An Overview of U.S. Forest Service Biomass and Bioenergy Research in the Wildfire Context

Harvesting woody biomass from forest restoration in Arizona to fuel a power plant.

Production of sawdust for animal bedding and compost from low-value roundwood.

Chips and biochar produced from biomass harvested from White River National Forest.

IEA Bioenergy
Technology Collaboration Programme

Carlos Rodriguez Franco
Senior Forester
Research and Development

Nathaniel M. Anderson
Research Forester
Rocky Mountain Research Station

USDA FOREST SERVICE US DEPARTMENT OF AGRICULTURE

Photos: Anderson

What's ahead?

- Background
  - Current conditions in the West
  - Forest management objectives
- Operational and economic challenges
- US Forest Service R&D Solutions
  - The Wildfire Crisis Strategy
  - Fuels mapping & treatment design
  - Forest operations and logistics
  - Industry and product development
- Conclusions
- Questions & discussion

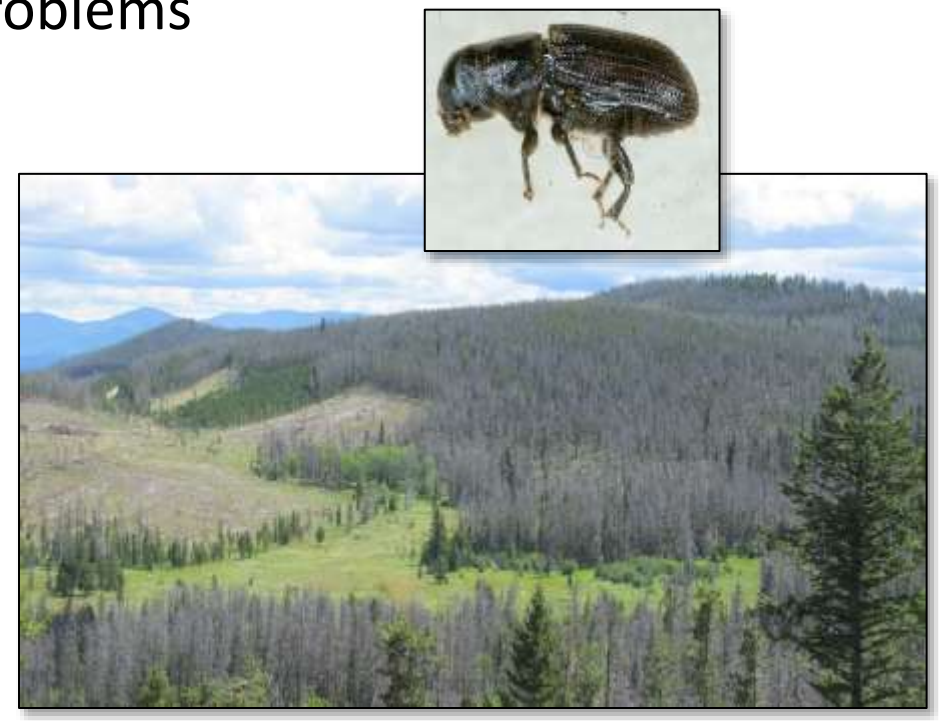
Woody biomass in the form of logging residues and mill residues in Colorado.

Photos: Anderson

Current Ecological Conditions

<u>Many millions of acres with:</u>

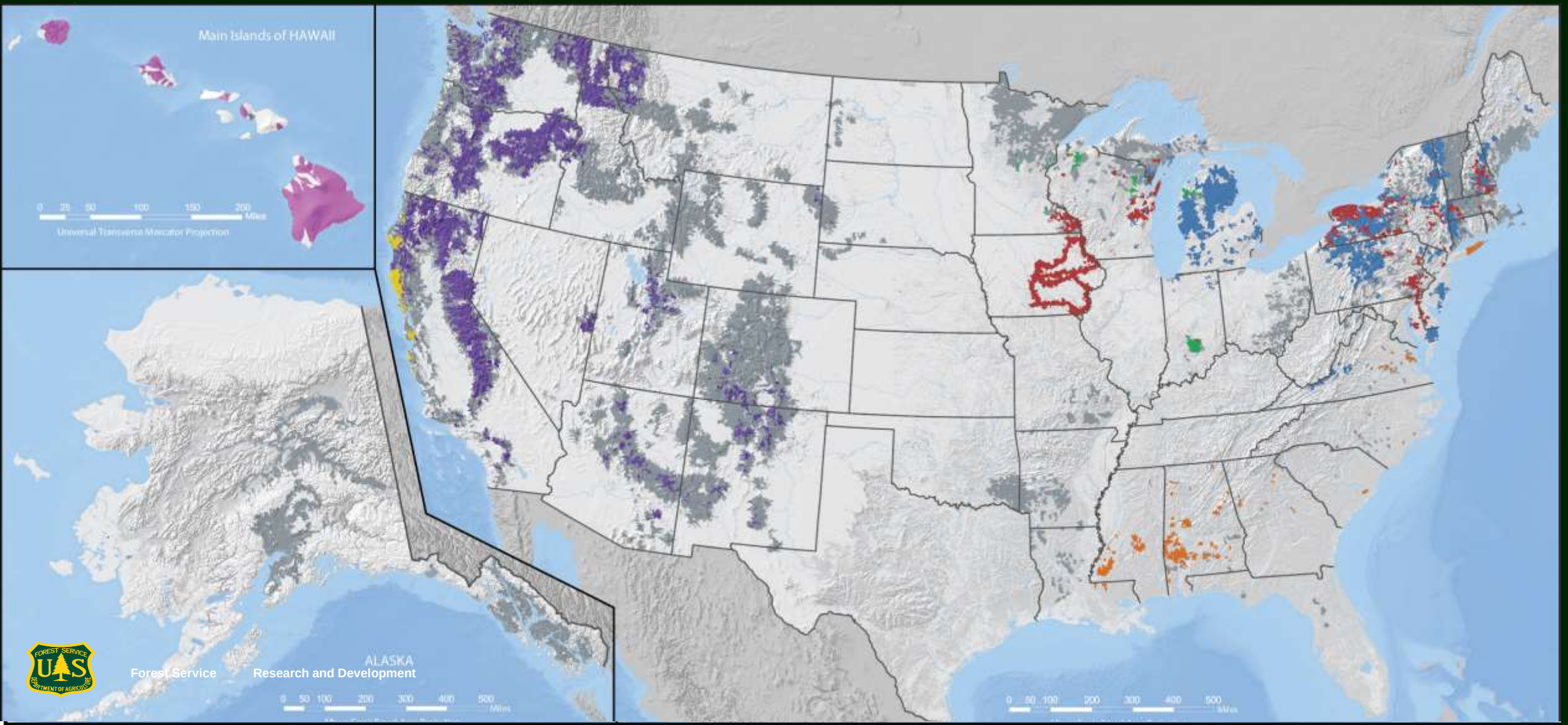
- Densely overstocked forests
- Increase in shade tolerant species
- Forest health problems
  - Drought stress
  - Insects
  - Disease
  - Damage
- High mortality
- Low vigor



A lodgepole pine (Pinus contorta) forest (left) in Montana, with high levels of tree mortality (80% to 90%) following infestation by the native mountain pine beetle, *Dendroctonus ponderosae* (inset). An overstocked mixed conifer forest in Colorado.

Photos: U.S. Forest Service (beetle) and Anderson

2021 INSECT AND DISEASE SURVEY—WATERSHEDS WITH TREE DAMAGE



Sudden oak death | Southern pine beetle | Emerald ash borer | Rapid ʻōhiʻa death | Fir engraver | Spongy moth | Oak wilt | ** Other damage

Source: https://www.fs.usda.gov/foresthealth

**Includes damage from spruce budworm, western blackheaded budworm, spruce beetle and other western bark beetles, eastern larch beetle, hemlock sawfly, browntail moth, beech leaf disease, and many other less significant pests.

National 2012 Composite Insect and Disease Risk Map

Total number of live trees of all species = 320 billion

The number of standing dead trees exceeds 7 billion nationwide (https://www.nrs.fs.usda.gov/pubs/gtr/gtr_wo079/gtr_wo079_191.pdf)

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71.7 million acres at risk in the coterminous United States

2013–2027 National Insect and Disease Forest Risk Assessment

https://doi.org/10.2737/WO-GTR-97

Figure 4-3. Average annual softwood growing stock mortality by region, 1952–2016.

Current Management Conditions

- Forests prone to large and severe wildfires
- Development in the wildland-urban interface (WUI)
- Climate change is making conditions worse
- Diverse values and ecosystem services at risk
- Escalating cost of wildfire management
- Fewer resources for all other management needs

Wildfire in the wildland-urban interface and combined USFS and DOI wildfire appropriations, FY2011-FY2020.

Source: Congressional Research Service 2020, with data derived from annual appropriations acts, supplemental appropriations acts, committee reports, explanatory statements, and other sources.

Photo: Stephen Lam/Reuters **Figure:** CRS 2020

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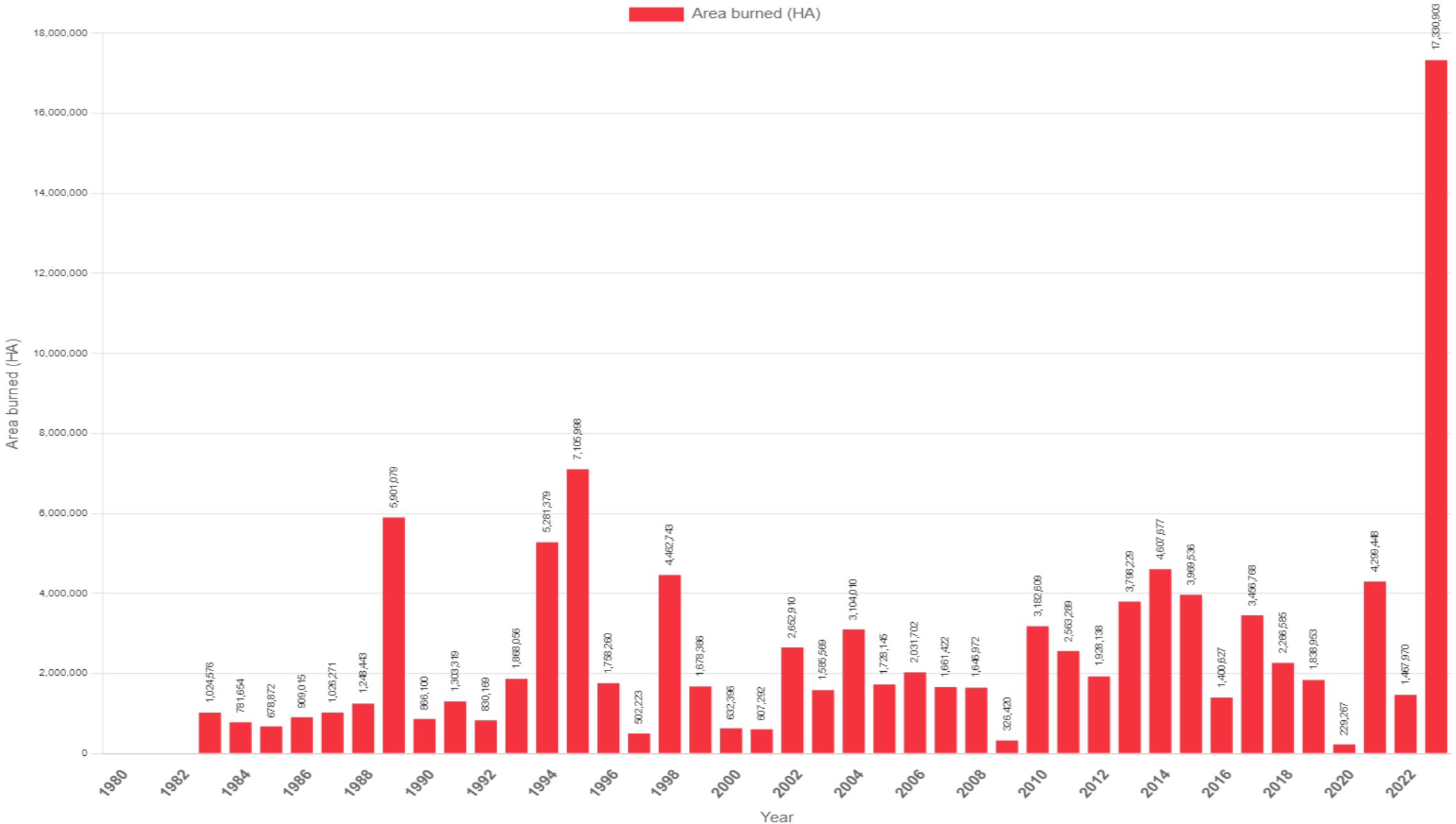
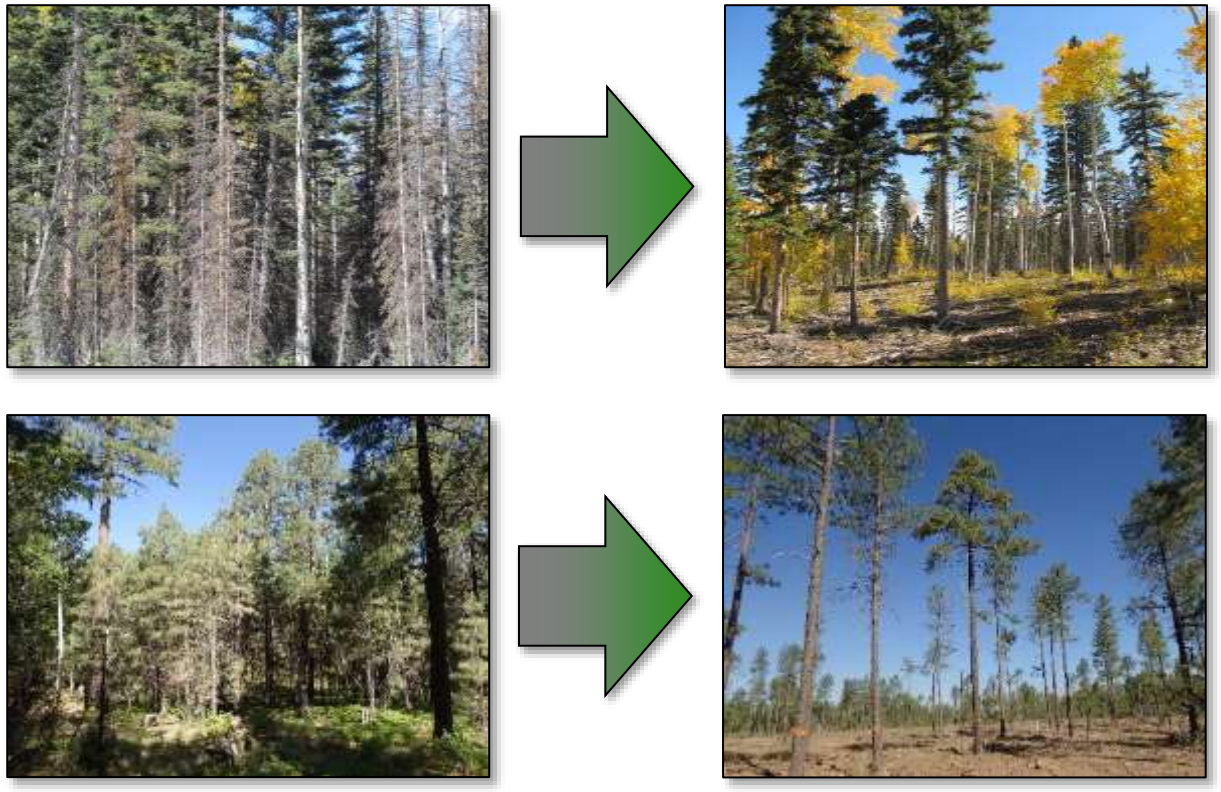
Science Serving Society

