UF IFAS
UNIVERSITY of FLORIDA

SCHOOL OF FOREST, FISHERIES, AND GEOMATICS SCIENCES

Recovery of Rare Earth Elements

Creating new markets from residues

Matias Kirst
University of Florida / IFAS
Florida Forestry Association Annual Meeting · Amelia Island

New or Emerging Markets

NY Times

Pycnandra acuminata

Why are critical minerals such as rare earth elements (REE) important?

REEs are difficult to recover, but are enormously important in the value chain.

$8B
2024 global market

≈2×
forecast by 2030

~80%
U.S. import reliance

Motors, turbines, electronics, defense, and high-efficiency manufacturing all depend on REE-containing materials.

What are rare earth elements?

REEs are a family of 17 metals —
not one element and not one market.

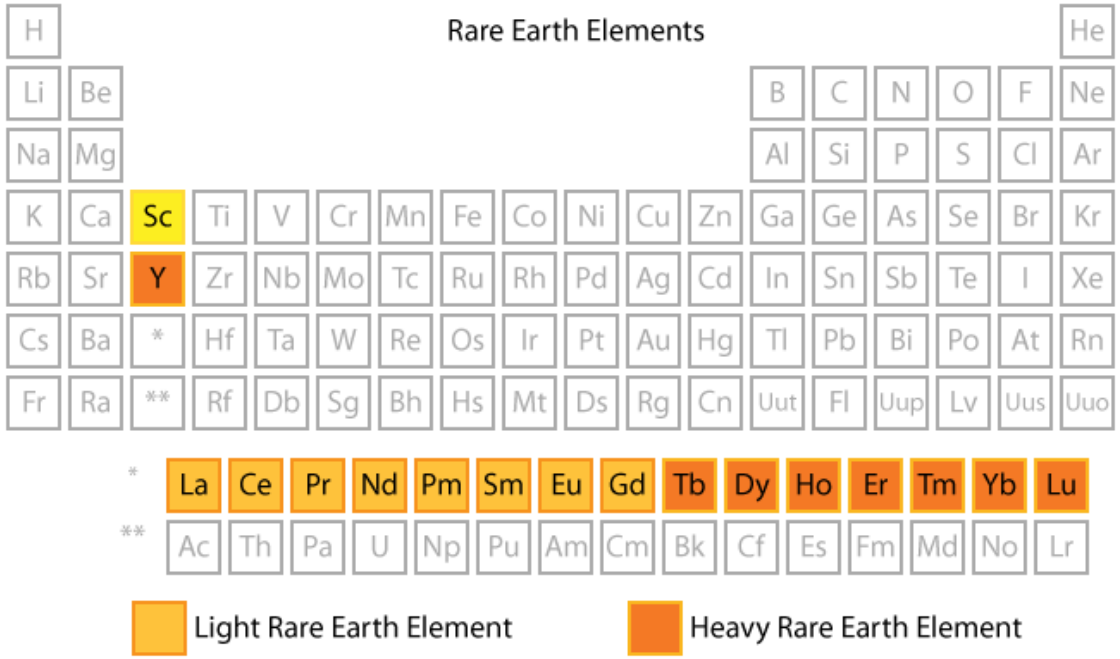
17 elements
15 lanthanides
+ Sc + Y

Heavy REEs are most valuable

1. Lanthanum — **La**
2. Cerium — **Ce**
3. Praseodymium — **Pr**
4. Neodymium — **Nd**
5. Promethium — **Pm**
6. Samarium — **Sm**
7. Europium — **Eu**
8. Gadolinium — **Gd**
9. Terbium — **Tb**
10. Dysprosium — **Dy**
11. Holmium — **Ho**
12. Erbium — **Er**
13. Thulium — **Tm**
14. Ytterbium — **Yb**
15. Lutetium — **Lu**

Also commonly included with REEs:

