Accelerated Domestication and the Circular Carbon Economy

A perspective from perennial cropping systems

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Presentation outline

- Poplar Life History
- Concept of Accelerated Domestication
- Genomewide Association Studies
- Targeted Phenotypes
- Epistasis and Pleiotropy
- Genomic Selection
- Poplar Ideotype
- Summary

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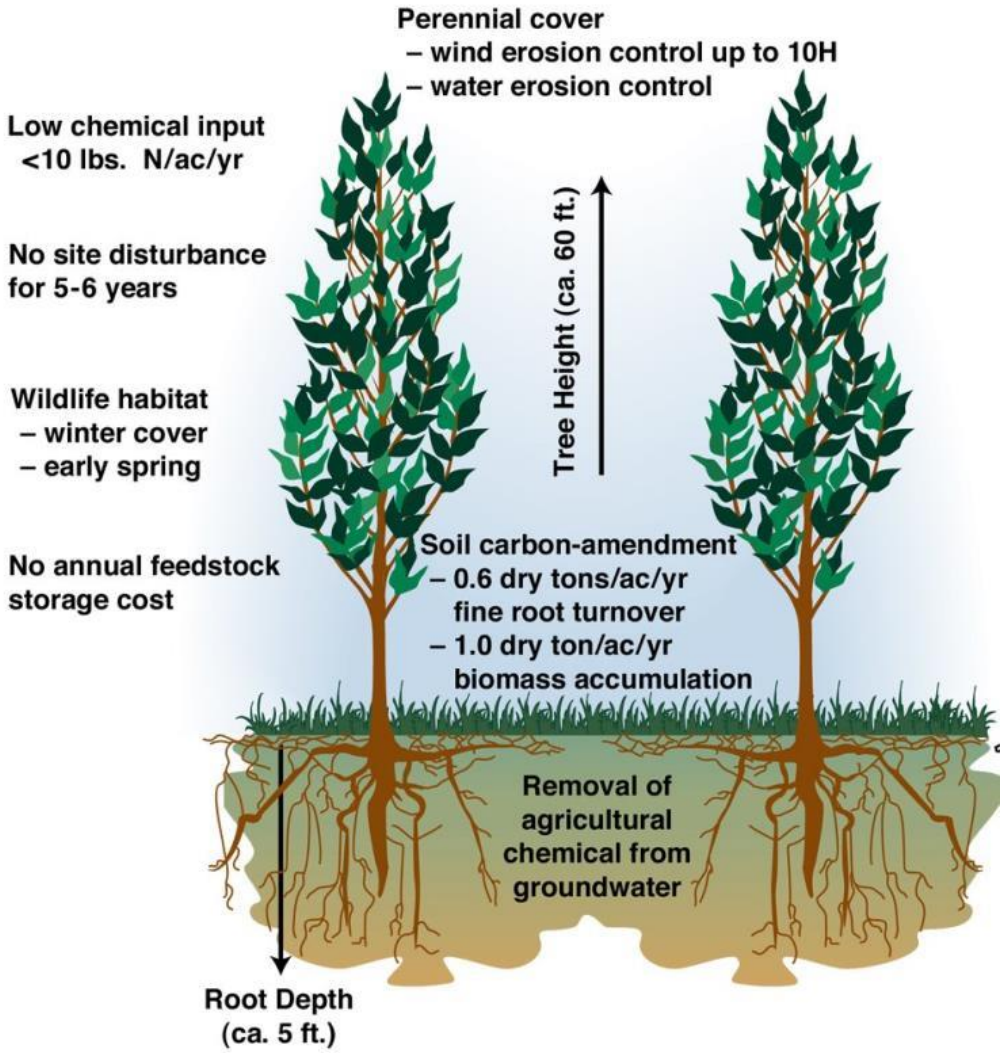
Poplar biology and a fully domesticated ideotype

Native poplars are:

Long-lived
Dioecious
Fast growing
Undomesticated
Perennial plants

Domesticated poplars also have:

Higher productivity per unit area
Greater number of stems per unit area
Drought/Stress tolerance
Nutrient-use efficiency
Reduced recalcitrance of harvested tissues
Greater product yield