June 28, 2023



Source: Canadian Interagency Forest Fire Centre (https://www.ciffc.ca/) September 14, 2023

Management Goals & Objectives



Examples of forest restoration in mixed conifer (top) and ponderosa pine forests (bottom) in Colorado and Arizona.

- Forest Landscape Restoration
  - Fire resilient forests
  - Drought resilience under climate change
  - More heterogeneity within range of variation
- Restore burned areas after fire
- Protect ecosystem function
  - Soil conservation and recovery
  - Watershed function and hydrology
  - Biodiversity
- Deliver ecosystem services
  - Timber, biomass, water, recreation, others
  - Carbon storage and climate change mitigation

Photos: Anderson

Big Biomass Challenges with Fuel Treatment

Low value, small diameter timber and non-merchantable biomass from a fuel treatment (left) and ignitions of prescribed fire using a helicopter (below).

Compared to commercial timber operations:

- Difficult implementation
- Complex residual stand conditions
- Higher costs and lower product values
- Limited markets for products
- More risk to personnel and property
- Complex valuation
- Large volumes of non-saw biomass
  - Tops and limbs
  - Small trees
  - Unmerchantable logs
  - Unmerchantable species

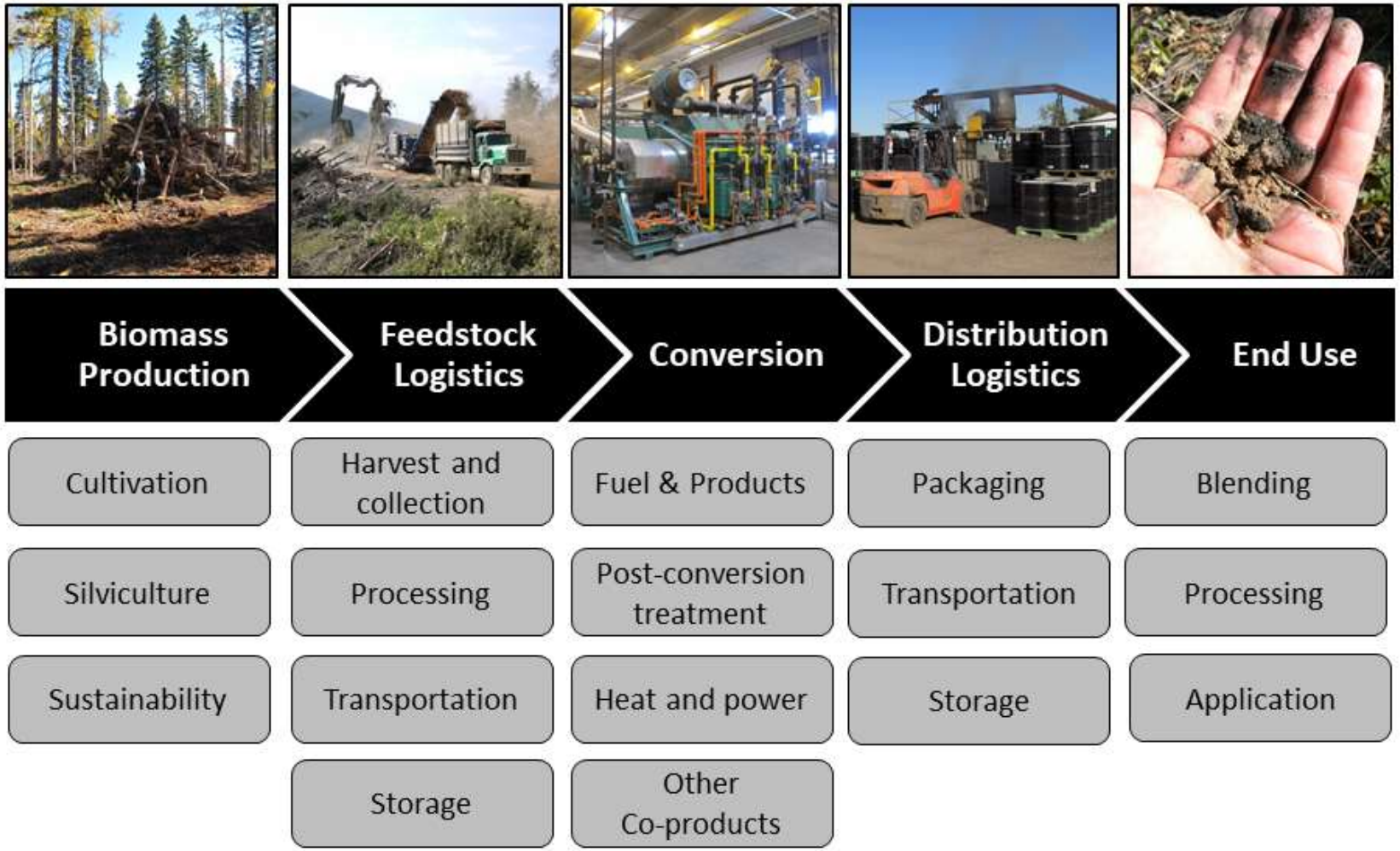
Photos: Anderson and Sharon Hood

The Bioproducts Supply Chain

- Can we leverage the forest industry and the bioproducts supply chain to facilitate fuel treatment?

"Because healthy forests depend on a healthy forest products industry, we will expand our partnerships with mills, loggers and other industry stakeholders."

- WSC Initial Landscape Investments

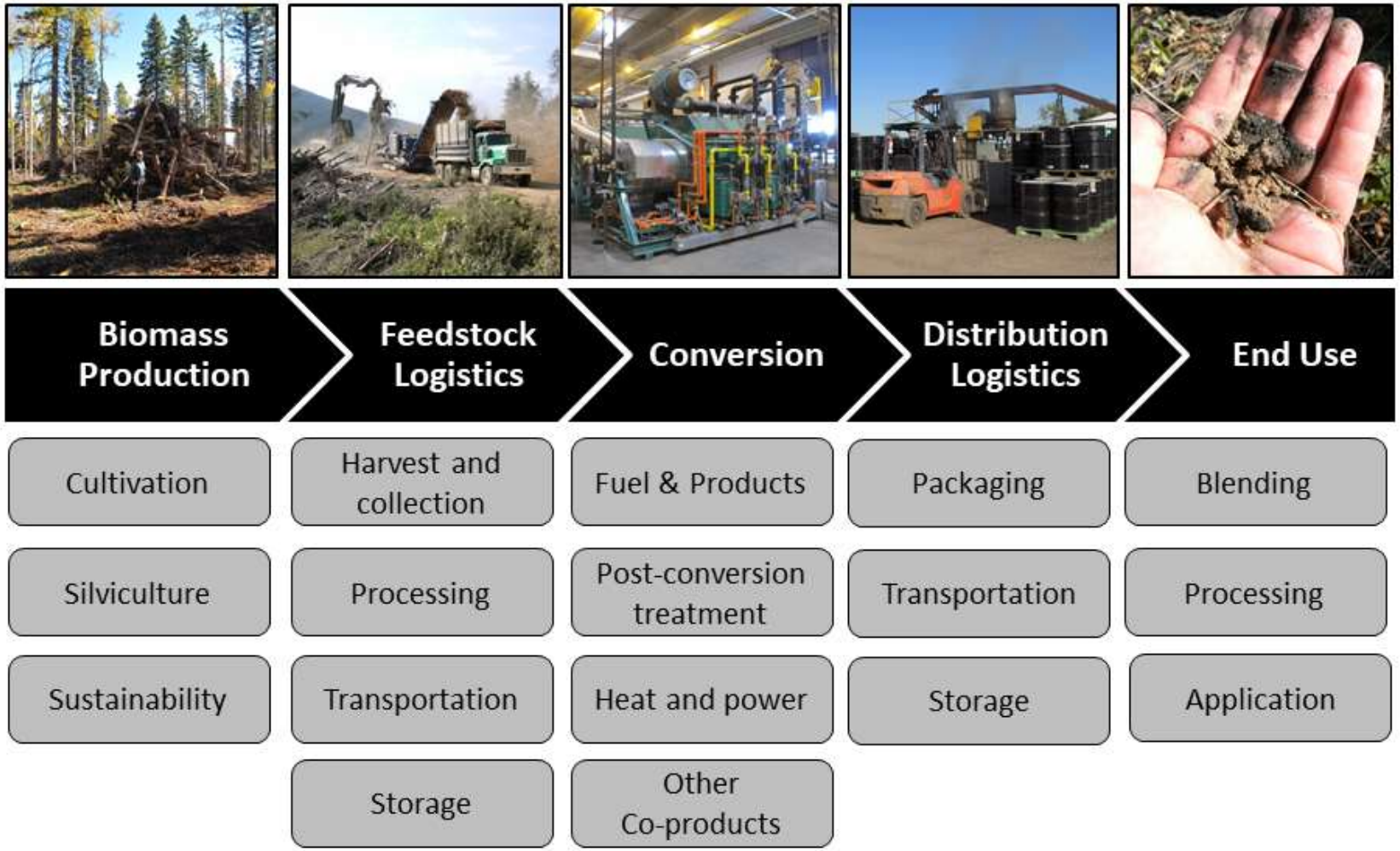


Anderson et al. 2017. Chapter 2 in *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation*, Cambridge University Press. (**Photos:** Anderson)

R&D Biomass Supply Chain Solutions

Four Examples:

1. The Wildfire Crisis Strategy
2. Fuels mapping & treatment design
3. Forest operations and logistics
4. Industry and product development



Anderson et al. 2017. Chapter 2 in *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation*, Cambridge University Press. (**Photos:** Anderson)

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The Wildfire Crisis Strategy