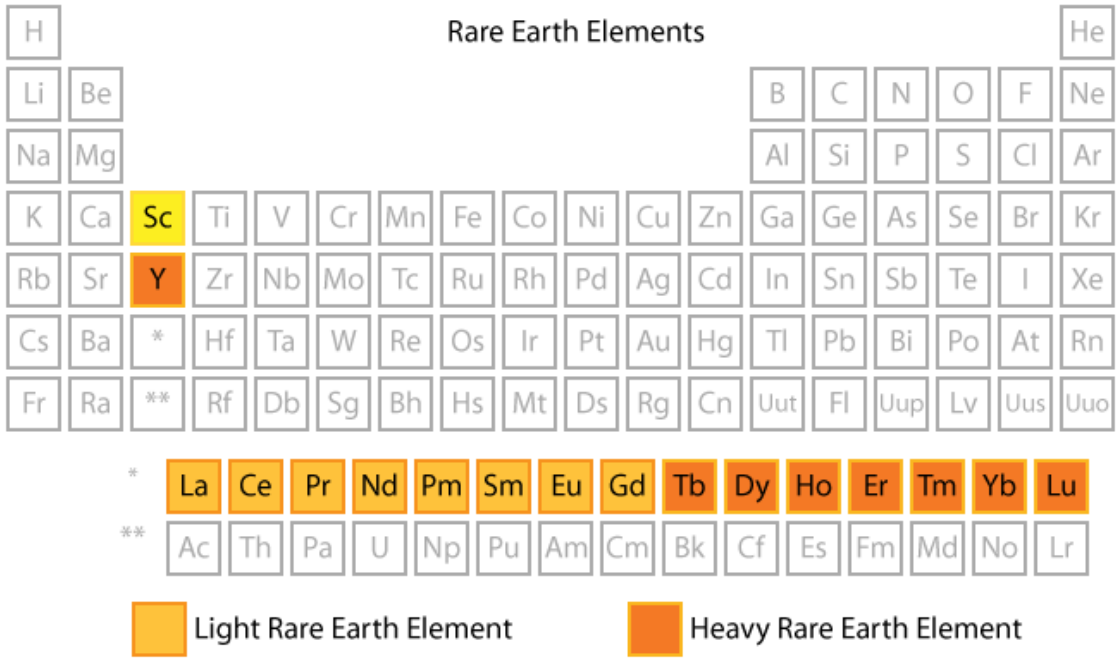
16. Scandium — **Sc**
17. Yttrium — **Y**



REEs are widespread — but highly dilute

REEs are widespread in soils, but usually only at ppm-level concentrations.

- **The challenge is not finding REEs.**
- **It is finding enough recoverable REEs per tons to justify processing.**
- **Or finding a way to concentrate them in an industrial residue (or a plant!).**



~1 mg/kg = 1,000 tons of soil for 1 kg of REE

Plants absorb REEs — some in large amounts

China has used REE-containing agricultural products for decades.

