Going under-ground: root traits as drivers of ecosystem processes

Trends in Ecology & Evolution 29 12:692-699 (2014)

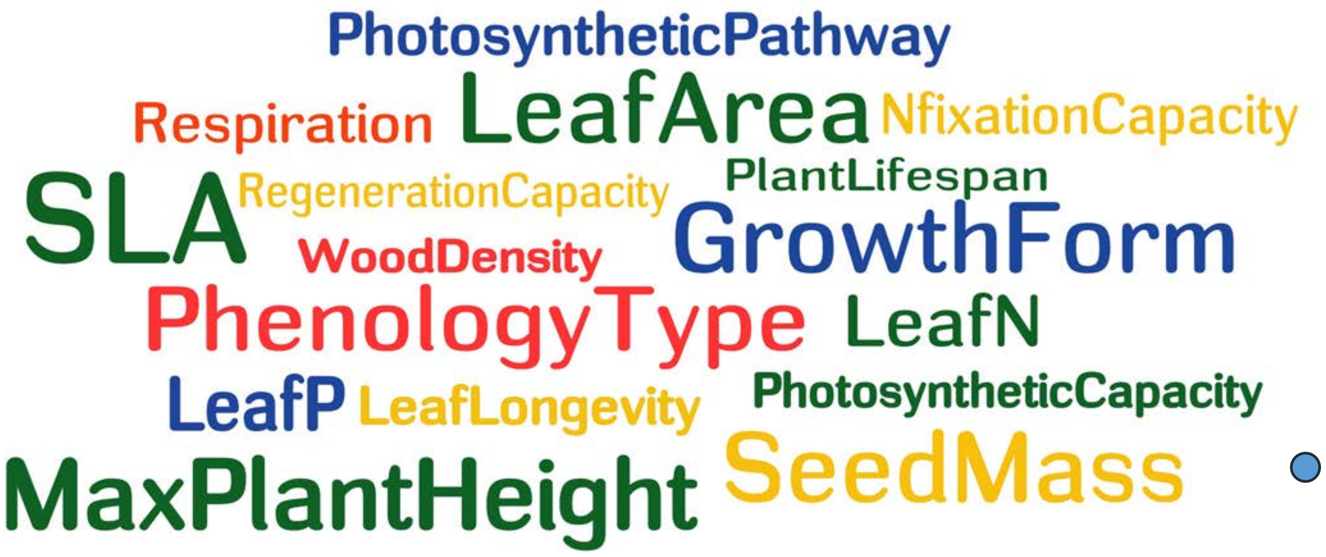
Luncheon seminar June 23, 2017

Community change and ecosystem processes

Slide # 1

Plant traits (特徵, 形質)

Community Change → Ecosystem Process



TRY Plant Trait Database HP

All above-ground traits??

Importance of belowground traits

Slide #2

1. Large amount of plant biomass
2. Provides anchorage
3. Nutrient absorption (nitrogen, phosphorus, etc..)
4. Water absorption

→ **Wide range of belowground strategies and high plasticity to changes in nutrient availability**

- <u>Architectural traits (構造的)</u>

Rooting depth, root length density, root branching

- <u>Morphological traits (形態的)</u>

Root diameter, specific root length, root tissue density, root dry matter content