WCS and BIL

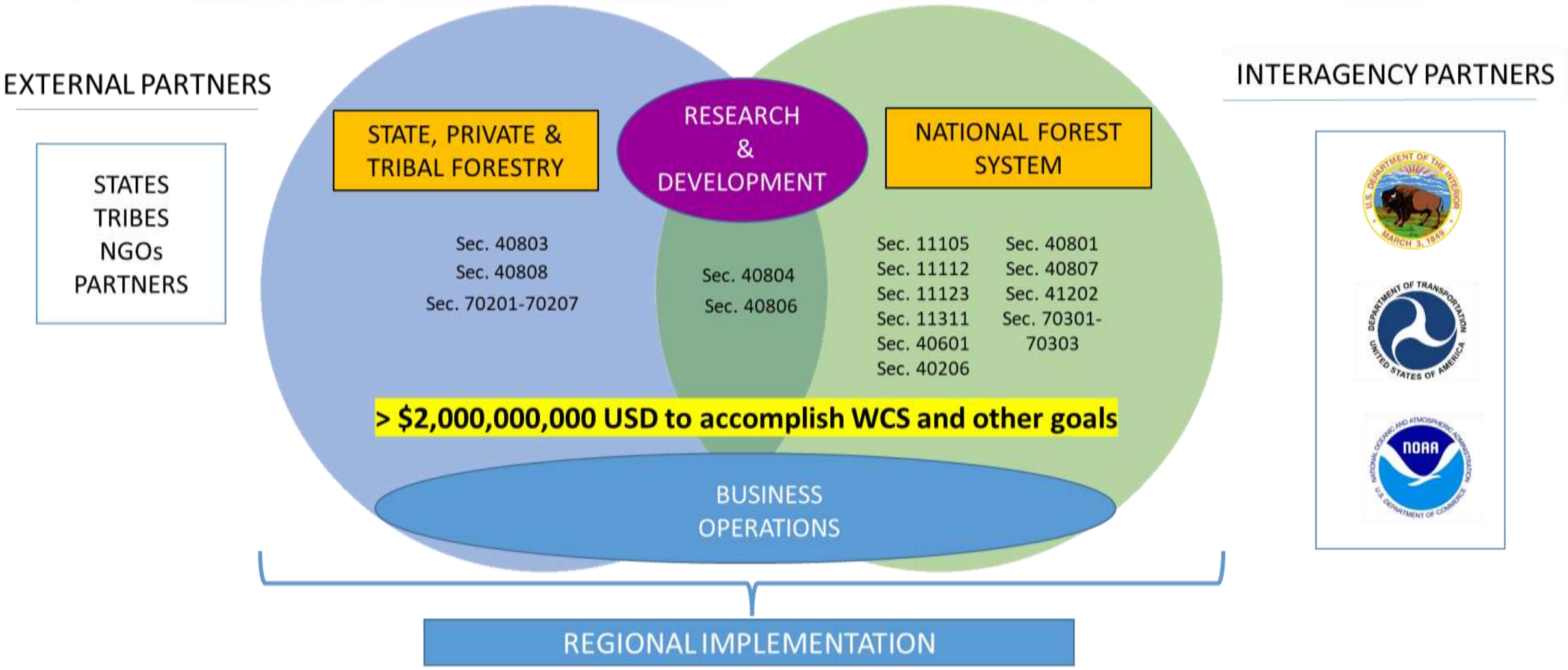
<u>Wildfire Crisis Strategy (WCS):</u>

- Maintain current 2 to 3 million acres/year
- +20 million ac on National Forest
- +30 million ac on Fed, Tribal, State & private
- Long-term maintenance of treated areas

<u>Bipartisan Infrastructure Law (BIL):</u>

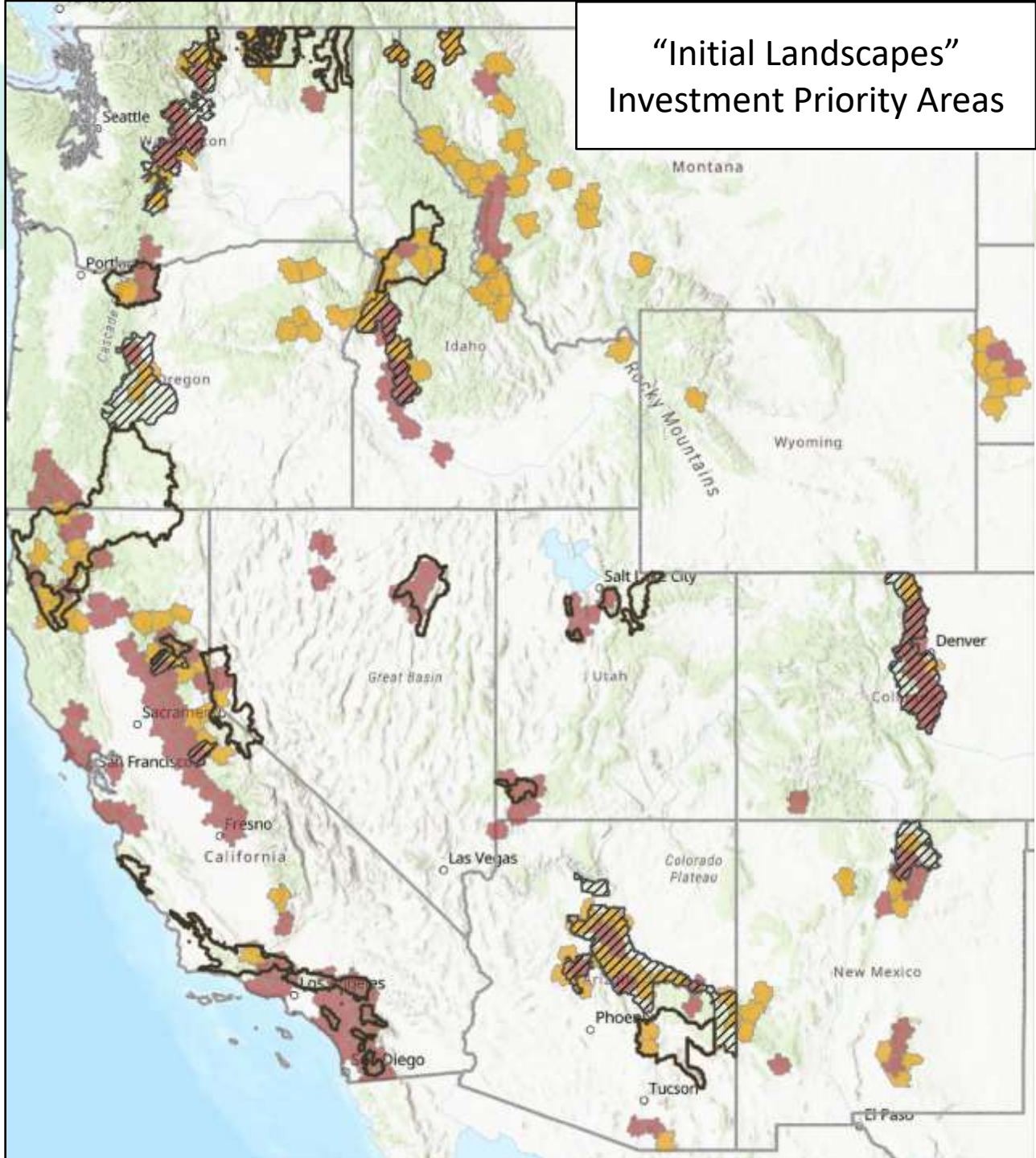
- > $2 billion USD to accomplish WCS
- And other land management goals

Large Public Investments



WCS/BIL Landscapes

- Risk level
- Critical infrastructure
- Scale
- Existing authorities
- Collaboration & partnerships
- Equity



The Opportunity and Potential

Feedstock

- Forest Residues
- Hazardous Fuel Treatments
- Short Rotation Woody Crops
- Wood Waste
- Conventional Forestry
- Mill Wastes & Residues

Conversion

- Manufacturing
- Co-firing
- Combustion
- Gasification
- Hydrolysis
- Digestion
- Pyrolysis
- Extraction
- Separation

Diverse Uses

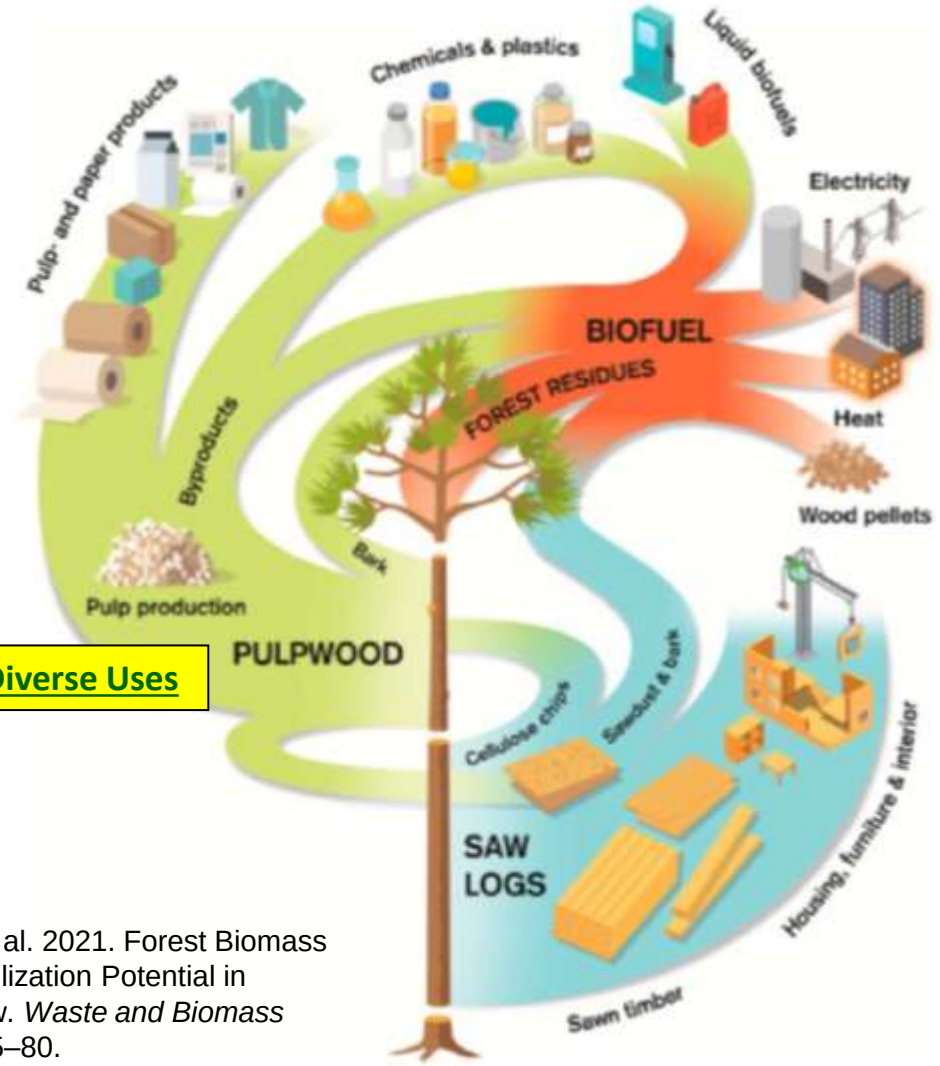


Figure: Kumar, et al. 2021. Forest Biomass Availability and Utilization Potential in Sweden: A Review. *Waste and Biomass Valorization* 12: 65–80.

