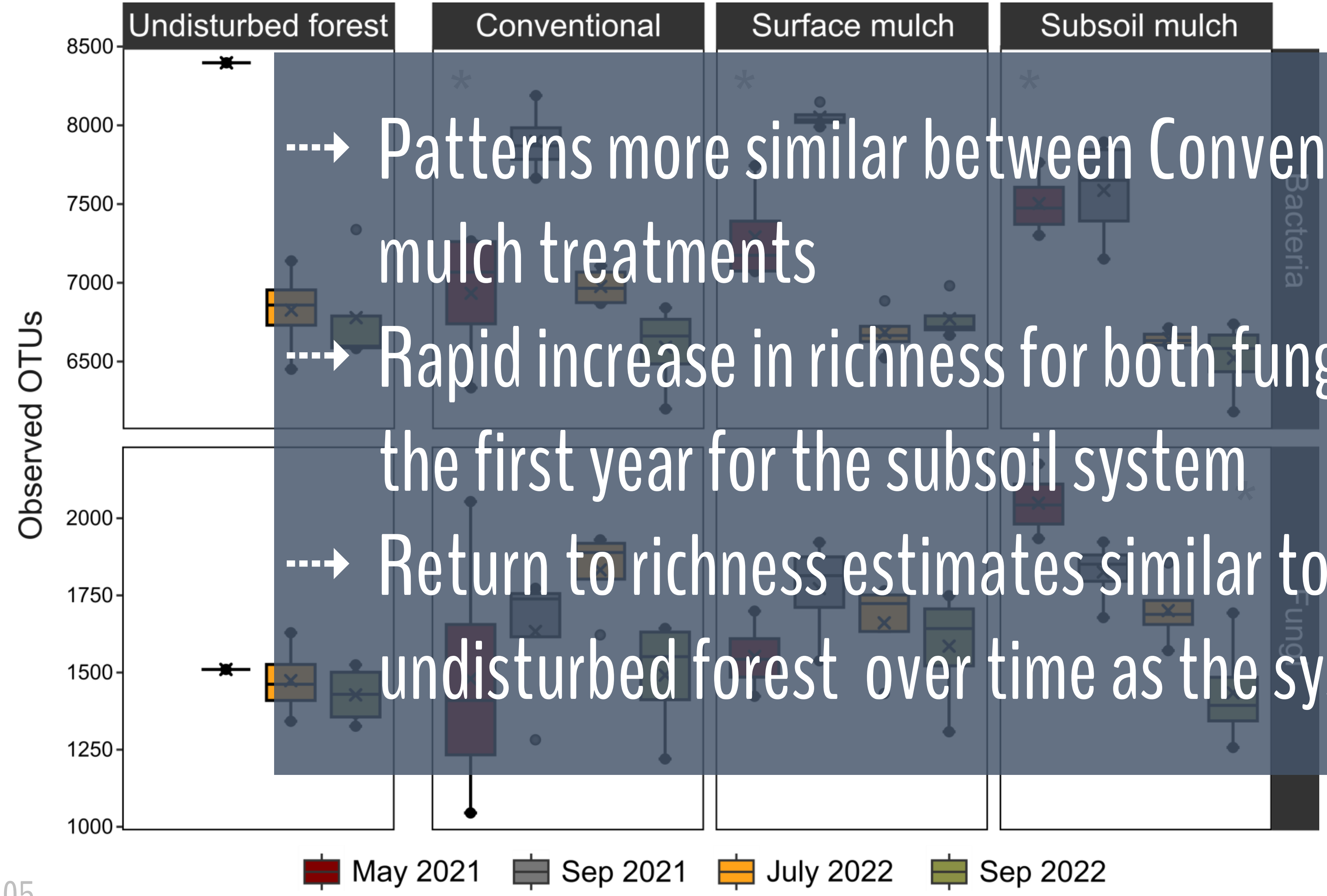
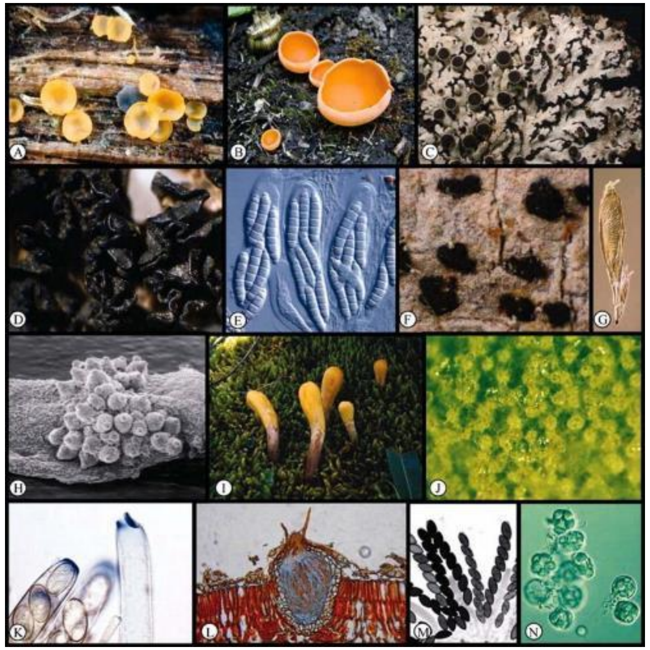


- Patterns more similar between Conventional and Surface mulch treatments
- Rapid increase in richness for both fungi and bacteria within the first year for the subsoil system
- Return to richness estimates similar to those of the undisturbed forest over time as the system stabilizes

* $p < 0.05$

What are the implications of this fundamental switch in fungal dominance?



Basidiomycota includes:

- Mushrooms (edible and poisonous), smuts, and rusts
- many ectomycorrhizal fungi
- many decomposers that are capable of breaking down lignin

Ascomycota includes:

- yeasts and filamentous fungi
- other mycorrhizal species
- many decomposers of other types of plant material
- pathogens

But lots of functional complementarity: many Ascomycota will perform the same role as Basidiomycota did in the forest, just in their own terms/time

Fungal pictures: DOI:10.1128/microbiolspec.FUNK-0053-2016