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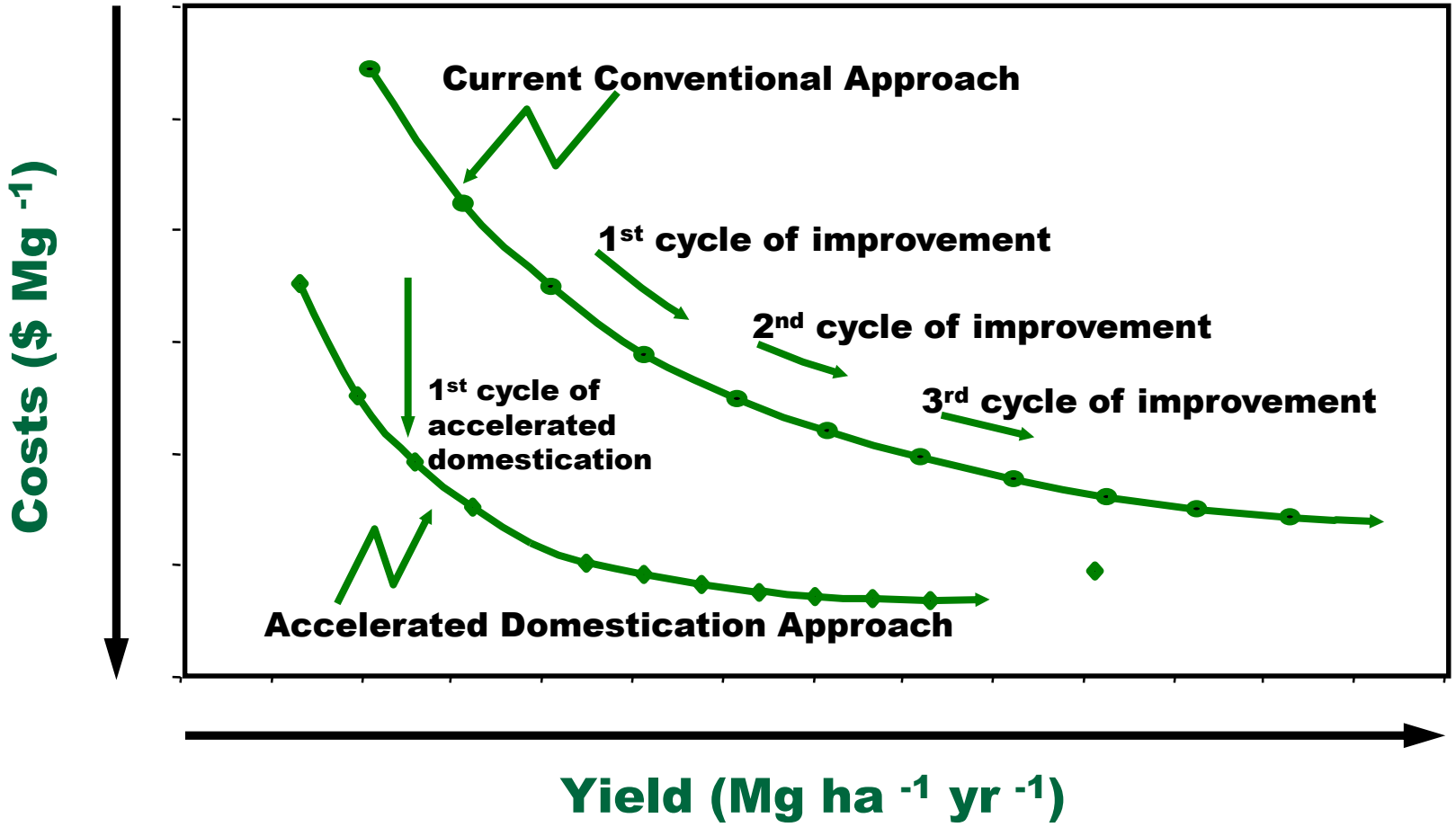
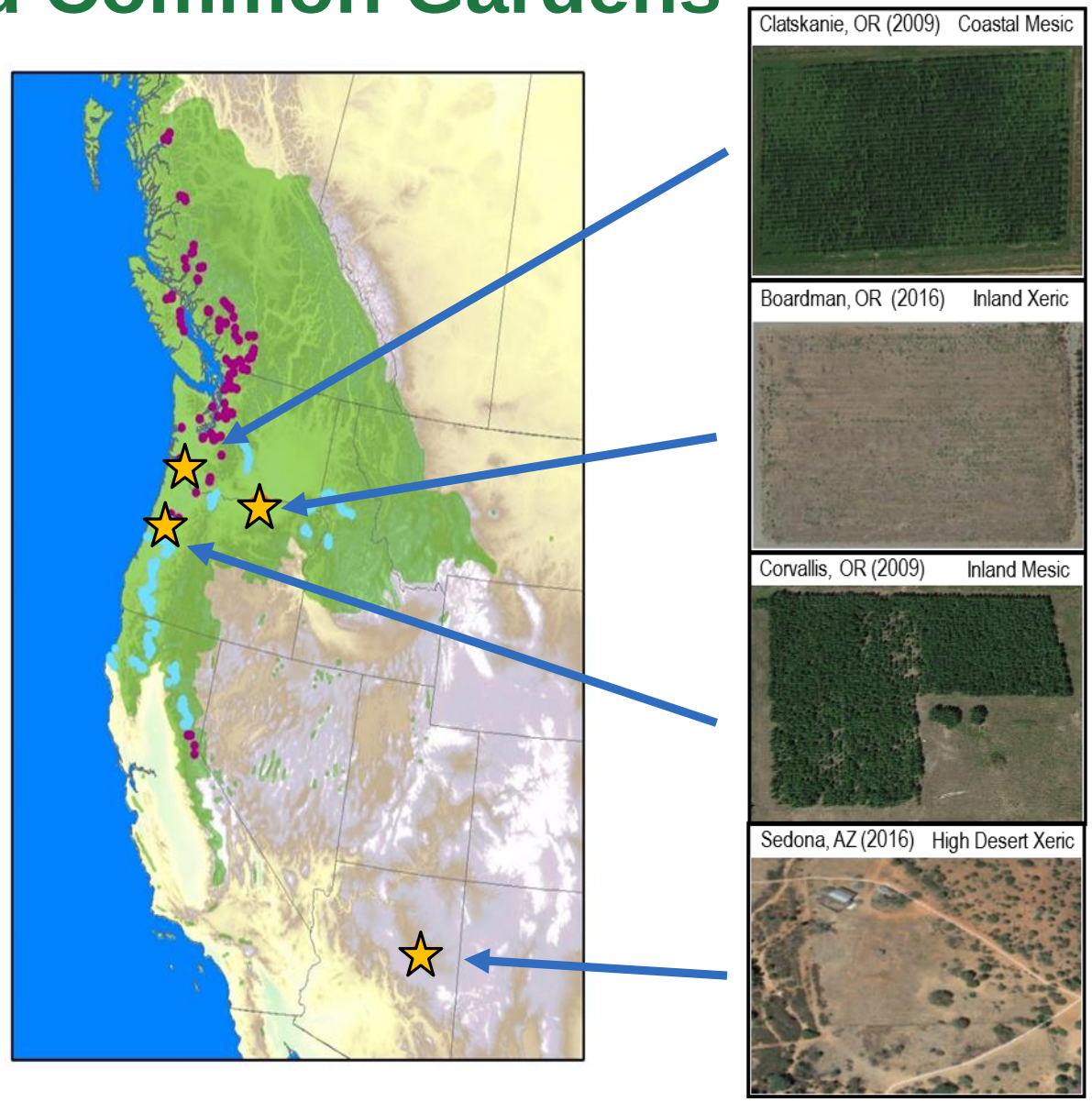
There is a relationship between yield and cost