Foliar sprays + seed treatments

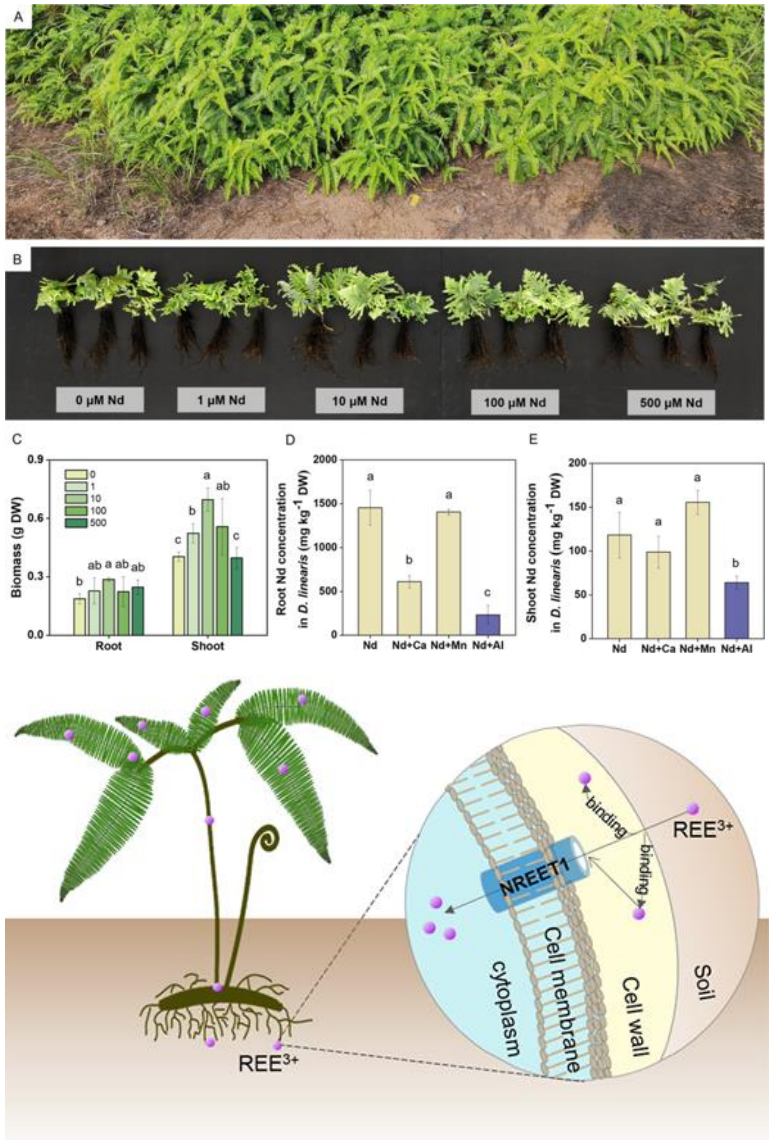
Fertilizer additives

Plant uptake is common

No essential function established

Reported low-dose responses: growth, photosynthesis, nutrient use, and stress tolerance

Dicranopteris dichotoma



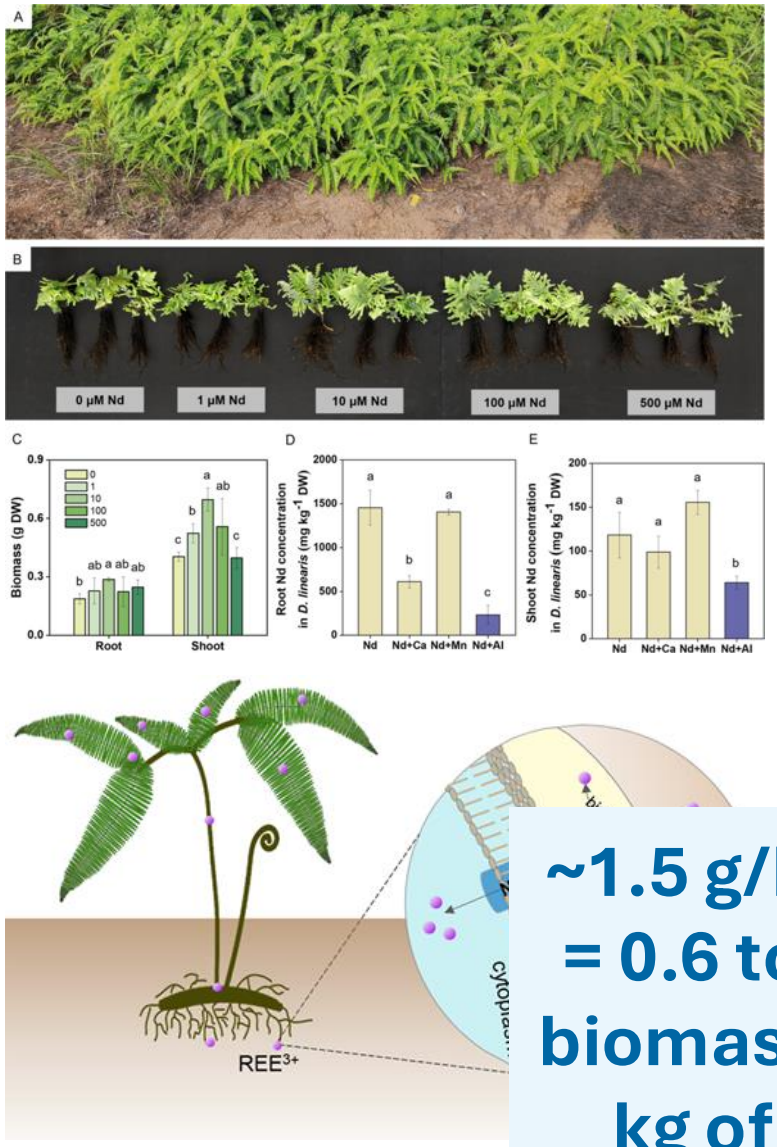
Plants absorb REEs — some in large amounts