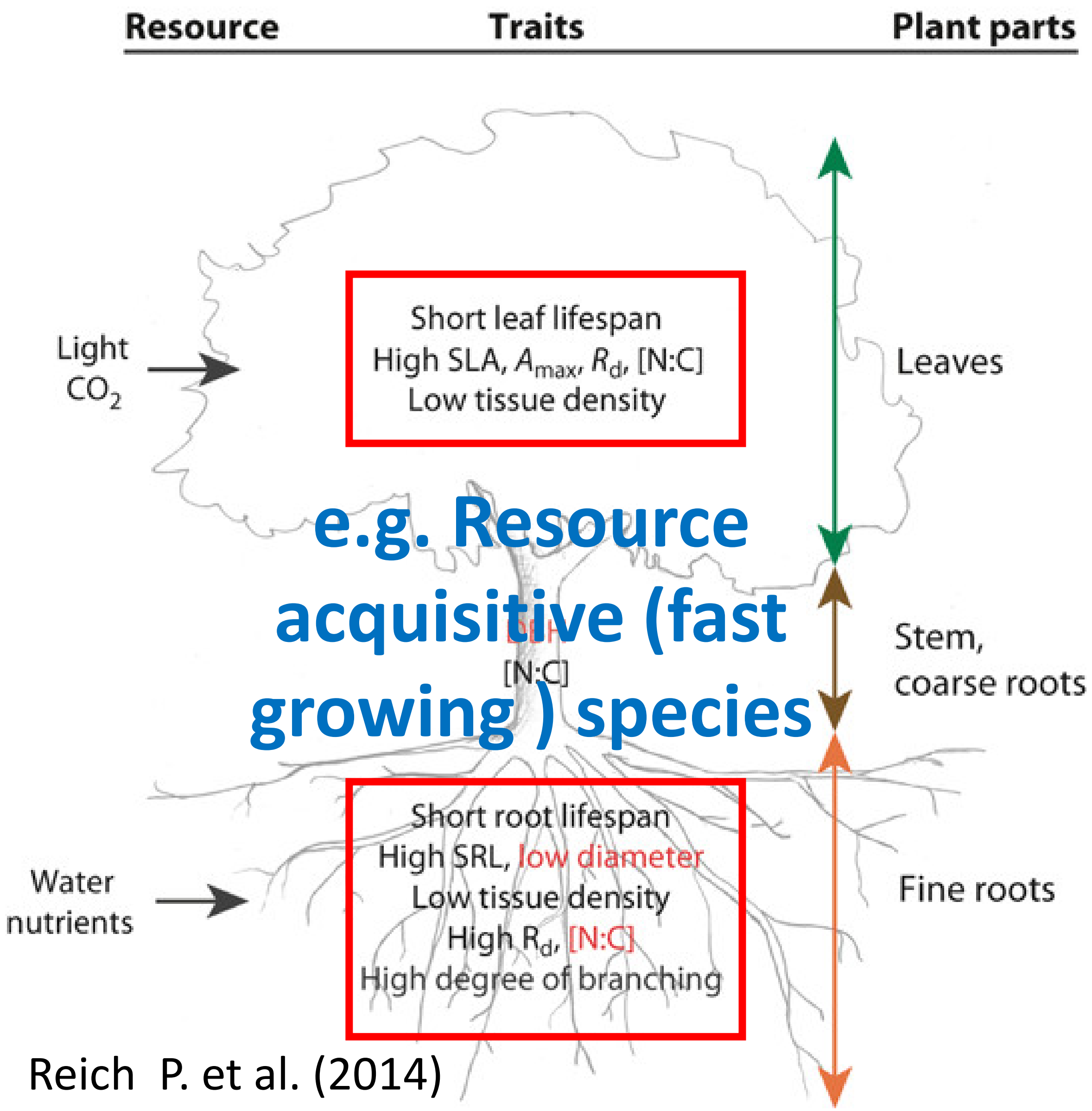
- <u>Physiological root traits (生理的)</u>

Nutrient uptake kinetics, root respiration, release of root exudates

- <u>Biotic traits (生物的)</u>

Interactions between roots and soil biota, associations with mycorrhizal fungi, rhizobia, interactions with pathogens

Resource economic spectrum（資源経済分布？）



e.g. Resource acquisitive (fast growing) species

Reich P. et al. (2014)
J. Ecology

Resource acquisitive strategy
(fast growing species)

Trait classification

Recourse economic spectrum

Resource conservative strategy
(slow growing species)