Traditional Breeding achieves incremental annual improvement

Accelerated Domestication disrupts the relationship between yield and cost

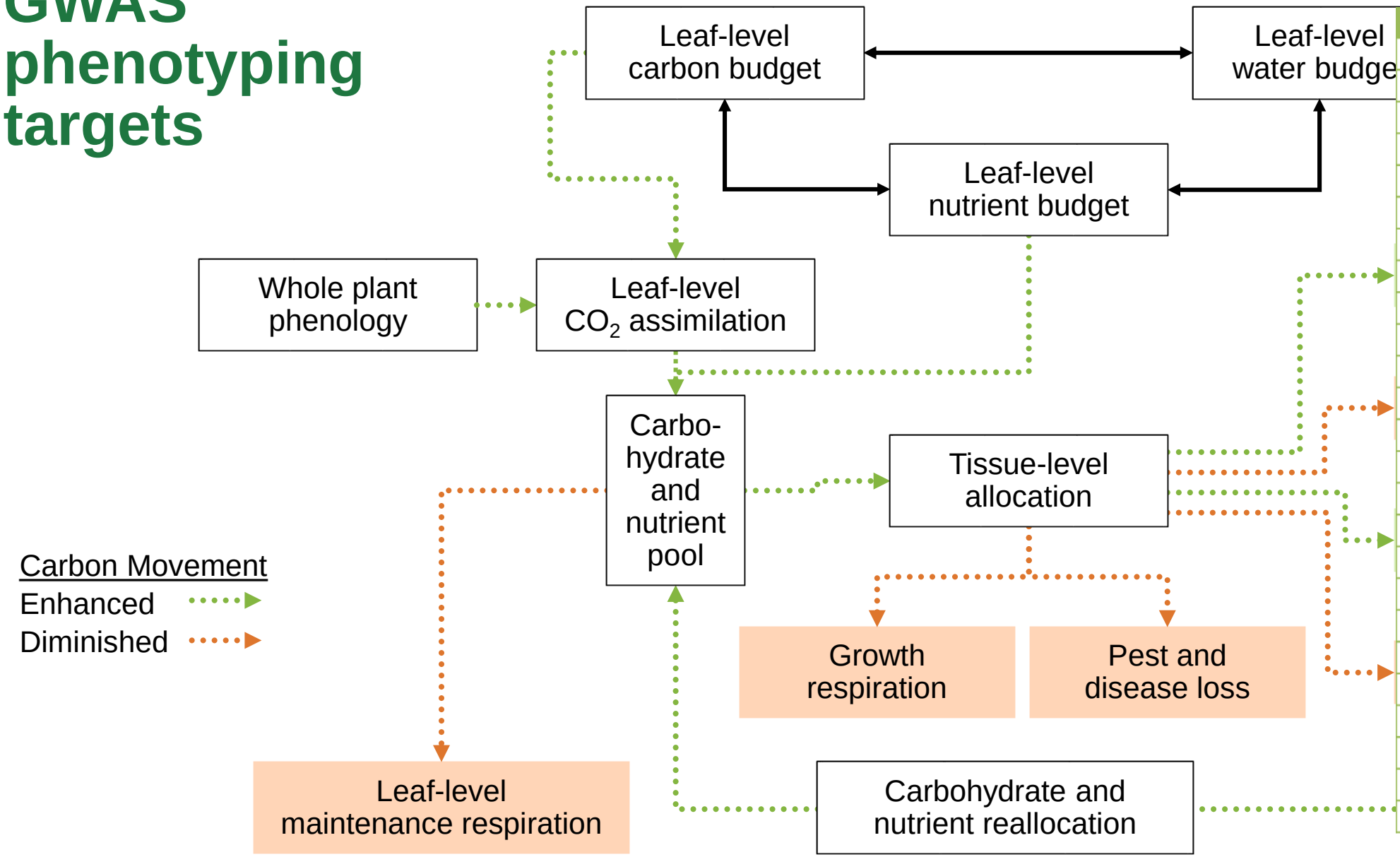


Genomewide Association (GWAS) and Common Gardens



- The selected population / panel
  - 1250 genotypes
  - Southern BC to Northern CA
  - Established in 4 common gardens
- Genotyping
  - Resequenced at a minimum of 18x depth
  - 68 million high-quality SNPs
  - A SNP every 17 bp
  - LD decays on average within 300 bp and in many cases within <20 bp
- Transcriptome
  - RNAseq data was generated for the 1250 genotypes for leaves, xylem and roots