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Fuels Mapping and Treatment Design

Characterizing Fuels

- Fuel Characteristic Classification System (FCCS)
- Accounts For All Relevant Fuel Components
- Integrates Known Fuel Loadings Or Generates Estimates
- User Can Modify Existing Fuelbeds, Save And Retrieve Custom Fuel Descriptions
- Provides Fire Behavior Information And Cross Walks To Fuel Models Used In The Fire Behavior Prediction System

http://www.fs.fed.us/pnw/fera/fccs/

USDA United States Department of Agriculture

FCCS Fuelbeds

- Canopy Stratum
- Shrub Stratum
- Low Vegetation Stratum
- Woody Fuel Stratum
- Moss, Lichen, Litter Stratum
- Ground Fuel Stratum

Snag Tree

Other Aerial Fuels

Crown Fire

Shrubs

Needle Drape

Graminoids

Herbs

Surface Fire

Sound Wood

Rotten Wood

Piles and Jackpots

Stumps

Lichen

Moss

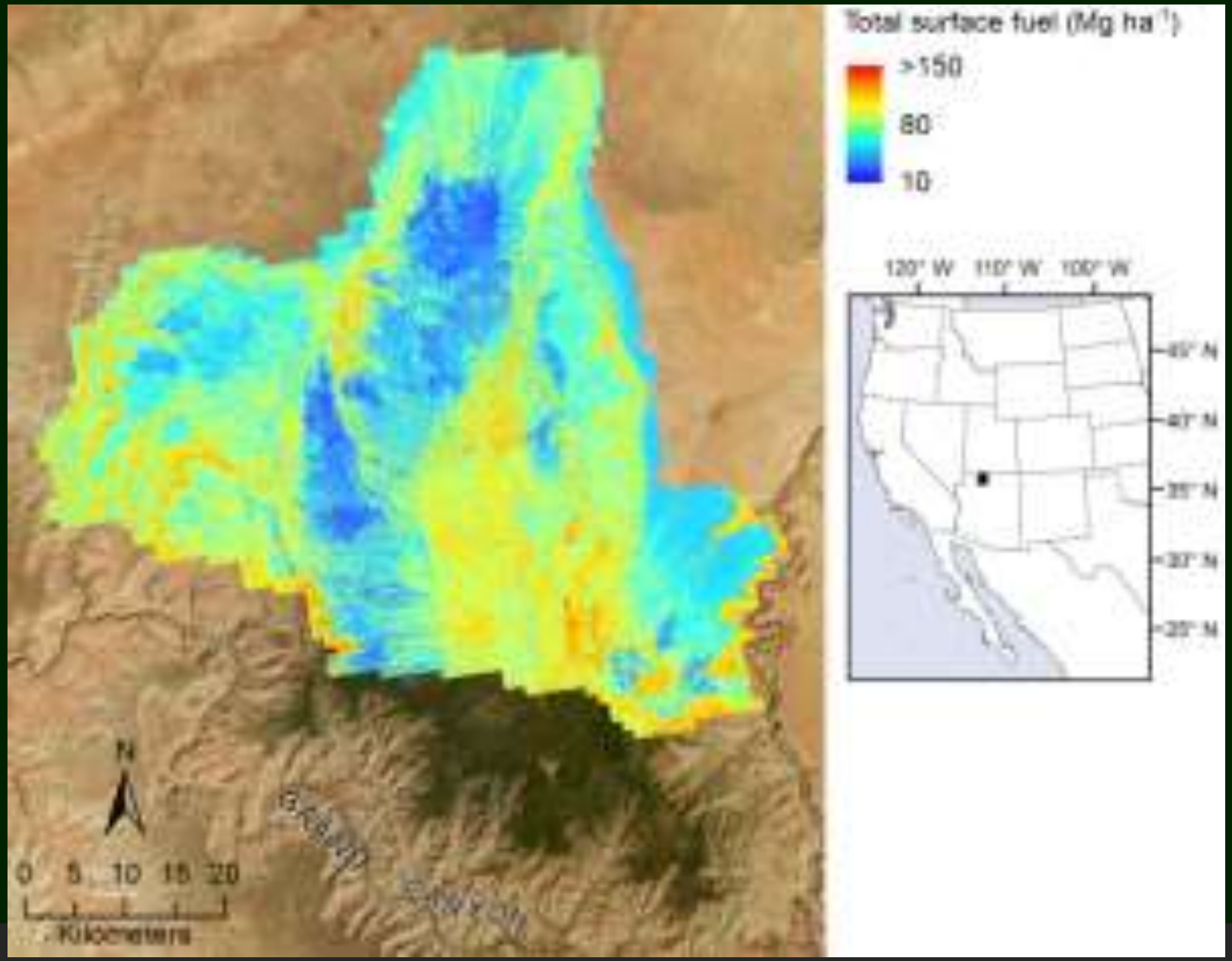
Litter

Duff

Basal Accumulation

Smoldering, Residual Effects

Fuel mapping with remote sensing data on the Kaibab Plateau, Arizona 2023



Source: Fuel mapping with remote sensing data on the Kaibab Plateau, Arizona | US Forest Service Research and Development (usda.gov)

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Mapping the Wildland Urban Interface

- ***WUI = Interface + Intermix***
- ***Interface***
  - Housing > 6 per km^2
  - Vegetation < 50%
  - Near a vegetated area
- ***Intermix***
  - Housing > 6 per km^2
  - Vegetation > 50%

Wildland Urban Interface 2000

WUI

- intermix and interface

Non-WUI

Vegetated

- very low density housing
- no housing

Non-vegetated or agriculture

- medium and high density housing
- low and very low density housing

- water

Fuels Treatment Decision Support

- To address the numerous and potentially overwhelming number of applications for fuels treatment decision support, the Joint Fire Science Program, DOI, and Forest Service R&D developed the Interagency Fuels Treatment Decision Support System (IFTDSS; https://iftdss.firenet.gov; JFSP 2009).

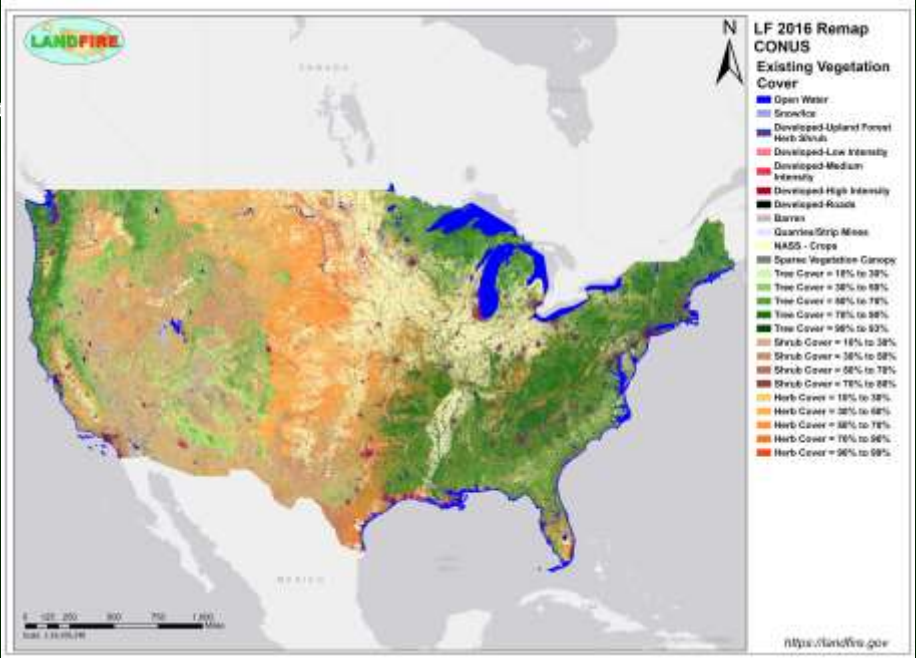
- Maintained by Forest Service R&D's Wildland Fire Management Research and Development Program, IFTDSS organizes wildland fuels planning data and applications into a seamless user environment.

LANDFIRE Products

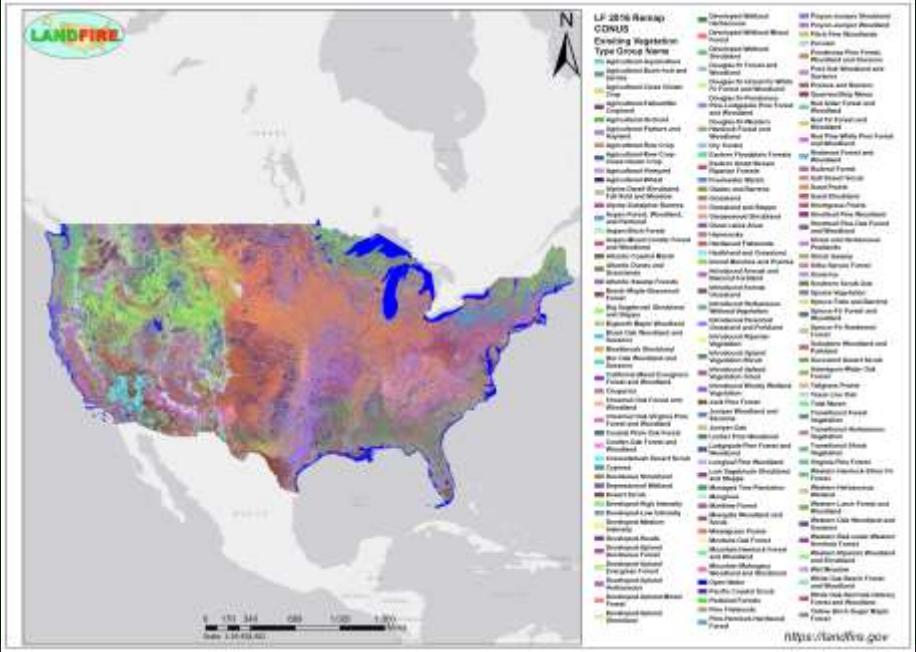
- Historical natural fire regimes (frequency, severity of fire)
- Departure from historical natural fire regimes
- Map based data for fire ecology assessment, fuels analysis and fire behavior prediction
- A suite of around 100 map based data layers
  - Vegetation types
  - Vegetation canopy height
  - Vegetation canopy density

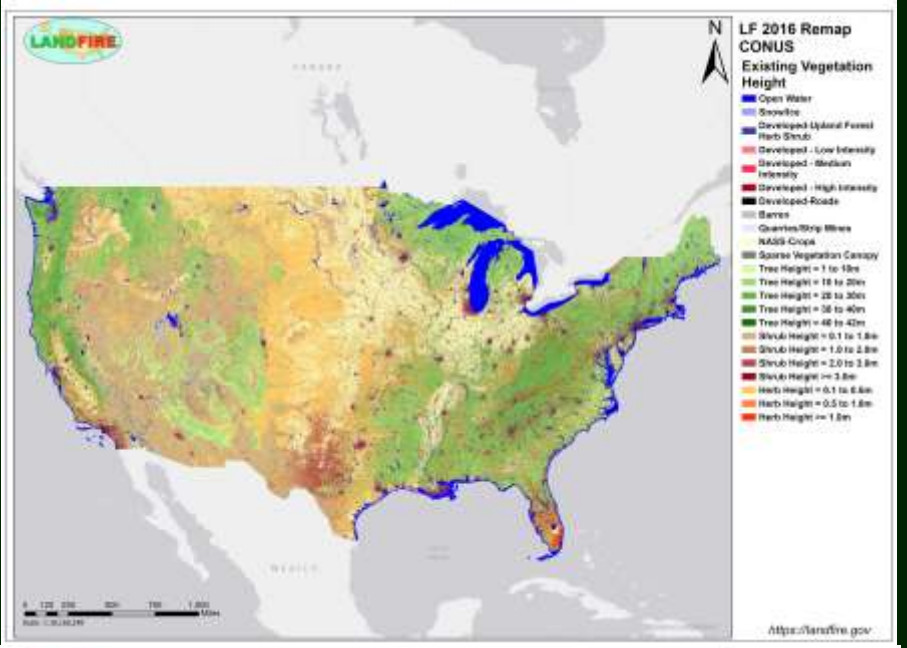
USDA Unit

Veg. cover



Veg. type





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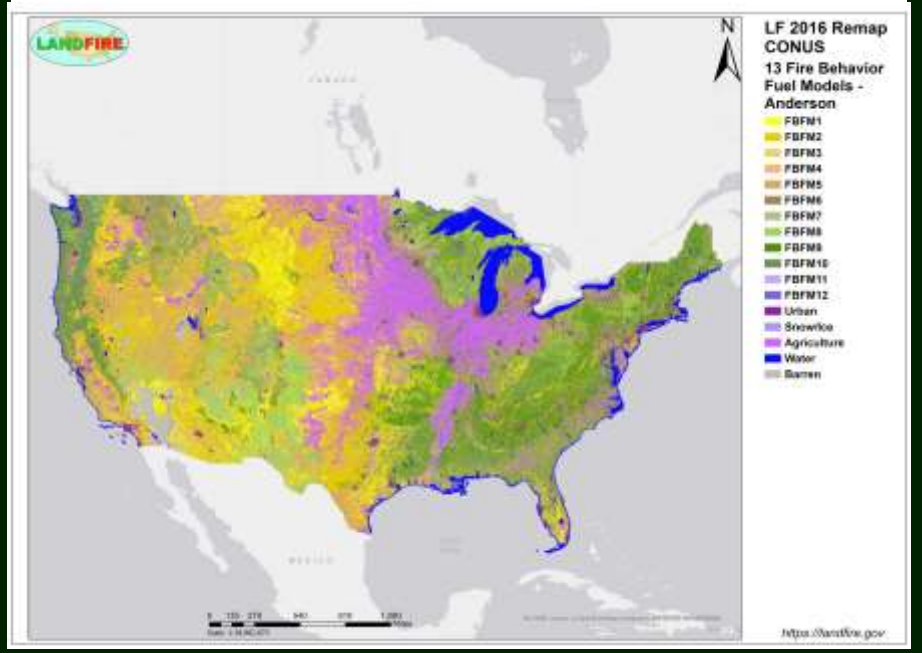