Looking at root traits as drivers of ecosystem processes

Slide #5

1. Carbon cycling

2. Nutrient cycling

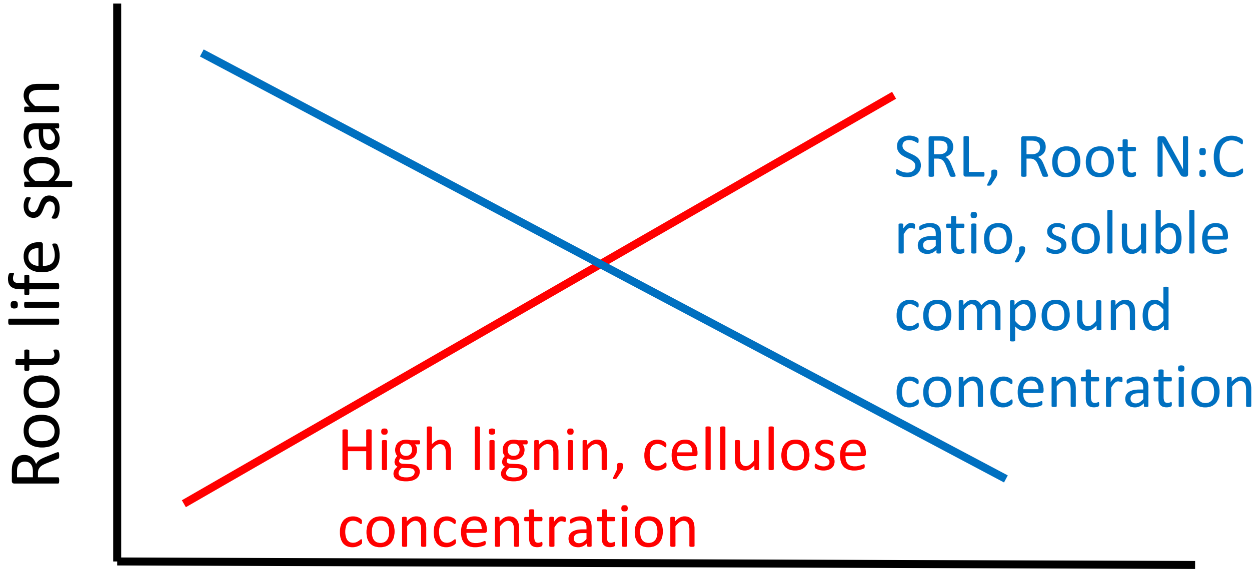
3. Soil structural stability

1. Carbon cycling

Input of carbon from root death

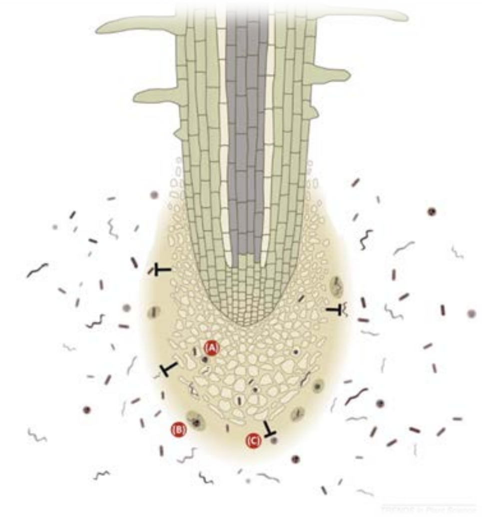
- Root density, rooting depth
- Root life span, turn over (pathogenic fungi, ECM)

Root death



1. Carbon cycling

CO_2 efflux（流出） from root respiration（呼吸） and exudation（滲出物）



- Respiration 40~50 % of total soil CO_2 flux
- Exudates: Amid acids, Sugars, Organic acids, Plant hormones…. etc.. (further explanation later on)