GWAS phenotyping targets



Trait definition	H^2
Bud flush (score)	0.79
Bud set (score)	0.51
Apical dominance (cm)	0.27
Internode length (mm)	0.34
Sylleptic branches (#)	0.25
Height (cm)	0.43
Diameter (mm)	0.16
Rust (score)	0.63
Arabinose (%)	0.69
Galactose (%)	0.64
Glucose (%)	0.46
Xylose (%)	0.69
Mannose (%)	0.39
Insoluble lignin (%)	0.66
Soluble lignin (%)	0.97
Total lignin (%)	0.65
Syringyl monomers (%)	0.39
Holocellulose (%)	0.11
Alpha cellulose (%)	0.42
Hemicellulose (%)	0.35
Fiber length (mm)	0.24
MFA bark (°)	0.44
MFA pith (°)	0.41
Average wood density (kg m^{-3})	0.56
Cellulose crystallinity (%)	0.40

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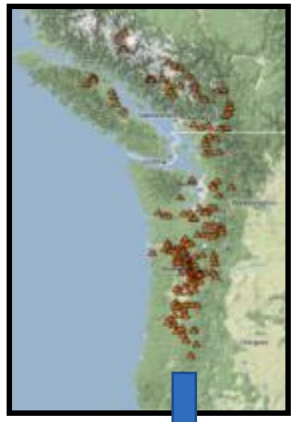
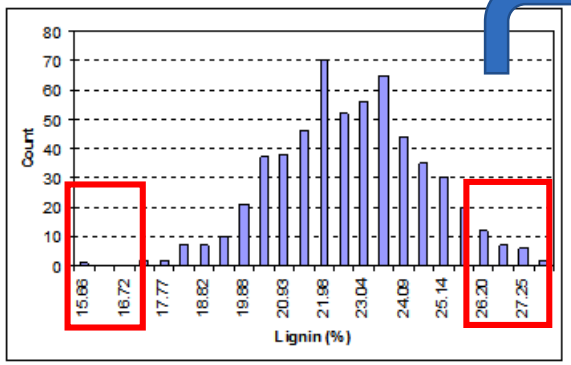
Genome-wide association approaches

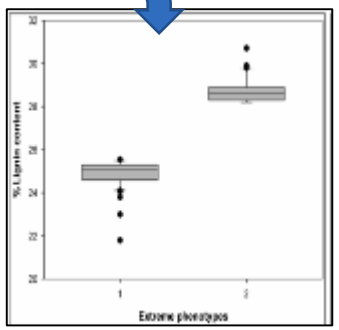
Assemble a population



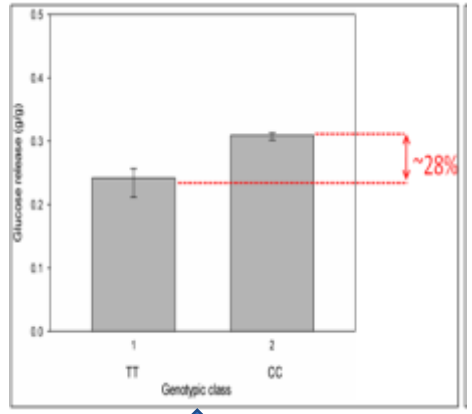
Phenotype the population

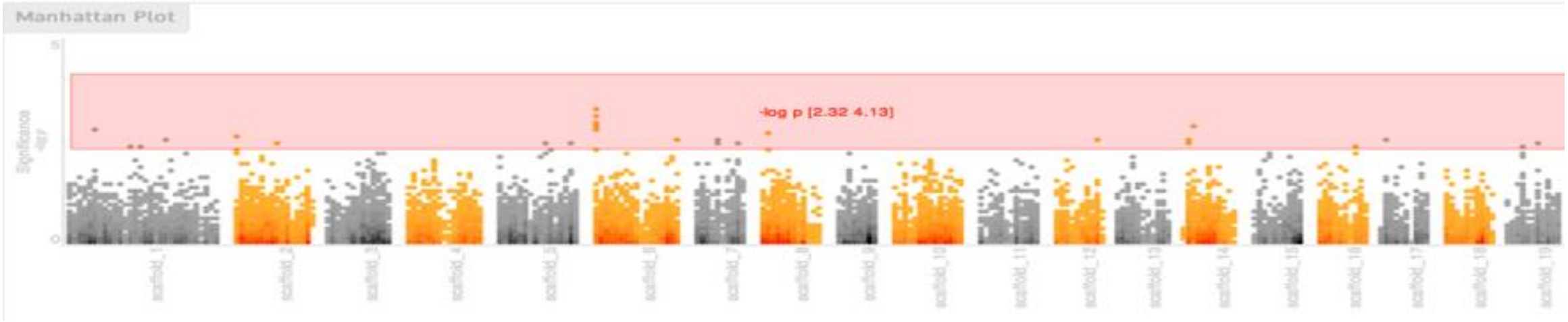


Create a SNP library



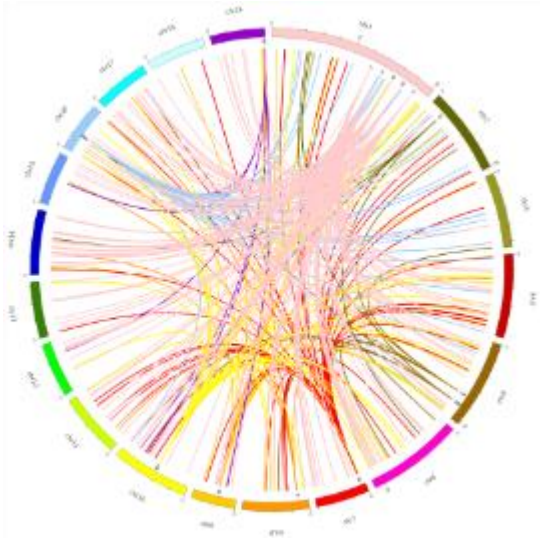
GWAS Analysis





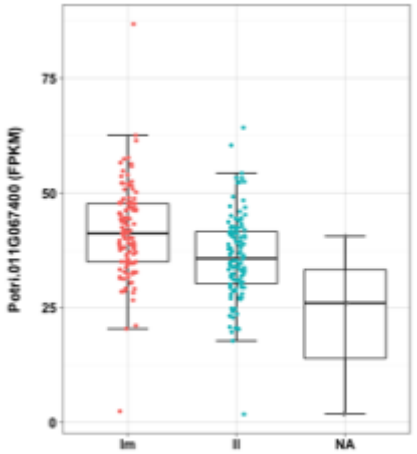
Epistatic Network: Transcriptional Hotspots