China has used REE-containing agricultural products for decades.

foliar sprays + seed treatments	**fertilizer additives**
plant uptake is common	**no essential function established**

Reported low-dose responses:
growth, photosynthesis, nutrient use, and stress tolerance

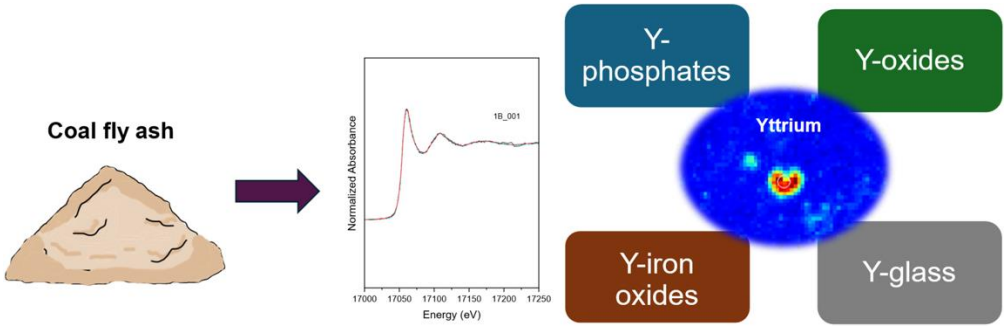
Dicranopteris dichotoma



~1.5 g/kg DW = 0.6 tons of biomass for 1 kg of REE

Recovery pathway 1: Critical minerals from forest outputs

Traditional value	→	Emerging value	→	Market outcome
timber pulp and paper bioenergy		Recover REEs from industrial by-products (fly ash, sludge, others)		a two-product forest output: wood + minerals



Dr. Yuanzhi Tang
Georgia Tech

The opportunity is **not to replace pulp, timber, or energy markets**. It is to: attach a higher-value product stream to material already moving through forestry infrastructure.

Why forestry is a credible platform

1.3M jobs
+$250B output

30–35M tons
logging residue / yr

Existing mills, boilers, trucks, and contracts

Ash concentrates mineral components

The **Southern forest products sector already aggregates biomass at industrial scale**. That is exactly what a new mineral feedstock market needs.
Mills may be able to ship graded feedstock, host extraction, or partner with regional recovery hubs.