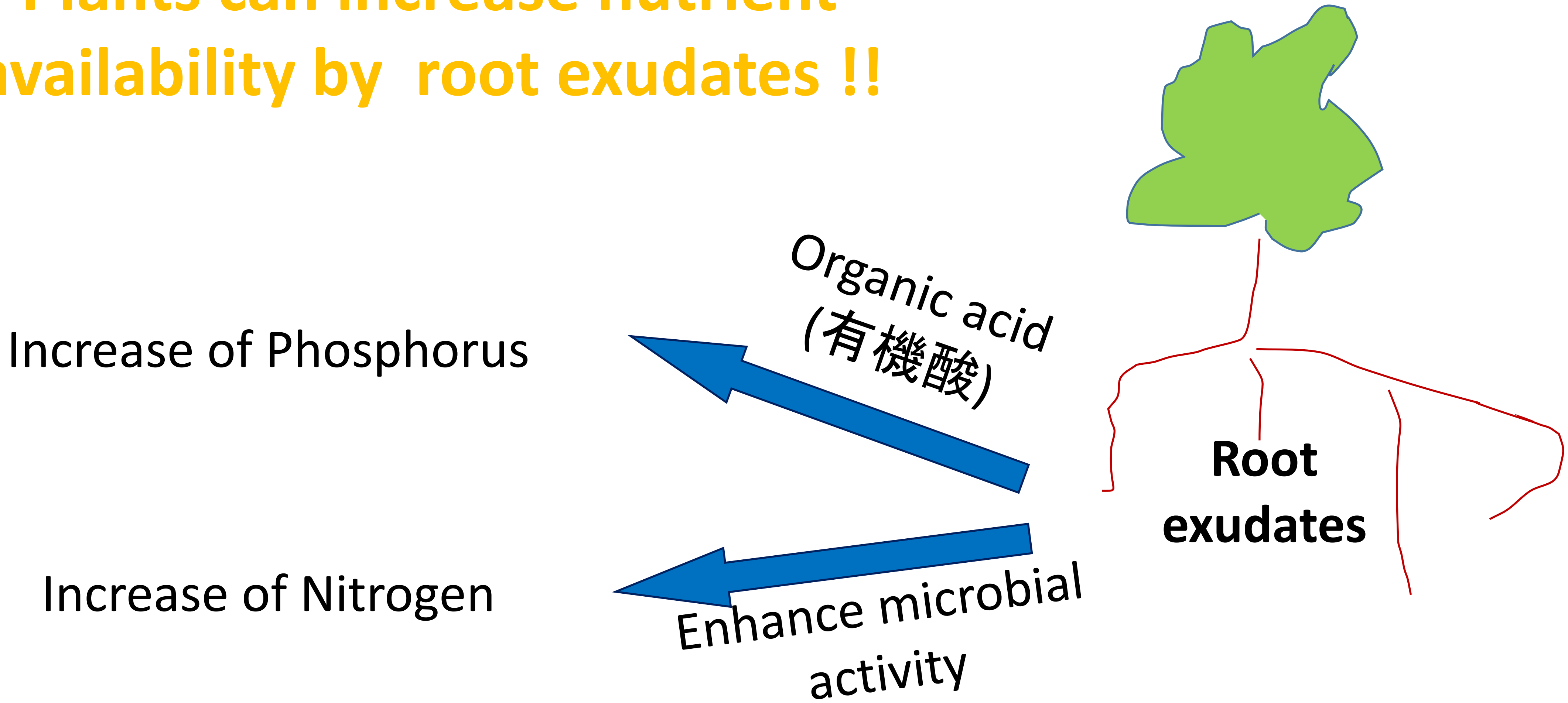
Indirect impacts

- Influences on composition of soil microbial community

e.g. Roots traits that stimulate fungi over bacteria (high lignin, low root N content) promotes soil C sequestration

2. Nutrient cycling

Plants can increase nutrient availability by root exudates !!



2. Nutrient cycling

Slide #9

AM fungi
dominant
（アーバスキュラー菌）

【In-organic（無機態） nutrient economy】
・Rapid decomposition rates
・ Rapid nutrient mineralization rates
・Uptake of in-organic N

ECM fungi
Dominant
（外生菌根菌）

【Organic（有機態） nutrient economy】
・Slow rates nutrient cycling
・Uptake of complex organic N

3. Soil structural stability

Soil stability

1. Root length density

- Fine and higher root density binds soil more effectively

2. Root diameter

- Roots push soil particles →larger roots increase soil bulk density adjacent to root, smaller roots decrease soil bulk density while increasing porosity

3. Rooting depth

- Deeper roots act to stabilize soil at depth, especially on slopes

3. Soil structural stability

4. Root exudates

- ❑ Increases soil aggregate (土壌粒団) stability

→ Root exudates contains polysaccharides (多糖) and proteins which act like glue and bonds mineral particles (鉱物粒子) together

