SRS-4160 – Forest Genetics and Ecosystems Productivity
Saucier, MS, Research Triangle Park, NC, College Station, TX, Gainesville, FL
Project Leader: C. Dana Nelson

Mission: To advance the scientific understanding of the roles of genetics, environment, and their interactions to provide guidelines and tools for improving the sustainable productivity of southern forest ecosystems.

Research Teams:

Southern Institute of Forest Genetics
Team Leader: C. Dana Nelson, Saucier, MS

Southern Institute of Forest Ecosystems Productivity
Team Leader: Kurt H. Johnsen, Research Triangle Park, NC

Problem 1. Genetics and Genomics

The unit will conduct genetic and structural genomics research on forest trees and their pests with applications in evolutionary biology, forest management, and tree improvement. Knowing the genes and their effects on traits that interact with other organisms and the environment will lead to breakthroughs in our understanding of ecosystem structure and function and development of new technologies for forest management.

Problem 1a. Genome mapping and molecular cytogenetics of important forest tree species and their most damaging disease and insect pests— We currently know very little about the genes influencing insect and disease resistance. Identification of these genes will help tree breeders to efficiently produce more resilient trees and provide silviculturists with information on how best to deploy improved trees for long-term resistance.

Problem 1b. Quantitative genetics of economic and ecologic traits, including mapping genes that regulate and control these traits— We do not know which genes influence important economic and ecologic traits. Knowing the genes and how they interact with each other and the environment will help tree breeders produce better trees more efficiently and provide silviculturists with information on how to deploy the improved trees for optimal performance and production.

Problem 1c. Population and conservation genetics of important forest species, including those that are sensitive, threatened or endangered— We do not know the genetic makeup of most forest species and of those in decline we don't know whether they have enough genetic diversity for their successful recovery and future health. Knowing the level, distribution and flow of gene diversity in species of concern will let forest managers form plans which have the best chance of meeting recovery and long-term management goals.

Anticipated outcomes in Problem 1:

-develop genetic interaction models for resistance to important tree insects and diseases, to help scientists and land managers better understand and manage against losses to forest pests (1a)

-develop genetic markers for forest tree species which pinpoint the genomic location of important insect and disease resistance genes, to help tree breeders more efficiently develop trees for long-term resistance (1a)

-identify the DNA sequence of specific genes conferring insect and disease resistance in forest trees, to help scientists better understand the underlying metabolic pathways involved in pest defense responses (1a)

-develop genetic markers that can be used to estimate virulence allele frequencies in natural populations of the fusiform rust fungus to allow forest managers to predict the likely resistance of various families when planted under field conditions (1a)

-evaluate genetic variation of resin yield in loblolly and longleaf pine populations to provide tree breeders and forest health professionals a more complete picture of a likely southern pine beetle defense mechanism (1b)

-model southern pine beetle outbreaks in clonal populations of loblolly pine to provide information to forest managers about genetic diversity needed to manage risk of stand failure in clonal forestry (1b)

-evaluate genetic variation for adaptive traits of longleaf pine to provide scientists and land managers with increased knowledge of the species' biology and options for management (1b)

-model escape of transgenes and their allele frequency behavior over generations to obtain a better understanding of the impact that genetically modified organisms (GMOs) may have on native tree populations and forest ecosystems (1c)

-provide federal and state land managers an assessment of current and predicted genetic population structures, levels of inbreeding, and patterns of gene flow for pondberry and other endangered forest species (1c)

-provide southern tree breeding cooperatives data on how levels of diversity in first generation selections, as well as advanced generation selections, compare to those existing in natural populations, such information will help tree breeders assess and track the affects of small population breeding and help them select new trees that might be incorporated into their existing breeding programs (1c)

-provide forest genetic and tree improvement colleagues with a DNA fingerprint kit that can be used to determine parentage, provenance, or population parameters of North American pines (1c)

Problem 2. Physiological Processes

The unit will conduct physiological and functional genomics research on forest trees with applications in tree improvement and forest ecosystem restoration and management. This work will provide a basis for conducting benefit/risk analyses so that managers can use state-of-the-art science to best manage forests for productivity and long-term sustainability.