Recovery pathway 2: trees designed to capture REEs

Engineered Populus

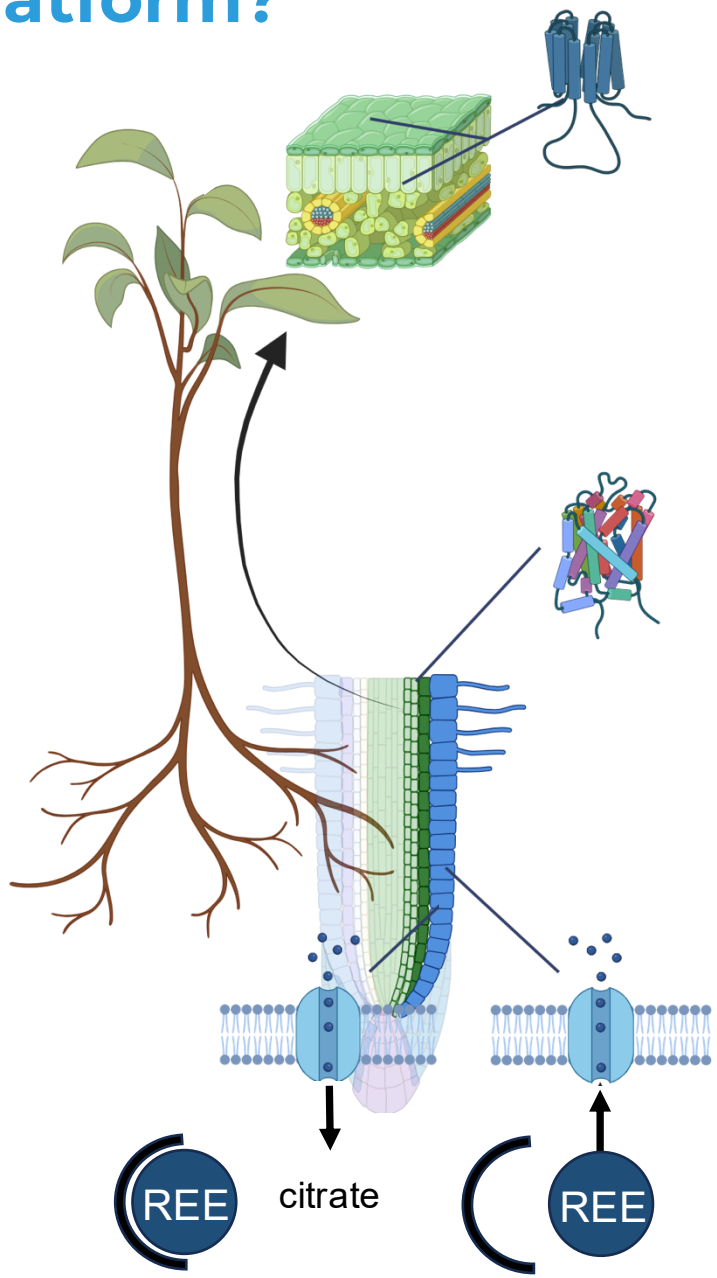
Grown on REE-enriched or mining-impacted soils

Aboveground biomass as harvestable ore

Fiber (biomass) value plus mineral value

Target concept: renewable phytomining systems that fit forestry growth cycles and logistics.

Why trees/forests are a credible platform?



4. REE storage

3. REE transport

2. REE uptake

1. (Bio)leaching

- REEs are bound to soil particles
- Plants don’t capture or store REEs
- We bio-designed trees to bioleach REEs (citrate transporters), uptake them (bacterial and plant transporters) and transport/store (His) in aboveground compartments.

Why trees/forests are a credible platform?

- In **FL >100,000 acres phosphate clay** settling areas (500-1,000 ppm REEs, ~5K tn./year REE annual, 600K total)
- In **GA Kaolin tailings** (300-5,000 ppm, HREEs)