- ❑ Forms hydrophobic coatings which act as water repellents

→ reduces wetting rates (湿潤速度) and slaking of soil （土壌の消和）

- ❑ More exudate release, stronger impact of soil stability

→ Species differ in exudate type

Large molecule exudates: effective binding

Small molecule exudates: greater impact on soil aggregation

3. Soil structural stability

5. Biotic root traits

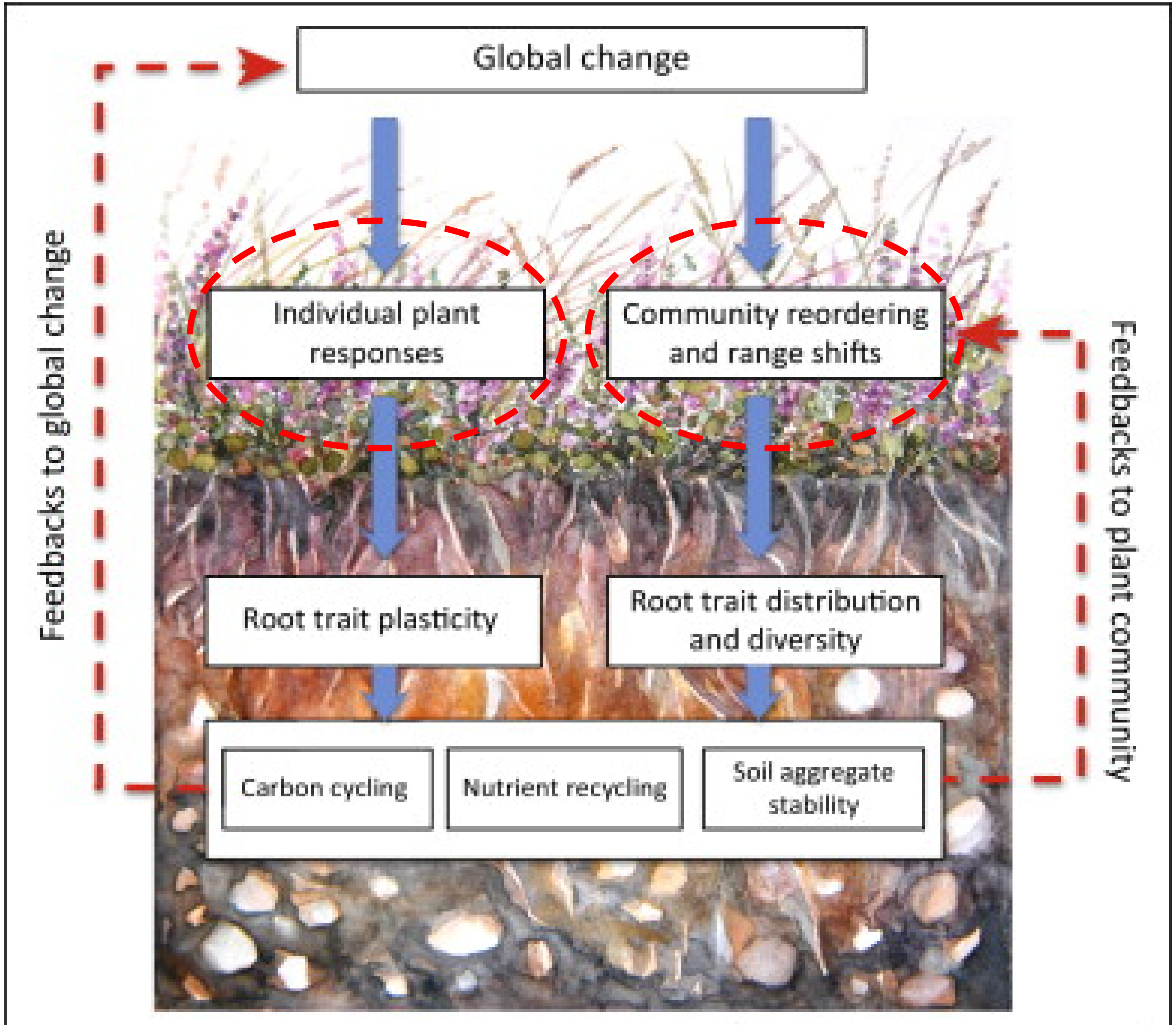
- ❑ Degree and type of mycorrhizal infection impacts on root aggregate stability

→ physical enmeshment of soil particles by network of mycelium (菌糸)

- ❑ Mycorrhizal fungi also impact soil formation

→ Acts as biological agents of mineral weathering

→ Enhances mineral dissolution through acidification and release of organic acids and chelating (キレート) compounds



Slide #13

Individual plant response

Increase of nitrogen

- Root branching (-)
- Mycorrhizal infection (-)

Drought (soil water availability)

- Architectural traits
- Morphological traits

Increase of CO_2

- Root length (+26.0%)
- Root diameter (+8.4%)
- Total root biomass (+28.8 %)
- Root respiration (+58.9%)
- Root exudates (+37.9%)
- Mycorrhizal infection (+3.35%)

Community reordering and range shifts

＜Local scale＞

❑ Dominance of deeper rooting species (reduced water availability, warming)

❑ Increase in relative abundance of C4 grasses, woody species and legumes (increase in CO_2)

＜Regional scale＞

❑ Expansion on species range: upward movement of alpine species, northward expansion of boreal forest, etc.. (warming)

→ new sets of root traits into ecosystems

→ results in changes in soil biochemical process and feedbacks to climate change

4. Conclusion and future challenges

		Carbon cycling		Nutrient cycling			Structural stability		
		Inputs	Decompo-sition	Inputs	Minerali-sation	Plant uptake	Erosion resistance	Porosity	Aggregate formation
Architectural	Root length density	↑	→	↑	↑	↑	↑	↑	↑
	Rooting depth	↑	→	↗	?	↑	↑	↑	→
Morphological	Specific root length	↑	↗	?	↗	↑	↑	↑	↑
Physiological	Root N content	↑	↑	↑	↑	?	?	?	?
	Root exudates	↑	?	↑	?	?	↑	?	↑
Biotic	Rhizobia	↑	↑	↑	↑	↑	↘	↑	↑
	Mycorrhizae	↑	→	?	→	↑	↑	?	↑
	Pathogens	?	↑	↑	↑	↓	?	?	?

TRENDS in Ecology & Evolution

Future challenges…

Improve knowledge on variation of root traits within and among species across plant communities and ecosystems
(Date base: TRY Plant Trait Database)

Improve understanding of mechanism by which root traits impact ecosystem processes via their interaction with microbial communities