<u>Problem 2a</u>. Ideotype identification and characterization for use in sustainable production forestry systems— Ideotypes are conceptual models that explicitly describe phenotypic characteristics of trees that result in predictable growth and yield results under specific environmental conditions. We will develop and test ideotypes useful for producing different forest products such as timber and biofuel. Our work will guide the gene discovery research so that novel ideotypes can be more efficiently created using genome-guided selection and breeding.

<u>Problem 2b</u>. Physiologic processes of forest trees growing under limiting conditions caused by abiotic and biotic agents— Stress due to environment and forest pests greatly reduce forest productivity. In addition, the responses of forests to increasing atmospheric CO_2 is likely dependent on limitations due to abiotic and biotic stressors. Understanding the physiological bases for stress responses and resistance will allow management efforts to maximize sustainable productivity under current and future conditions.

<u>Problem 2c</u>. Gene discovery and gene expression studies of important forest tree traits such as growth rate, tree form, carbon-, nutrient- and water-use efficiency, bioenergy conversion— We do not comprehend the impact(s) of genes critical for both ecological stability as well as the rapid domestication of commercial tree species. This work will supplant our ability to select and breed trees particularly well suited for producing specific products under specific environments and management regimes. It will also guide the efficient selection of genotypes in natural forests and breeding programs to be included in gene conservation efforts and to be used in forest restoration.

<u>Anticipated outcomes in Problem 2:</u>

- identify traits and their combinations that represent ideotypes for different forest products under specific forest management regimes, to determine the benefits of developing ideotypes for deployment in plantation forestry (2a,c)

- identify genes controlling the above traits that are important attributes of productive ideotypes, to provide candidate genes for potential use in genome-guided breeding (2b,c)

- demonstrate that different genes for candidate traits can be recombined and selected for in southern pine breeding populations, to demonstrate the efficacy of developing ideotypes via genome-guided breeding (2a,b,c)

- identify genes associated with phenotypic plasticity, to guide the efficient selection of genotypes to include in gene conservation programs (2a,c)

- identify genes or combination of genes that confer phenotypic plasticity, to provide information so that forests can be managed for increased resilience under varied environmental conditions including changes that might occur due to global climate change (2b,c)

- identify genotypes that are highly productive under low native soil nutrition, to allow land managers to grow highly productive plantations while minimizing fertilizer inputs (2b)

- quantify genetic variation among and within important forest tree species regarding forest damage due to hurricanes, to improve the ecological and economonic stability of forest ecosystems in hurricane prone regions of the southeast (2b)

- characterize genetic and environmentally induced variation on cellulose, hemicellulose and lignin quantity and quality, to provide candidate genes for breeding and selection to produce bioenergy feedstock with improved conversion efficiency (2c)

Problem 3. Carbon and Nutrient Cycling

The unit will conduct research that integrates molecular, cellular, physiologic, geologic, and ecologic principles and system approaches to explain processes governing carbon and nutrient cycling for applications in sustainable forest management. We are only beginning to understand the complex array of processes associated with ecosystem health. Changing one aspect of a forest ecosystem (for example, fertilization) may increase productivity of the currently desired product (for example, timber). However it will also perturb and modify other important aspects of forest function such as below-ground process. Only by improving our understanding of how processes are impacted, and then interact with other processes, can we predict the ramifications of management actions and/or climate change on long-term forest sustainability.

Problem 3a. Productivity and sustainability of forest stands over rotations including nutrient cycling and conservation and above- and below-ground carbon sequestration— Our knowledge of below ground processes represents the weakest link in our ability to manage productive and sustainable forests over multiple rotations. We will conduct research on nutrient cycling and conservation and above- and below-ground carbon sequestration. This work will permit growth to be optimized while providing the lowest energy and nutrient inputs into the systems. It will also allow us to estimate the extent that managed forests can also sequester carbon.