Trans-acting eQTN hotspots
(i.e. >20 co-expressed loci)

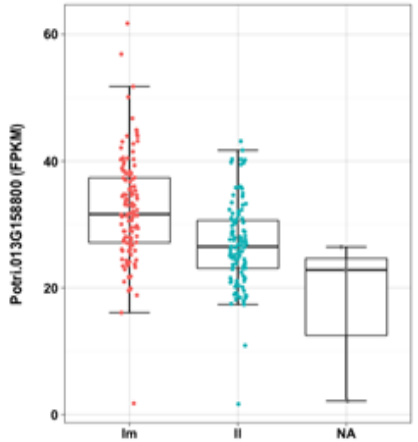


Trans-acting eQTN hotspots
on chromosome 1

Co-expressed Loci

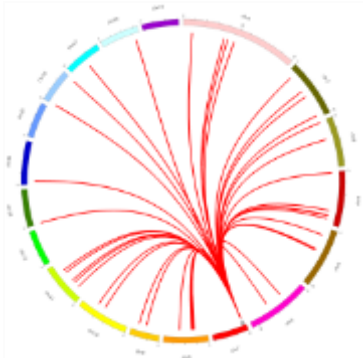


Gene A

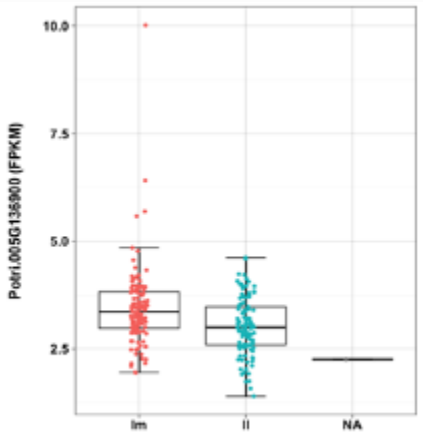


Gene B

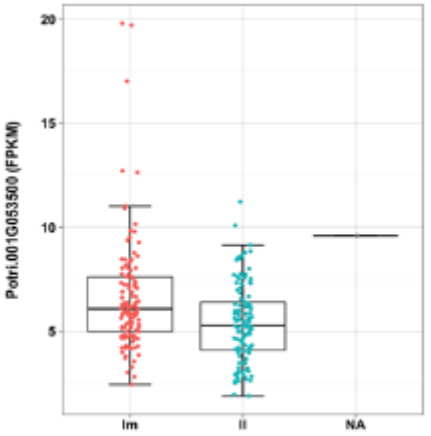
Trans-acting eQTN hotspots
on chromosome 7