Fire behavior fuel models

Source: LANDFIRE: LF 2016 Remap Maps of the United States and Insular Areas

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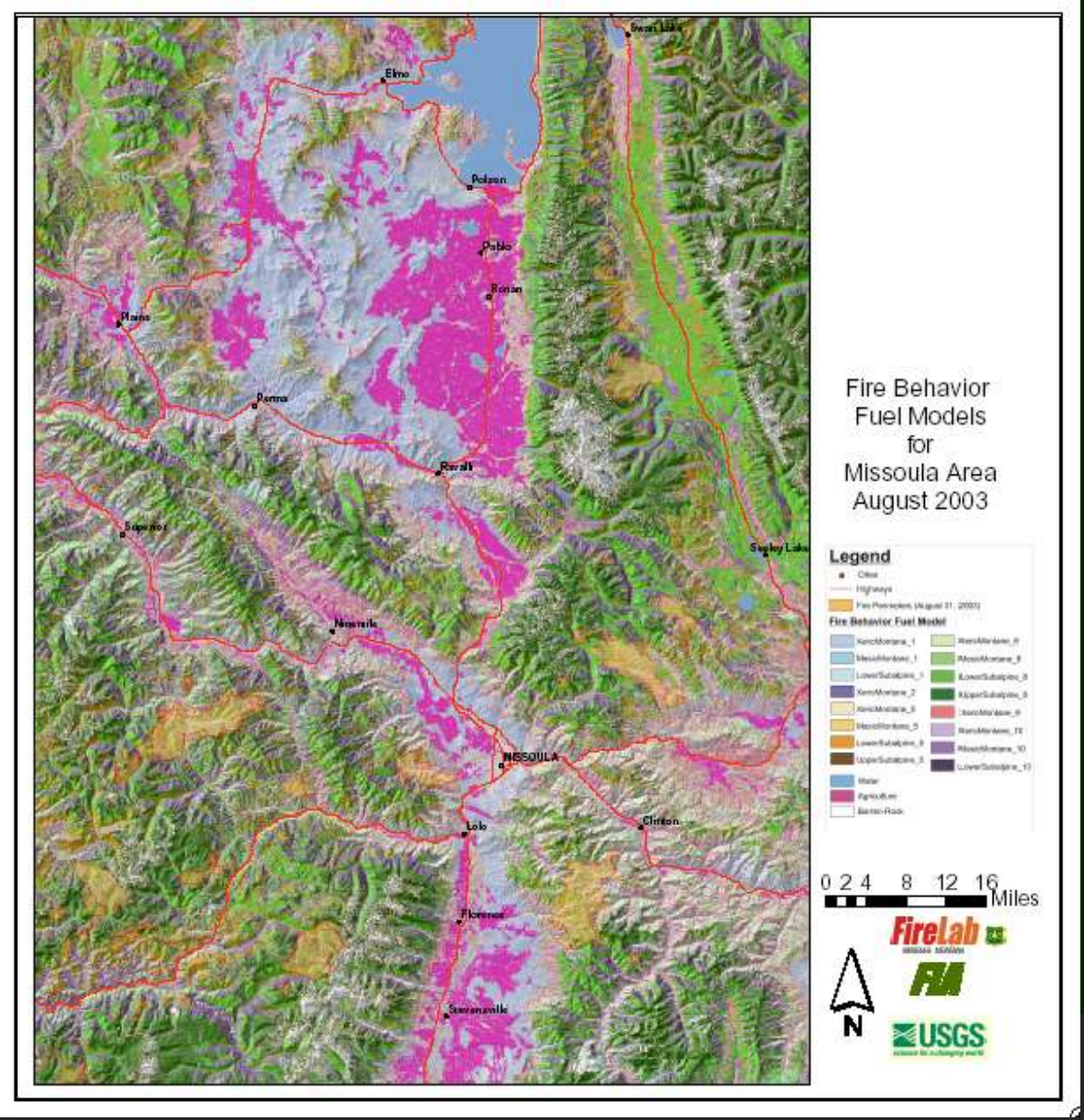
LANDFIRE Fuel Models



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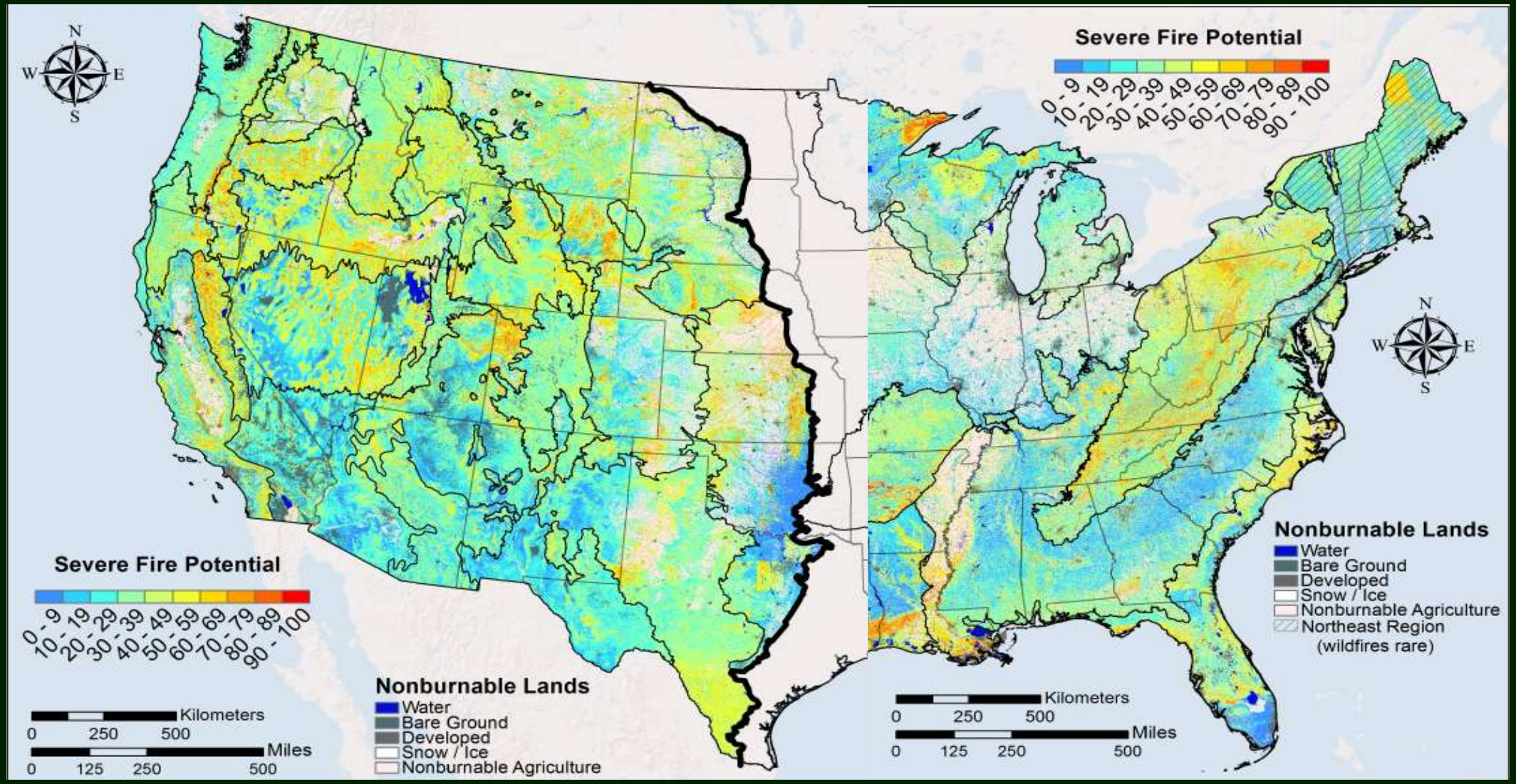
Severe Fire Potential Map for the Contiguous United States

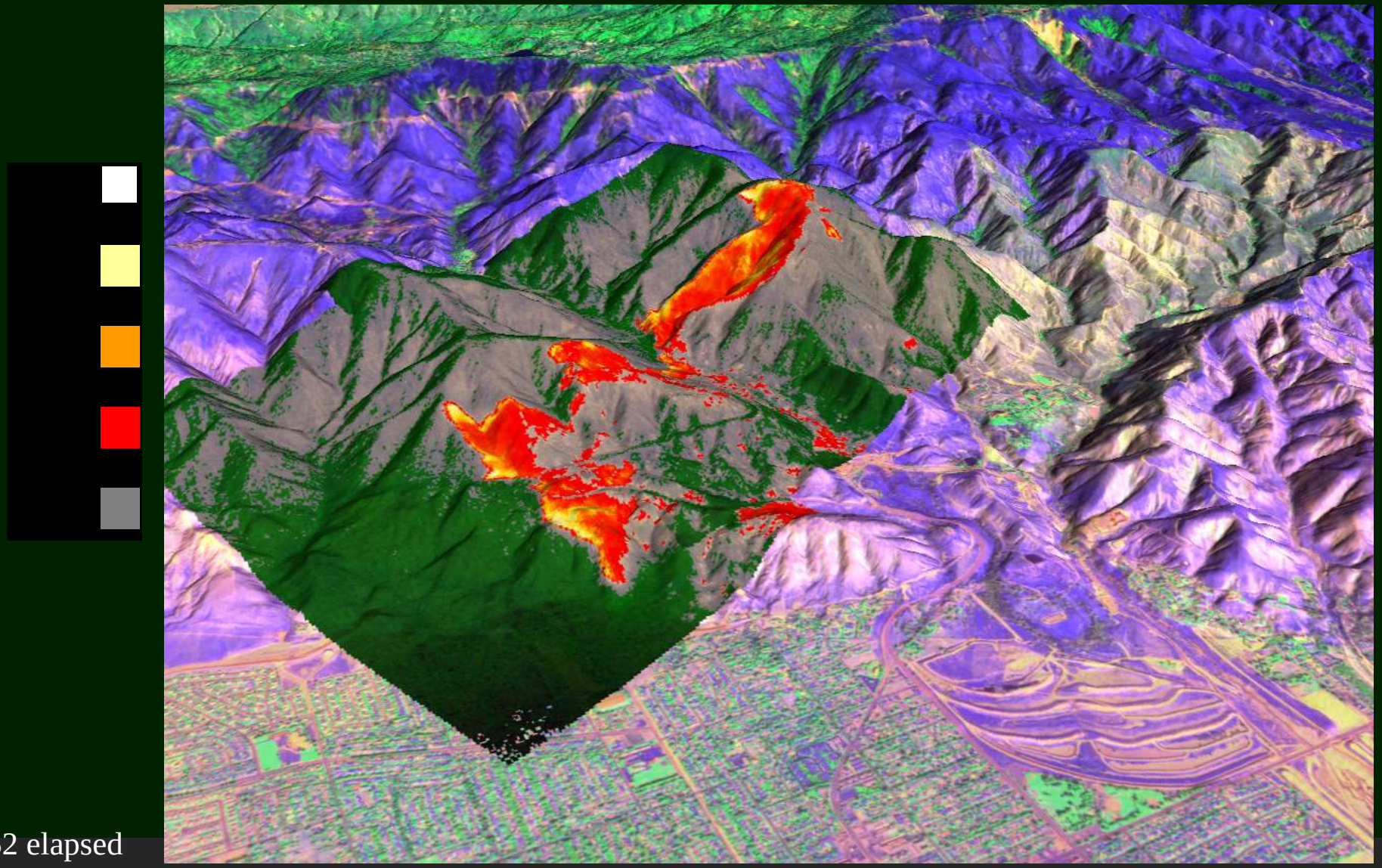


Forest Service Research and Development

Source: Dillon, Gregory K.; Panunto, Matthew H.; Davis, Brett; Morgan, Penelope; Birch, Donovan S.; Jolly, William M. 2020. Development of a Severe Fire Potential map for the contiguous United States. Gen. Tech. Rep. RMRSGTR-415. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 107 p. https://www.fs.usda.gov/rm/pubs_series/rmrs/gtr/rmrs_gtr415.pdf