Problem 3b. Process modeling to integrate research information into tools for forest managers and policy makers— The products of reductionist research need to be incrementally incorporated into the simplest models and into tools for forest managers and policy makers. We will work toward integrating research results to produce process models so the best state-of-the-art science can be applied to address an array of problems including but not limited to: quantifying forest carbon at scales ranging from the stand to the region; safely utilizing the rapidly domesticated forest trees in intensively managed ecosystems; designing management systems to optimize bioenergy yield in plantations thus creating a new forest product and reducing reliance on fossil fuels; and restoring degraded forests so that they can sustainably provide multiple benefits to society.

Anticipated outcomes in Problem 3:

- quantify the impacts of management and environmental variables on the recalcitrance of below-ground carbon, to improve the capacity of forests to sequester carbon below-ground.guide the management of forests where carbon sequestration is a primary goal or a co-benefit (3a)

- quantify the impacts of varying forest management options including the choice of both species and genotype on belowground carbon allocation, to guide the management of forests where carbon sequestration is a primary goal or can provide a co-benefit (3a)

- assess the varying recalcitrance of below-ground biomass of loblolly versus longleaf pines, assess a potential co-benefit that may provide landowners further incentives for restoring longleaf pine ecosystems (3a)

- quantify the impact of proactive carbon inputs during site preparation on mineral cycling and carbon sequestration, to explore the potential of developing new management tools for increasing carbon sequestration (3a)

- develop methodology to quantify belowground carbon allocation in forest trees, to use in developing methodology for quantifying forest carbon sequestration for use in carbon credit programs (3a,b)

- develop a system based on simple metrics so that landowners can estimate carbon stocks and carbon sequestration, to provide simple and tangible methods for landowners to use to utilize to obtain carbon credits (3b)

- provide estimates for impacts of elevated CO_2 on forest productivity to be incorporated into regional models, to provide information to be used for land use planning and developing carbon management policy (3b)

- develop management regimes to optimize bioenergy production, including both specification for both genotype and stand culture, to provide land mangers with tools to manage land to produce bioenergy feedstock and to provide policy makers information for assessing the potential of using woody crops for bioenergy production (3b)

Environmental considerations: The program of research proposed includes experimental activities that are generally limited in scope and intensity and are not expected to degrade the quality of the forest or human environment. The environmental effects of specific actions will be considered during the development of study plans, as well as the existence of extraordinary circumstances related to any proposed action, and categorical exclusion will be documented as a part of the study plan according to FSH 1909.15, Chapter 30. For research involving the use of toxicants, environmental considerations will be evaluated within individual study plans, or by Environmental Assessments (EA) or Environmental Impact Statements (EIS) prepared with or reviewed by the cooperating District or Forest staffs. For research having the potential to affect a plant or animal species that is federally listed as endangered or threatened or proposed for such listing, the principal investigator will consult with the U.S. Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended.

Key Cooperators and Partners: Our research is conducted in partnership with academic and industrial scientists from around the world and professional resource managers from across the Southern Region. Key contacts with whom we currently have cooperative agreements, active studies and collaborations, or consultations include the following organizations:

Universities: Auburn University; Boston University; College of Charleston; Duke University; Louisiana State University; Mississippi State University; North Carolina State University; Oklahoma State University; Old Dominion University; Oregon State University; Shaw University; Texas A&M University; University of Missouri; University of Florida; University of Georgia; University of Idaho; Virginia Tech.

Federal Agencies: Brookhaven National Laboratory and Oak Ridge National Laboratory, U.S. Department of Energy; The National Arboretum, USDA Agricultural Research Service; Southern Region (Region 8), National Forests in Mississippi, DeSoto National Forest and DeSoto Ranger District, Southern Area Forest Health Protection, USDA Forest Service; Jackson Field Office, U.S. Fish and Wildlife Service

State Agencies: Arkansas Forestry Commission; Georgia Forestry Commission; Mississippi Forestry Commission; Missouri Department of Conservation; Texas Forest Service

Private organizations: Plum Creek Timber Company, Weyerhaeuser Company, International Paper Company, Temple-Inland, Inc., MeadWestvaco, Rayonier, Inc., ArborGen, LLC, CellFor, Inc., Smithsonian Environmental Research Center, The American Chestnut Foundation

International institutions: Canadian Forest Service; Czech University of Life Sciences, Prague; North American Forestry Commission; Swedish University of Agricultural Sciences; Universidad de Concepción