News Channel 8 photo by Paul Lamison

Bio-designed trees for REE phytoming

⇩

Biomass harvested for bioenergy

⇩

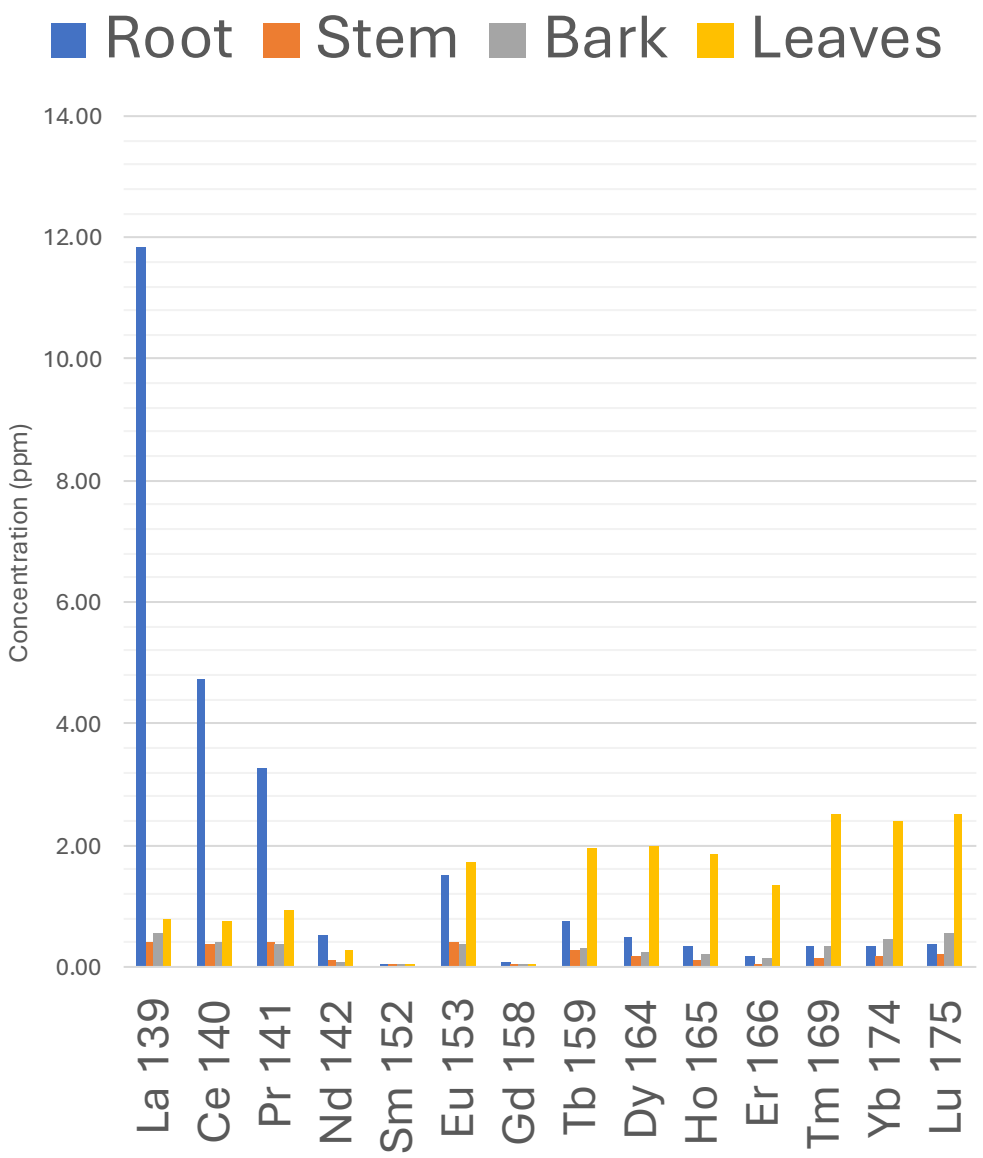
Ash/bio-ore recovered

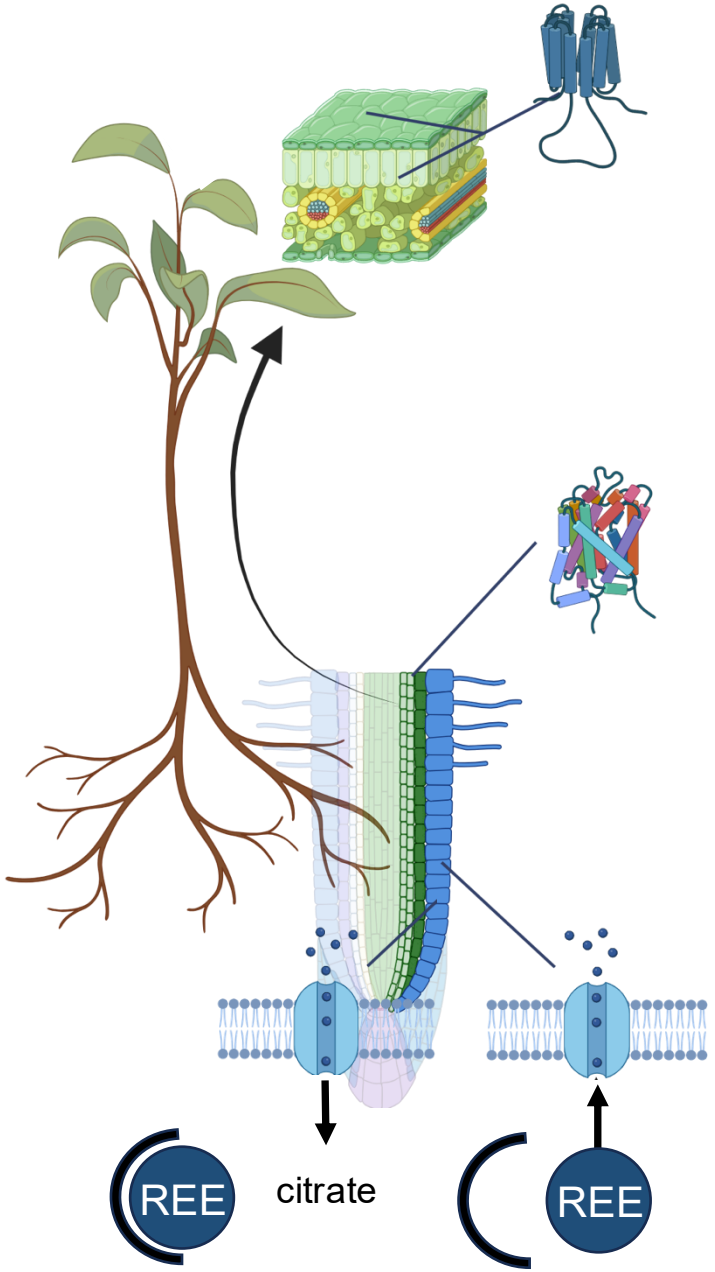
(1–3% of dry biomass mass concentration factor 30–100×)

⇩

Refining/processing

Ongoing work



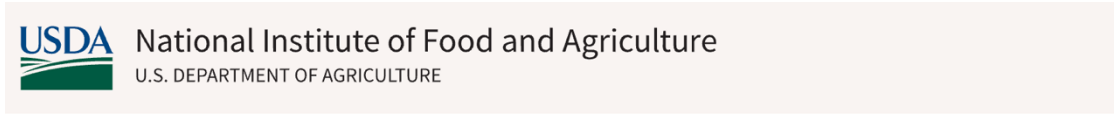


4. REE storage

3. REE transport

2. REE uptake

1. (Bio)leaching



Thank you!