Old Fire, San Bernardino National Forest 2003

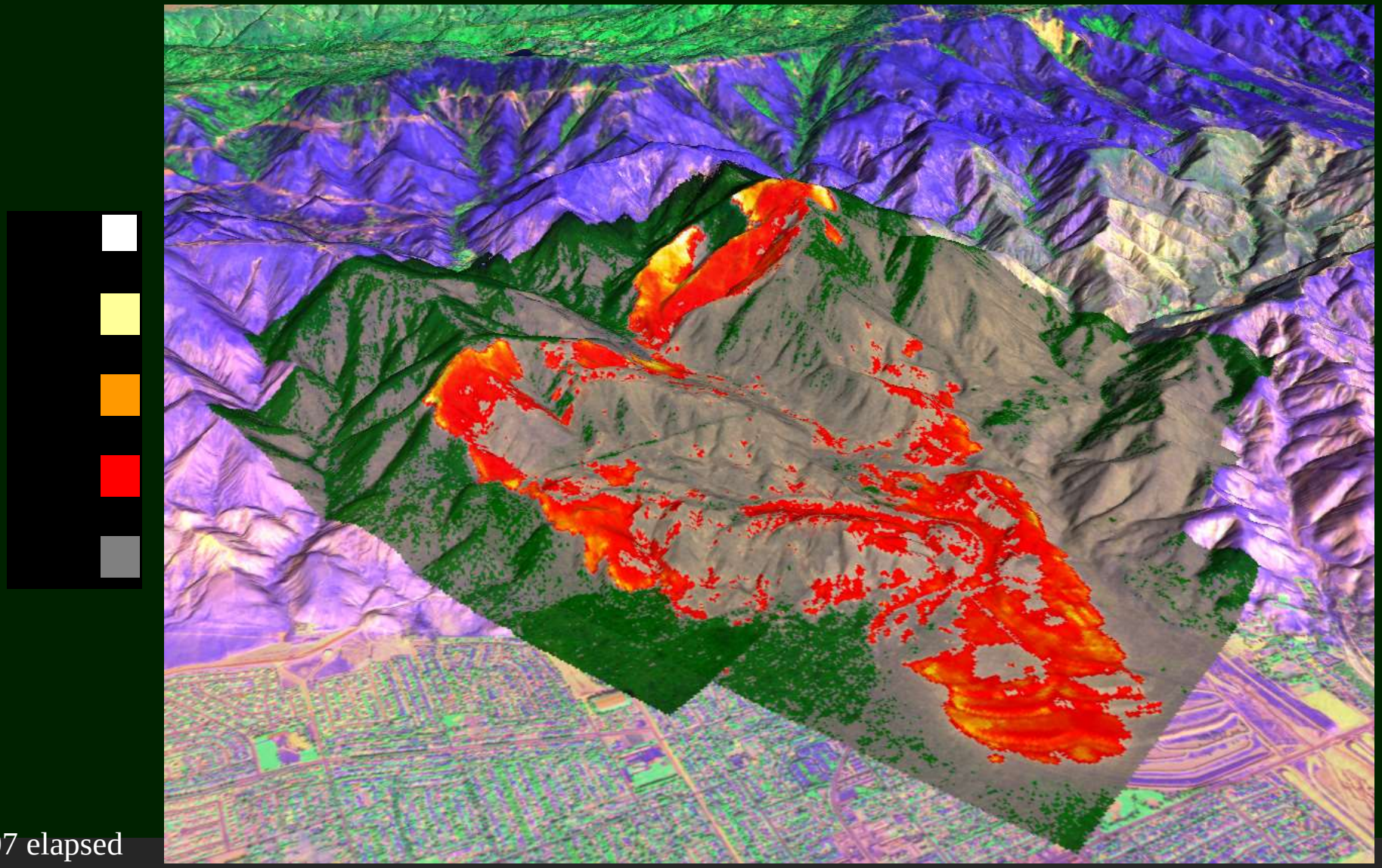
USDA United States Department of Agriculture



1:52 elapsed time

Old Fire, San Bernardino National Forest 2003

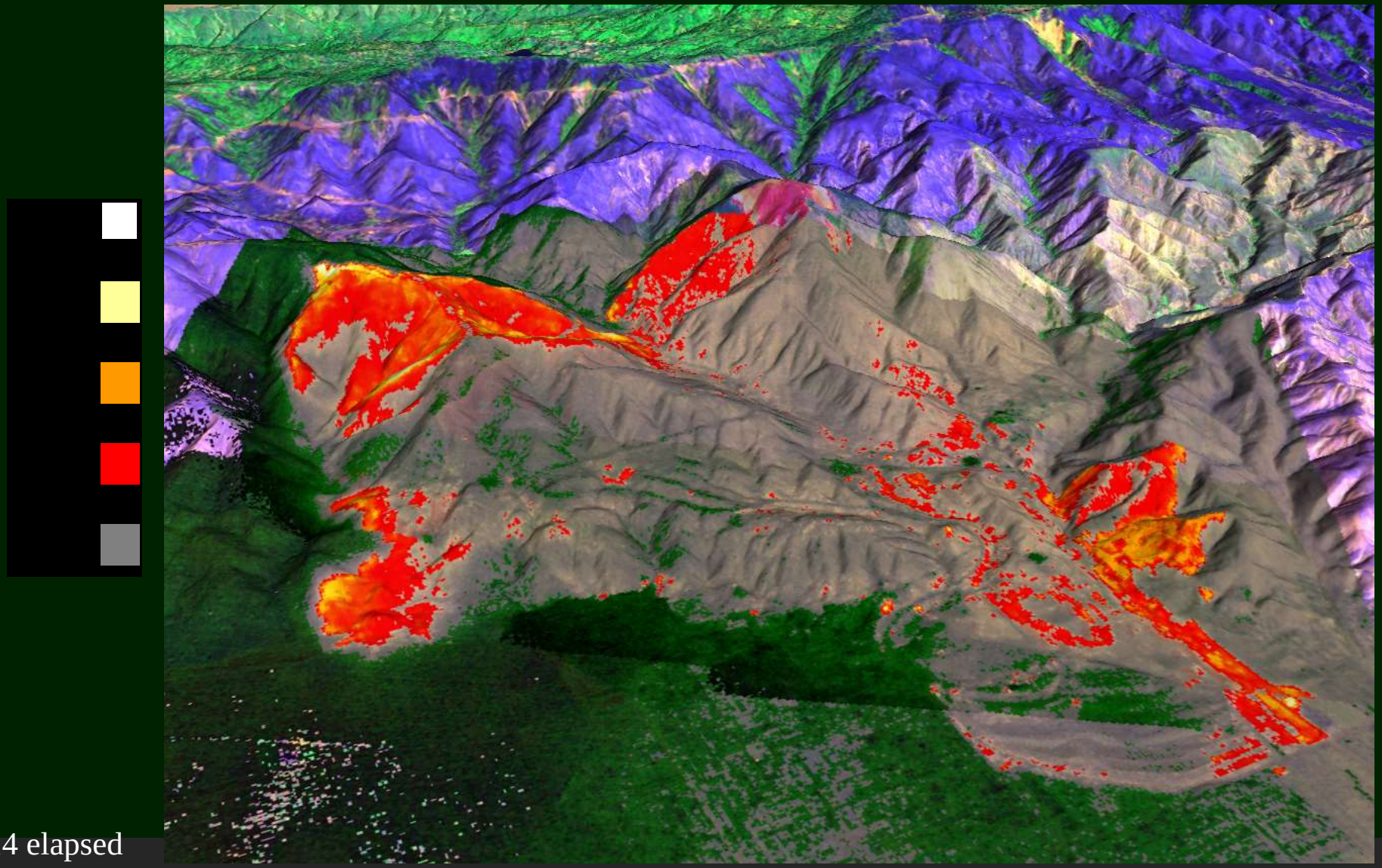
USDA United States Department of Agriculture



2:07 elapsed time

Old Fire, San Bernardino National Forest 2003

USDA United States Department of Agriculture



3:14 elapsed time

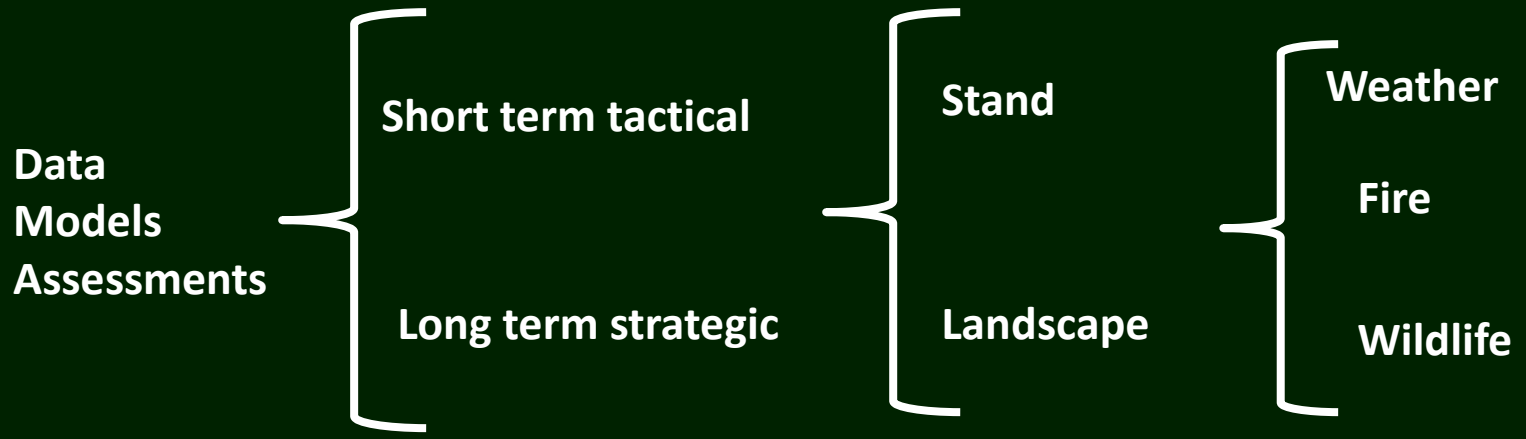
Scenario Investment Planning

The scenario investment planning is an analytical framework that integrates different analytical tools with Production Possibility Frontiers techniques to simulate forest management alternatives and tradeoffs at different planning scales for different objectives.

Some of the objectives are:

- Prioritization of landscape fuel treatments based on limited budget.
- Determination of priority areas to decrease the transmission of fire to adjacent lands or communities at high risk.
- Determination of prescribed burning areas and natural fire occurrence.
- Determination of tradeoffs for alternative restoration strategies among other applications.

Analytical Tools for Scenario Planning



Geospatial information (involves scale)

Vegetation Attributes
- LANDFIRE (includes more than vegetation information)
- FIA

Fire behavior systems
- Probabilistic
  - FSPro
  - FlamMap
  - FSim
  - ArcFuels
  - BehavePlus
  - IFTDSS
- Deterministic
  - FAR[illegible]TE

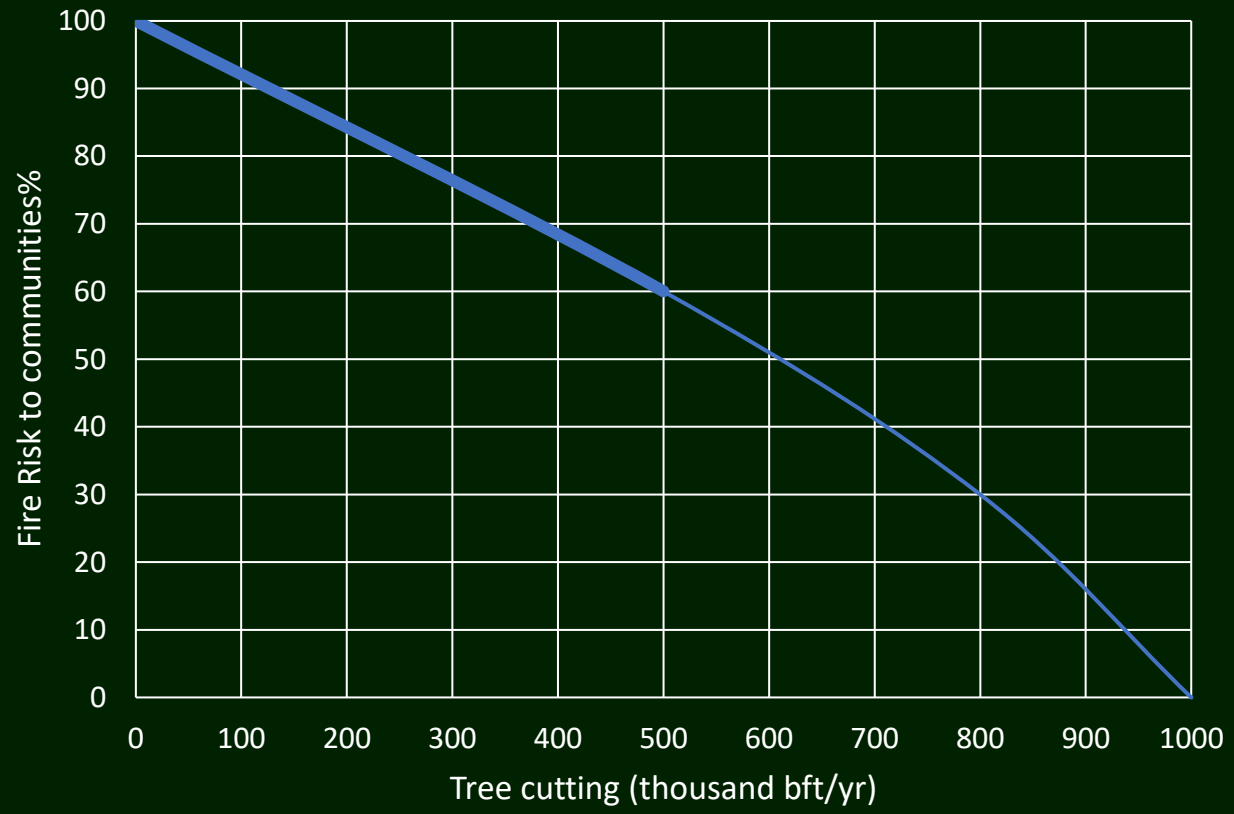
Wildland Fire Risk Assessment
- Fire Simulator: A [illegible] of probabilistic wildfire risk components for the continent[illegible] United States.
- Pacific Northwest Quantitative Wildfire Risk Assessment

Other Data Sets Assessments used in Scenario Planning
- Wildland Urban Interface
- Terrestrial Condition Assessment
- Watershed Condition Framework
- National Insect and Disease Risk Map

Forest Simulation Landscape Models
- Landscape Treatment Designer – LTD.
- LANDIS-II---A Forest Ecosystem Computer Model for Simulating Growth, Succession, and Disturbance Effects.
- The Fire and Fuels Extension (FFE) to the Forest Vegetation Simulator (FVS)
- CRAFT (Comparative Risk Assessment Framework and Tools).
- Ecosystem Management Decision Support.