Co-expressed Loci

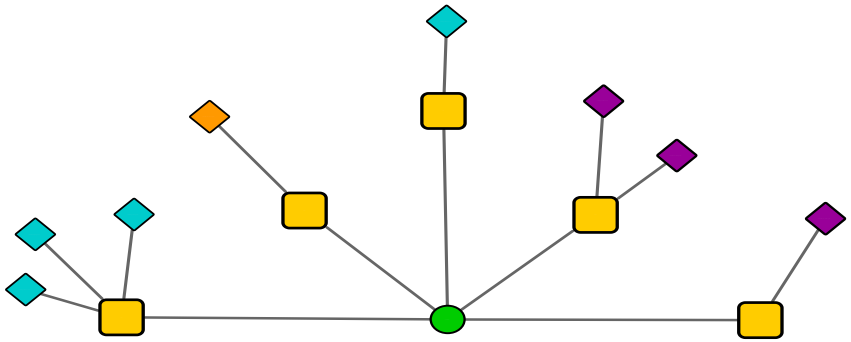


Gene C



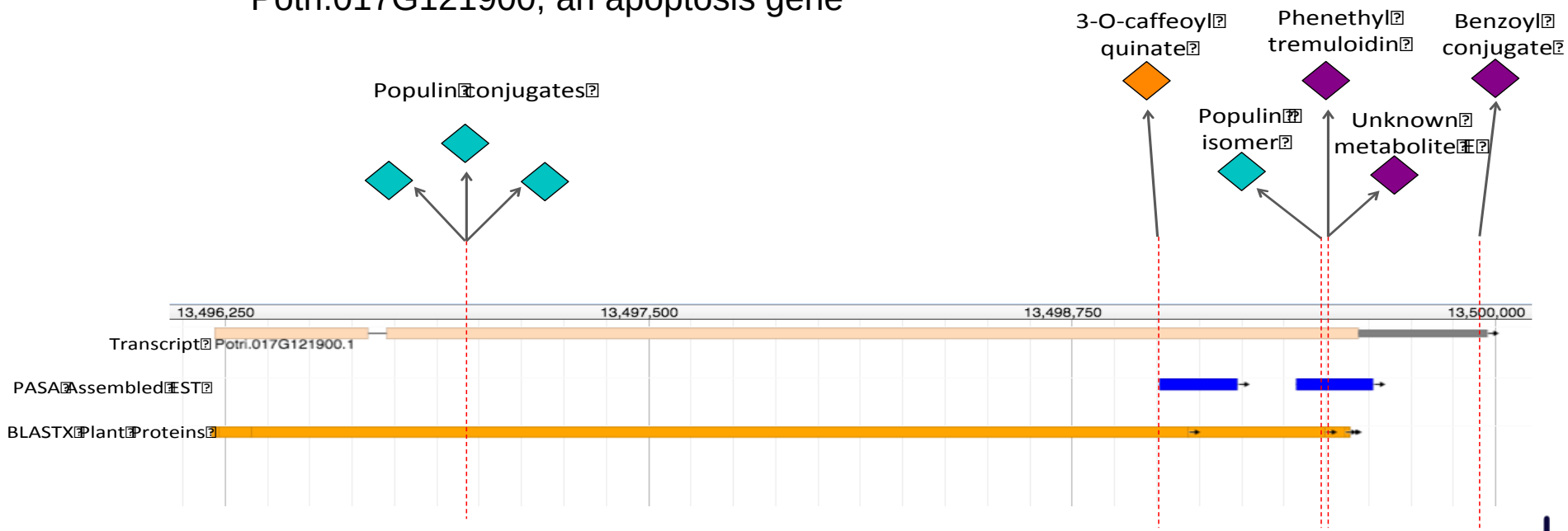
Gene D

Example of Complex Pleiotropic Signatures



Module
Gene
Phenotype (metabolite)
Salicylate-related metabolite
Lignin-related metabolite

Potri.017G121900, an apoptosis gene



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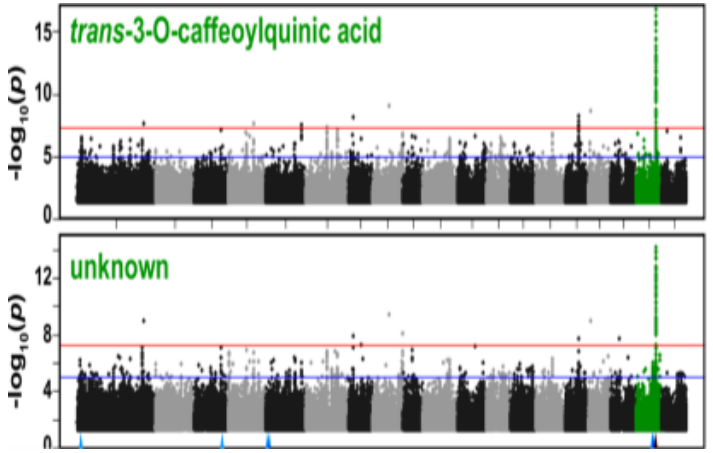
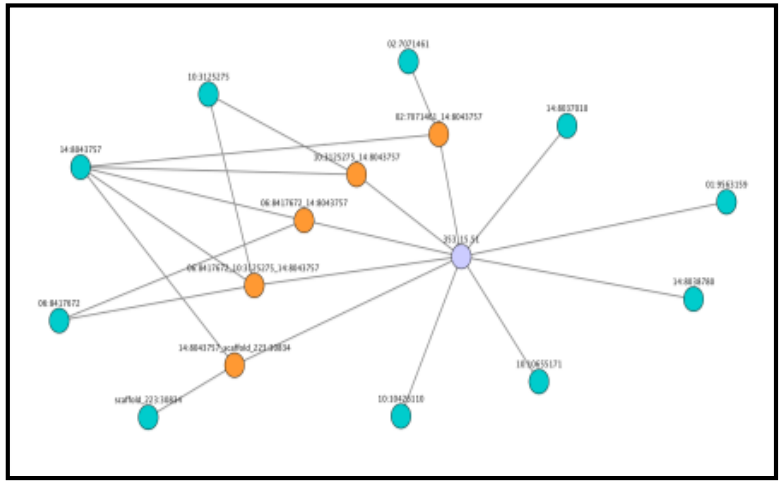
Genomic selection and technoeconomic analysis