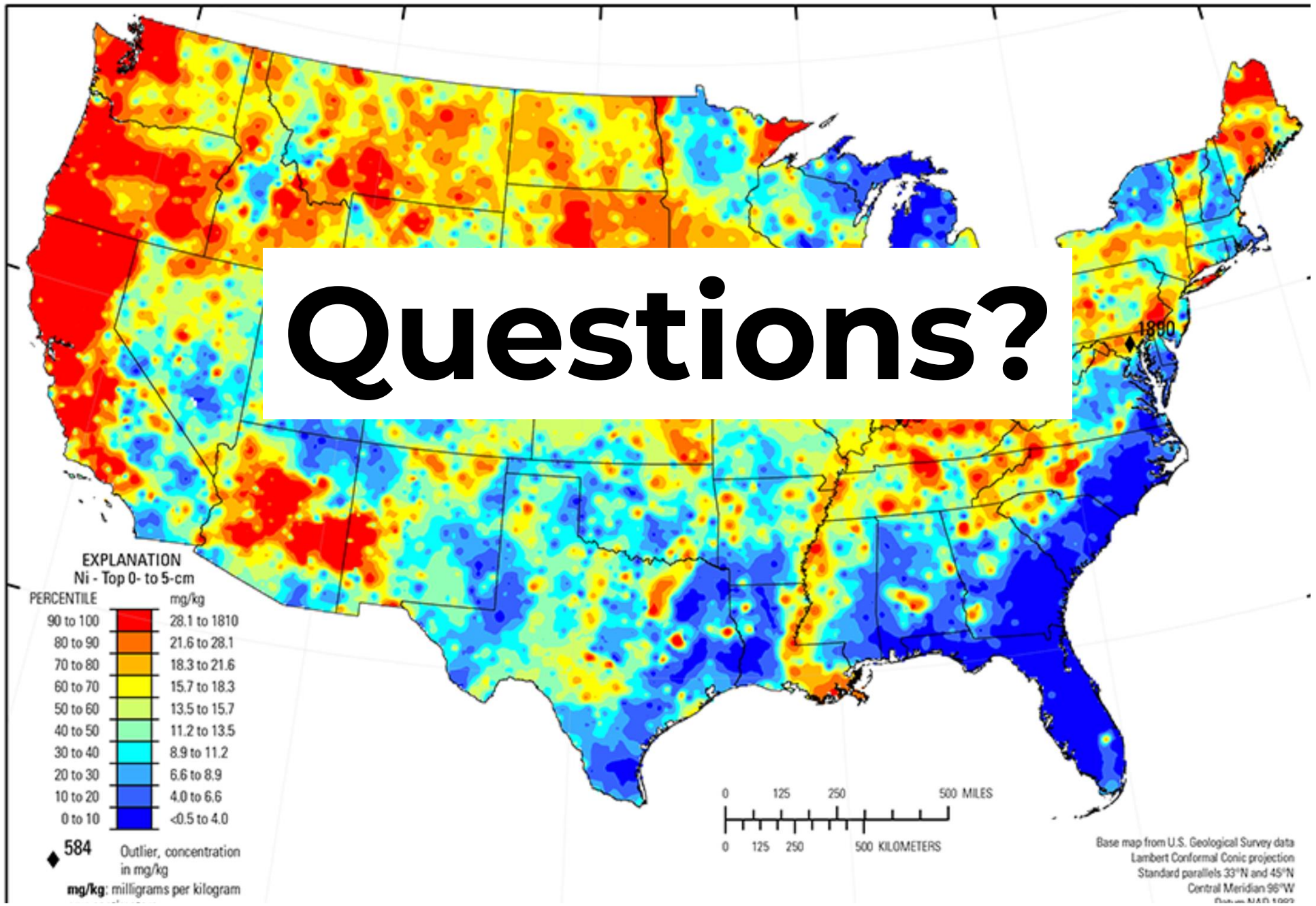
GREAT SOUTH TIMBER & LUMBER, LLC.

Bio Resource

GRU
More than Energy

REX LUMBER

FLORIDA FORESTRY ASSOCIATION


EXPLANATION
Ni - Top 0- to 5-cm
PERCENTILE
mg/kg
90 to 100
28.1 to 1810
80 to 90
21.6 to 28.1
70 to 80
18.3 to 21.6
60 to 70
15.7 to 18.3
50 to 60
13.5 to 15.7
40 to 50
11.2 to 13.5
30 to 40
8.9 to 11.2
20 to 30
6.6 to 8.9
10 to 20
4.0 to 6.6
0 to 10
<0.5 to 4.0
584
Outlier, concentration in mg/kg
mg/kg: milligrams per kilogram
1800
0 125 250 500 MILES
0 125 250 500 KILOMETERS
Base map from U.S. Geological Survey data
Lambert Conformal Conic projection
Standard parallels 33°N and 45°N
Central Meridian 96°W

Questions?