PPF

Production Possibilities Frontier (PPF) refers to the maximum combinations of goods and services an economy can produce efficiently using its available resources and technology within a given period of time. It is the boundary between the goods and services that can be produced from those that cannot.



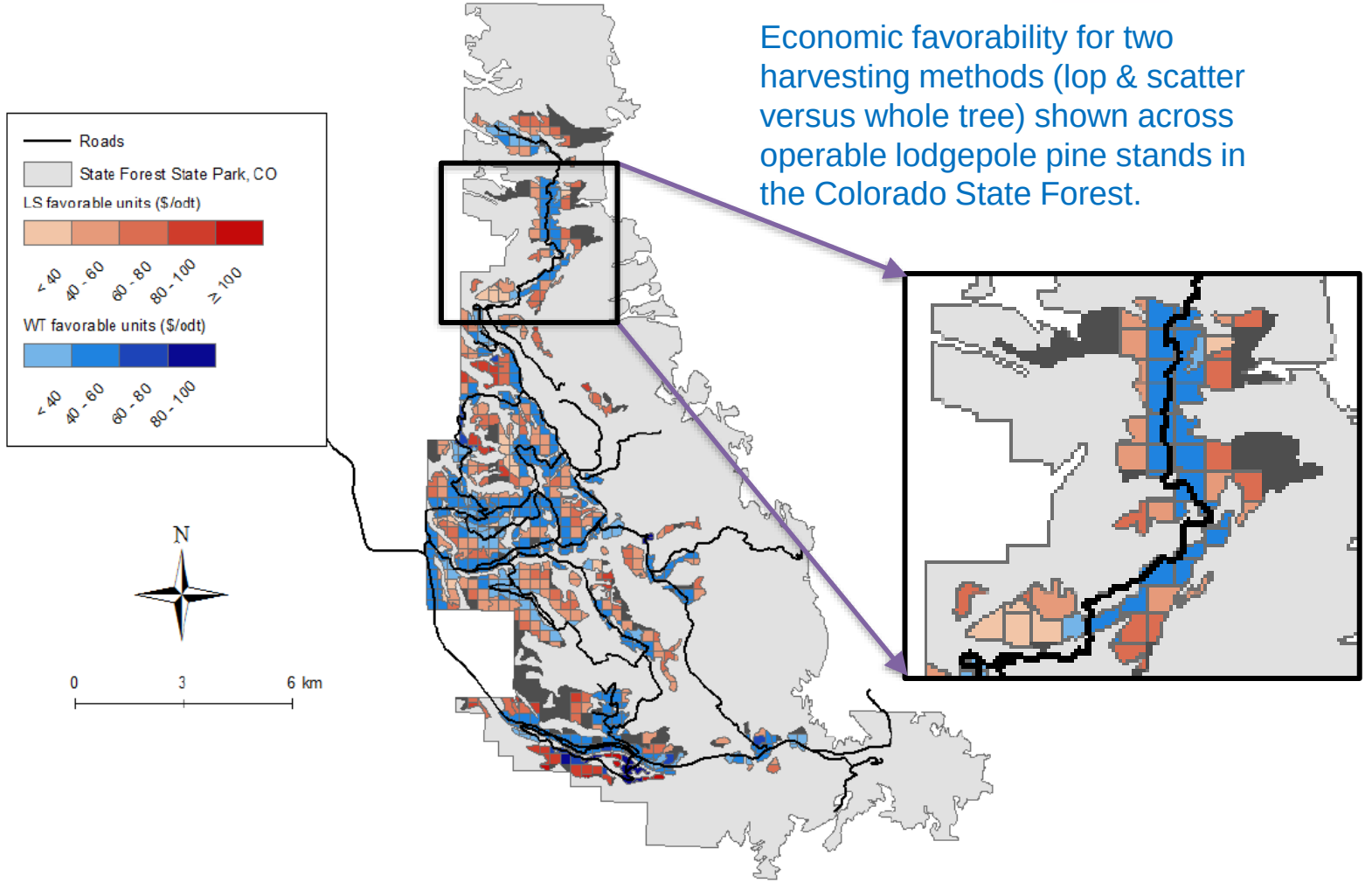
Forest Operations and Logistics

Forest Operations Research

- Cost reductions
- New technologies
- Efficiency & lifecycle analysis
- Machinery & systems synthesis
- Site impacts
- Human safety

Planning

- Harvest cost mapping
- Optimizing biomass harvest to reduce costs and impact



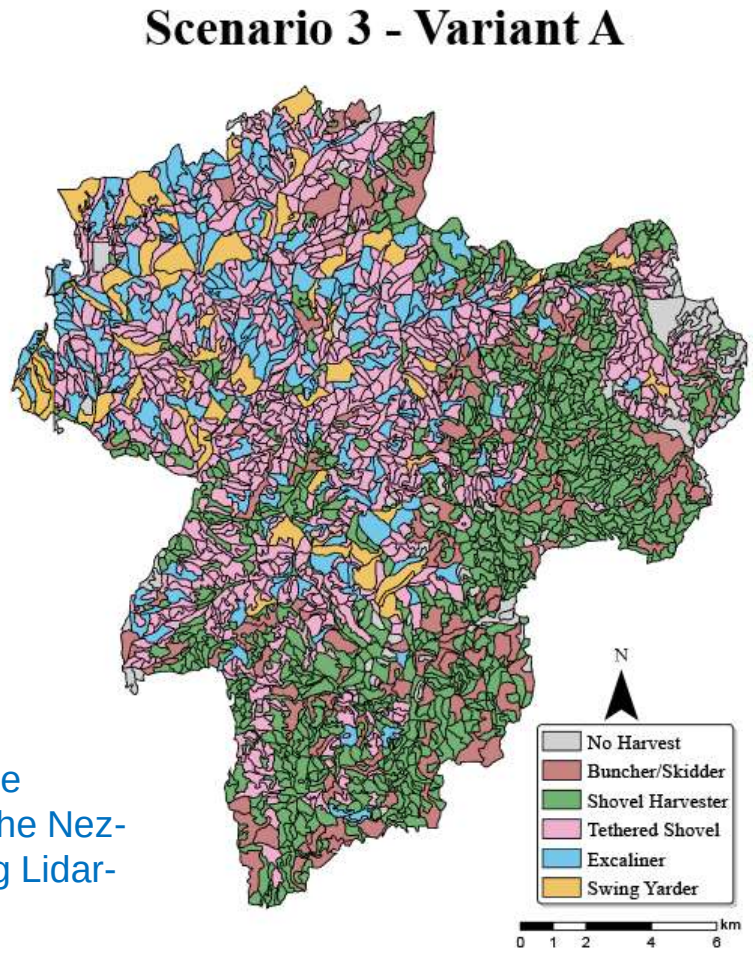
Economic favorability for two harvesting methods (lop & scatter versus whole tree) shown across operable lodgepole pine stands in the Colorado State Forest.

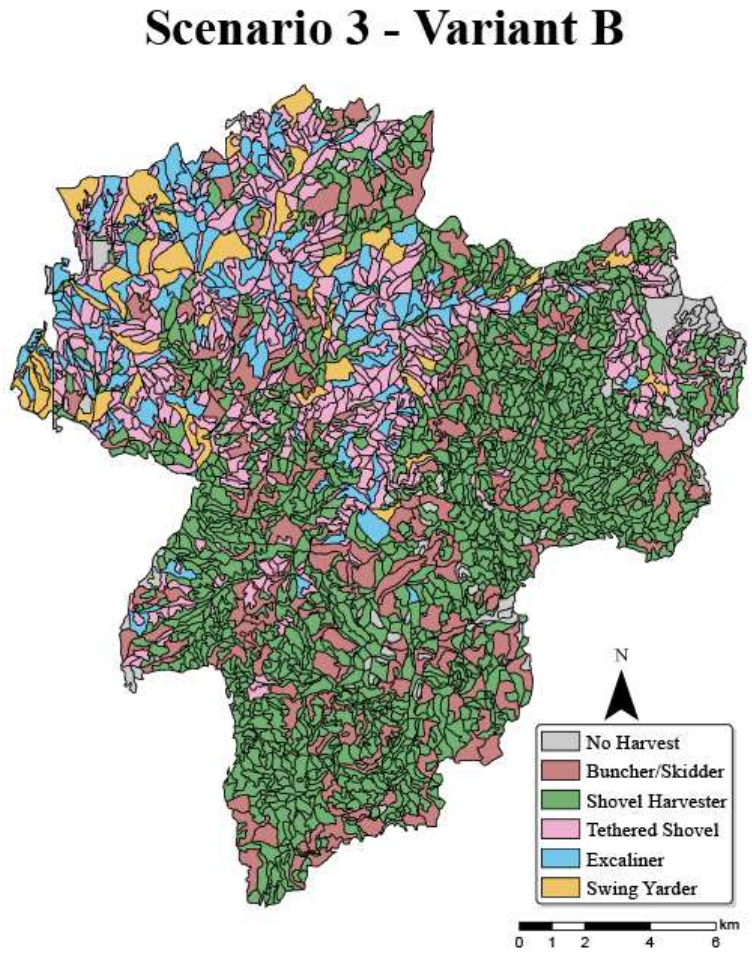
Han, et al. 2018. Productivity and costs of two beetle-kill salvage harvesting methods in northern Colorado. Forests. 9: 572.

Planning

- Optimizing logging system deployment to reduce costs and environmental impacts

Assigning the most favorable harvest system to units on the Nez-Pierce National Forest using Lidar-based landscape analysis.