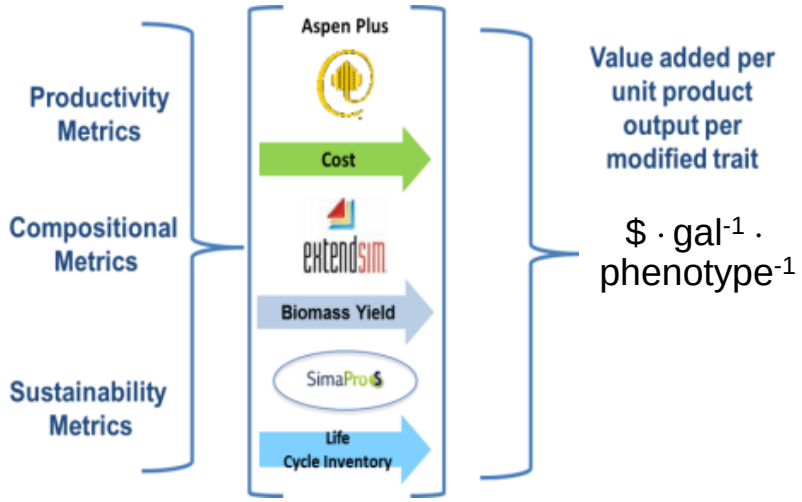
GWAS results

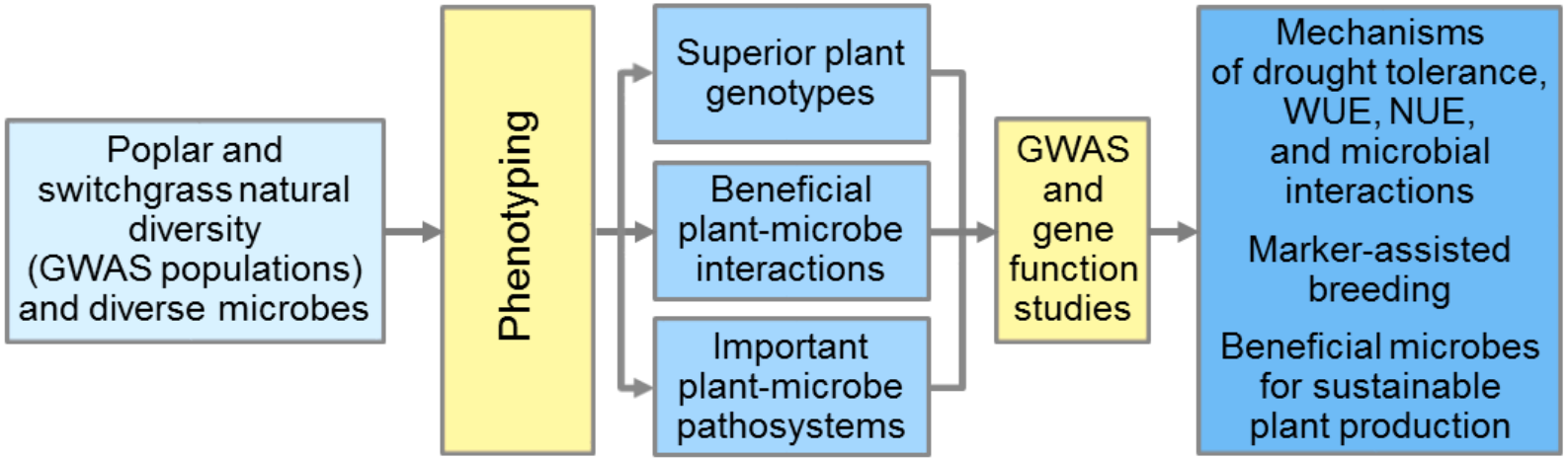


Epistatic and pleiotropy networks



TEA output





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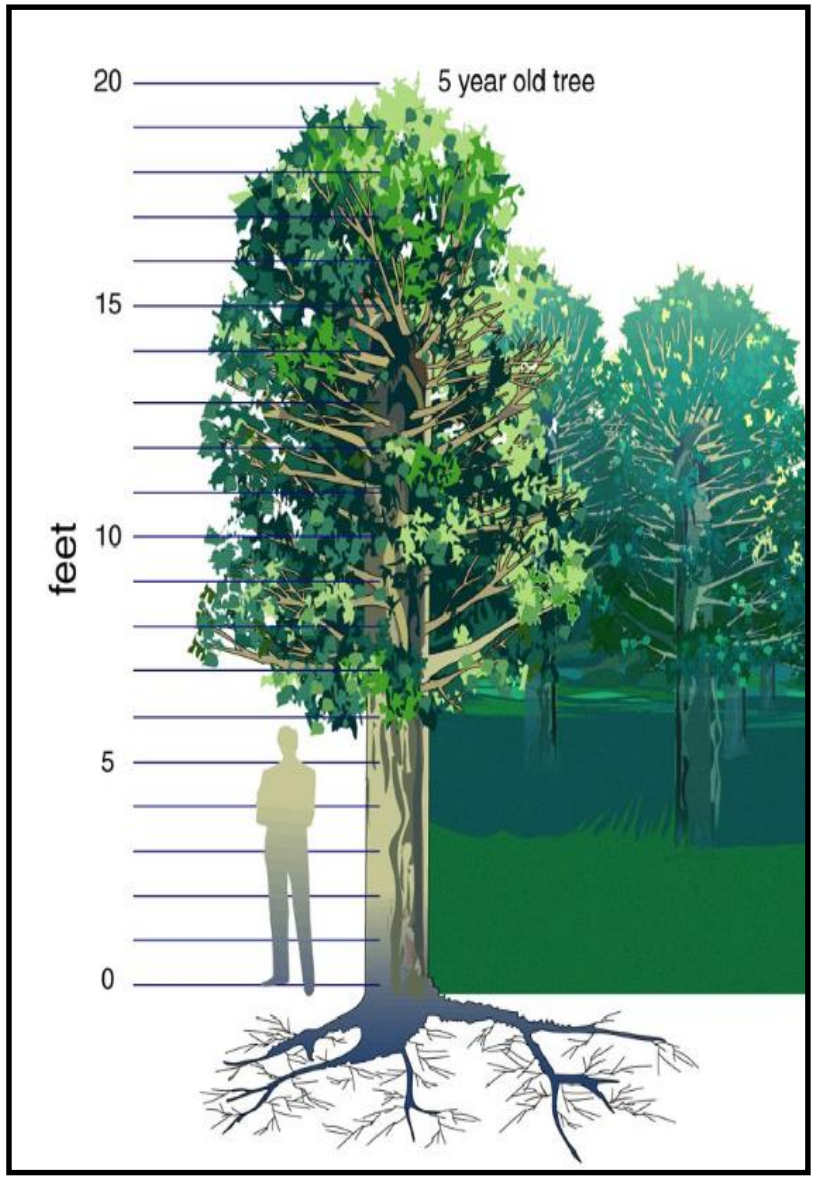
Genomic selection can disrupt the yield to cost relationship and accelerated the domesticated of poplar

Domesticated Ideotype

- Higher productivity per unit area
  - Reduced flowering
  - Reduced height growth
  - Compact crown
  - Enhanced radial growth
- Greater number of stems per unit area
- Water-use efficiency
- Nutrient-use efficiency
- Favorable plant-microbe interactions
- Greater product yield
  - Reduced stem biomass recalcitrance
  - increased root recalcitrance
  - Greater rooting depth



Poplar feedstock, biofuels and bioproduct targets and goals

Sustainable Feedstocks

Yield (biomass per unit area per unit time)

- >50% improvement

Sustainability

- Water-use efficiency (WUE): <10% yield loss under drought
- Nitrogen-use efficiency (NUE): >20% improvement
- Pest and pathogen resistance
- Favorable microbial associations

Feedstock uniformity

- Biomass composition over time and environments

Biofuels Targets

Fuels portfolio

- >80% carbohydrate solubilization at >120 g/L solids loading
- > 30 g/L iso- and/or n-butanol
- > 1 g/L C6 esters (e.g., ethyl butyrate, butyl butyrate, butyl acetate)

Bioproduct Targets

Microbial products

- 2-pyrone-4,6-dicarboxylic acid, ß-ketoadipate, cis,cis-muconate

Catalytic products

- 4-propyl guaiacol and 4-propyl syringol

Materials

- Polyurethanes and foams from high molecular weight lignins

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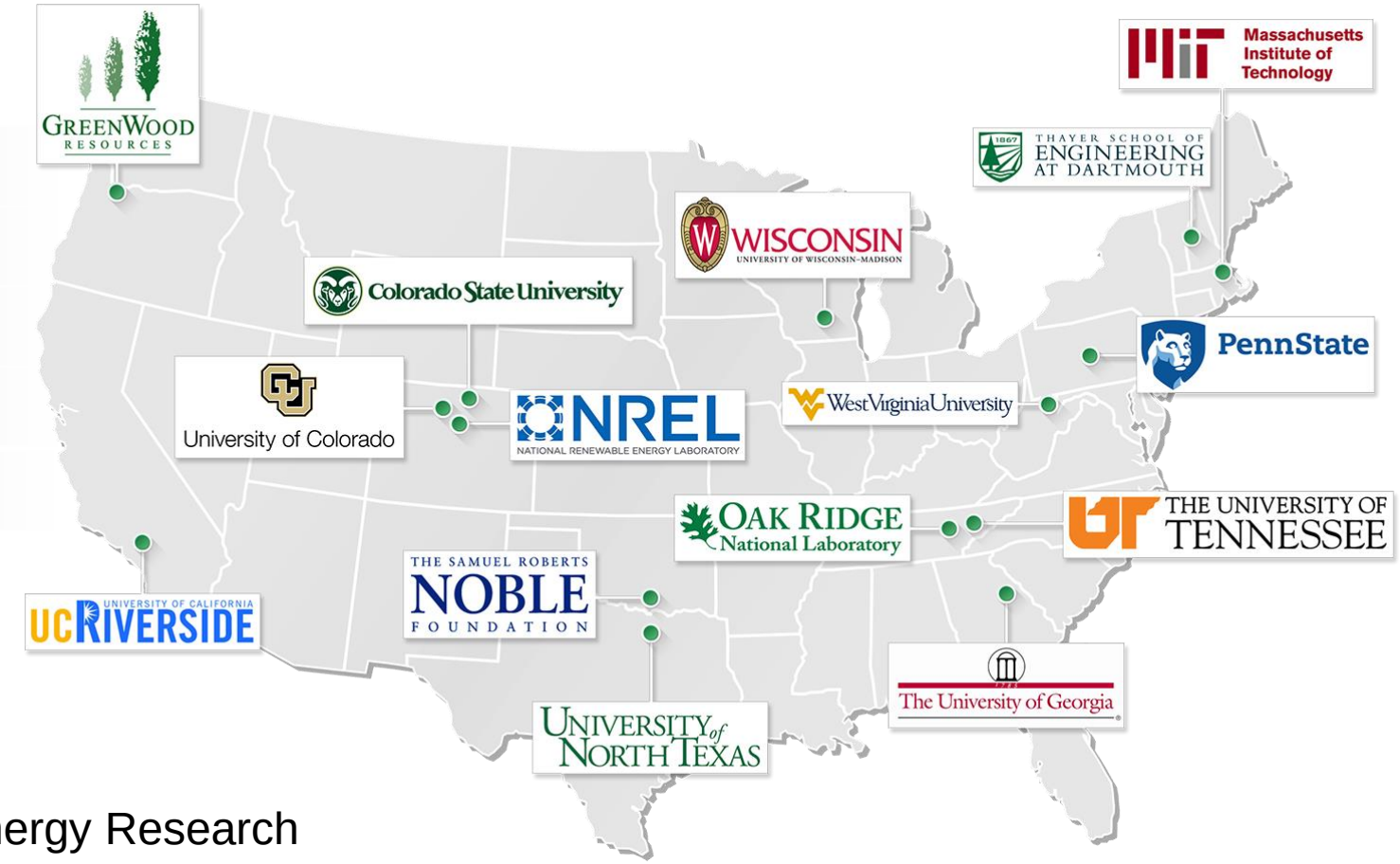
CBI research partners and sponsor

CBI research partners:

- 2 national laboratories
- 11 academic institutions
- 1 research foundation
- 1 private company
- 40% new PIs and/or institutions



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Sustainable Cropping Systems

Domesticated Feedstocks

Advanced Biofuels and Bioproducts

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