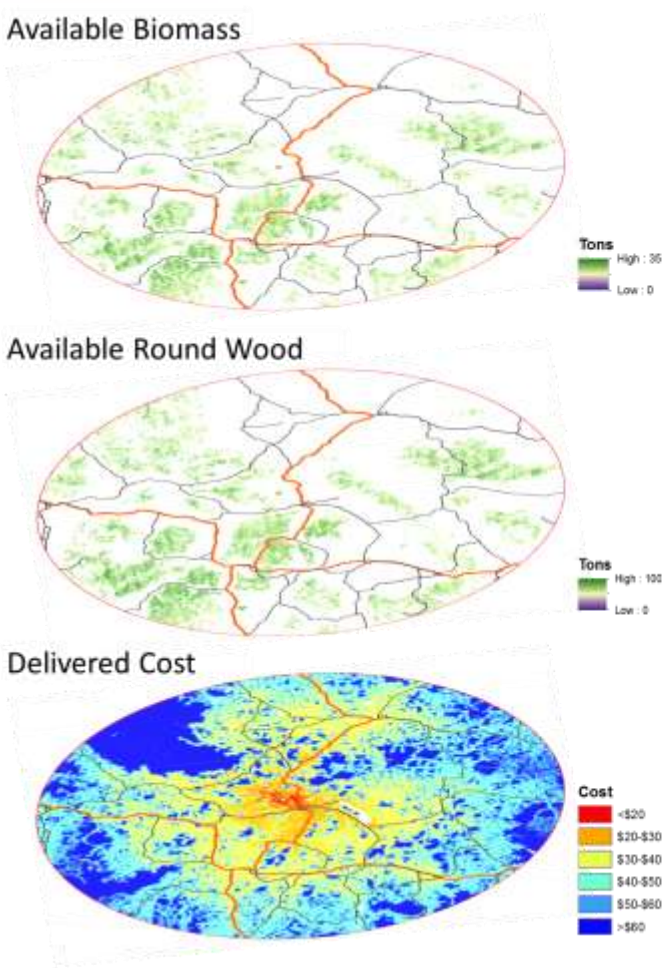


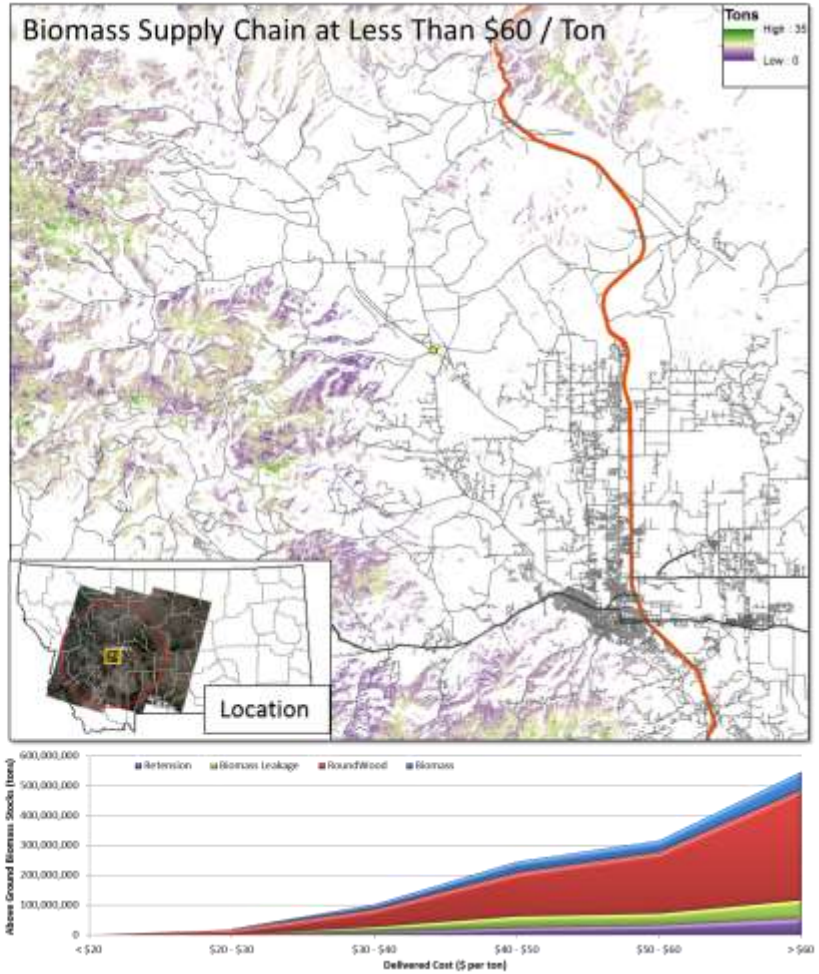


Becker, R., R. Keefe, N. Anderson, and J. Eitel. 2018. Use of lidar-derived landscape parameters to characterize alternative harvest system options in the Inland Northwest. International Journal of Forest Engineering. 29(3): 179-191.

Planning

- Supply chain modeling
- Facility siting
- Cost estimation
- Decision tools





Outputs for biomass logistics and procurement planning using the RMRS Raster Utility: https://www.fs.fed.us/rm/raster-utility/

Hogland, Anderson & Chung. 2018. International Journal of Geo-Information. 7(4): 156.

Operations Research

- Empirical cost models
- Simulation modeling

Comparing the costs and productivities of different fuel treatment operations in Arizona and New Mexico.

Table 13. Observed and modeled total stump-to-truck costs per tonne by operation in USD. Values may not perfectly sum because of rounding.

	Operation				
Function	1	2	3	4	5
Observed costs ($ per tonne)					
Felling	$4.54	$7.74	$13.17	$3.76	$16.06
Skidding	$8.13	$17.31	$11.37	$4.65	$12.47
Processing	$7.80	$7.38	NA	$5.89	$7.87
Loading	$3.86	$2.54	$9.38	$4.65	$3.42
Grinding	$9.02	$9.24	N/A	N/A	N/A
Round wood cost	$24.34	$34.97	$33.93	$18.94	$39.83
Round wood with biomass cost	$33.36	$44.21	N/A	N/A	N/A
Modeled costs ($ per tonne)					
Felling	$4.33	$4.54	$7.74	$4.84	$15.58
Skidding	$6.72	$9.38	$8.50	$9.59	$11.68
Processing	$7.51	$7.83	NA	$6.51	$7.87
Loading	$3.36	$3.27	$7.29	$4.65	$3.42
Grinding	$9.02	$9.24	N/A	N/A	N/A
Round wood cost	$21.92	$25.02	$23.53	$25.58	$38.55
Round wood with biomass cost	$30.94	$34.26	N/A	N/A	N/A

Townsend, et al. 2019. Harvesting forest biomass in the US southern Rocky Mountains: cost and production rates of five ground-based forest operations. International Journal of Forest Engineering 30(2): 163-172.

Designer Feedstocks

- Slash sorting
- Value handling
- Precision grinding
- Production screening
- New biomass products

Photos: Han-Sup Han (Waste to Wisdom)

Precision grinding

"Sawdust" from roundwood for animal bedding.

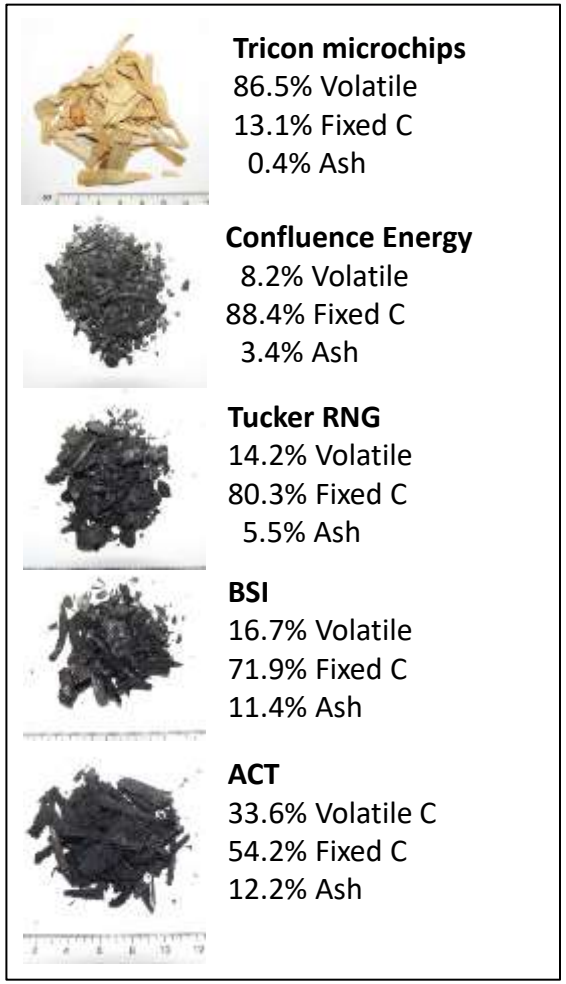
Photos: Anderson

Production "microchips"

Mobile pyrolysis and biochar

- Equipment development
- Field trials
- Operations research
- Economic models
- Workshops and other outreach activities

Mobile slash management with biochar outputs



Biochar outputs from various pyrolysis systems.

Photos: Anderson

Product Development

USDA United States Department of Agriculture

Nanotechnology: From Discovery to Commercialization

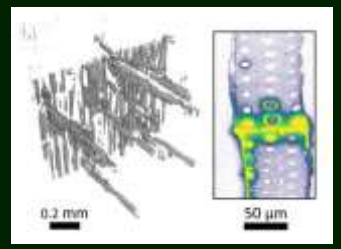
Selected Success Stories and Ongoing Projects

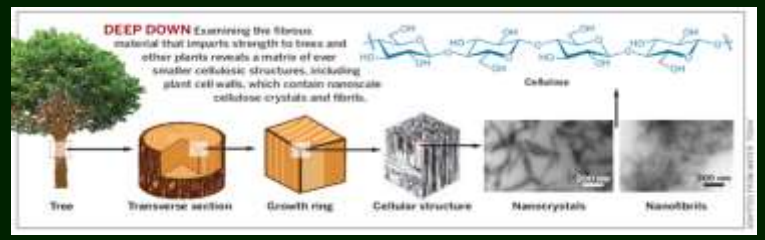
Understanding wood at the nano-scale

Production of cellulose nanomaterials from wood

Develop transformative applications

International Standards Development for commercialization



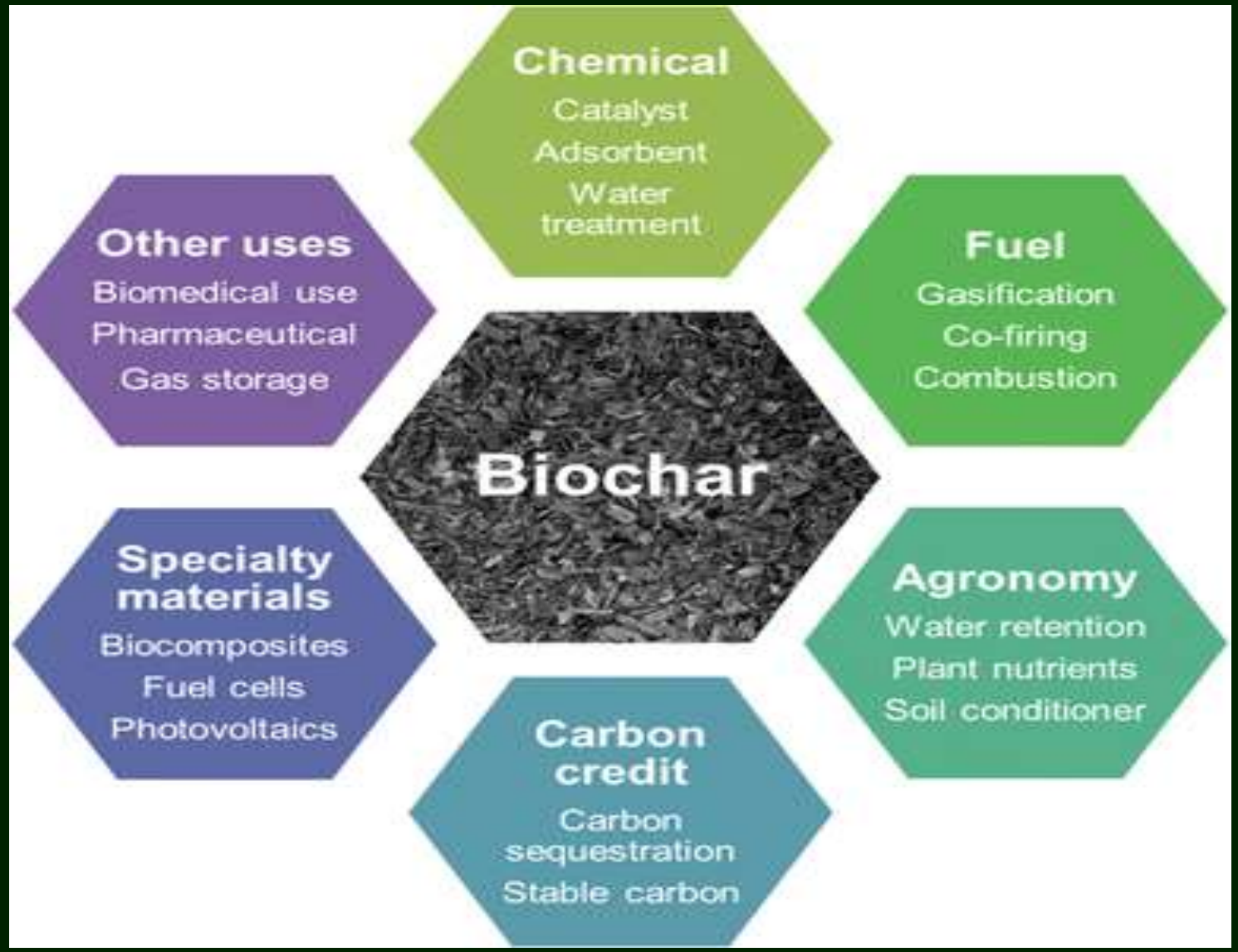


Mass-Timber Program

Selected Success Stories and Ongoing Projects

- Mass-timber includes CLT, Glulam, paralam, LVL, composite lumbers, and other mass-timber products
- Research in structure resilience in seismic conditions, fire performance, durability and interaction with environment, technical support for CLT manufacturing, life cycle assessments
- Participation in standards and building code development

Selected Success Stories and Ongoing Projects

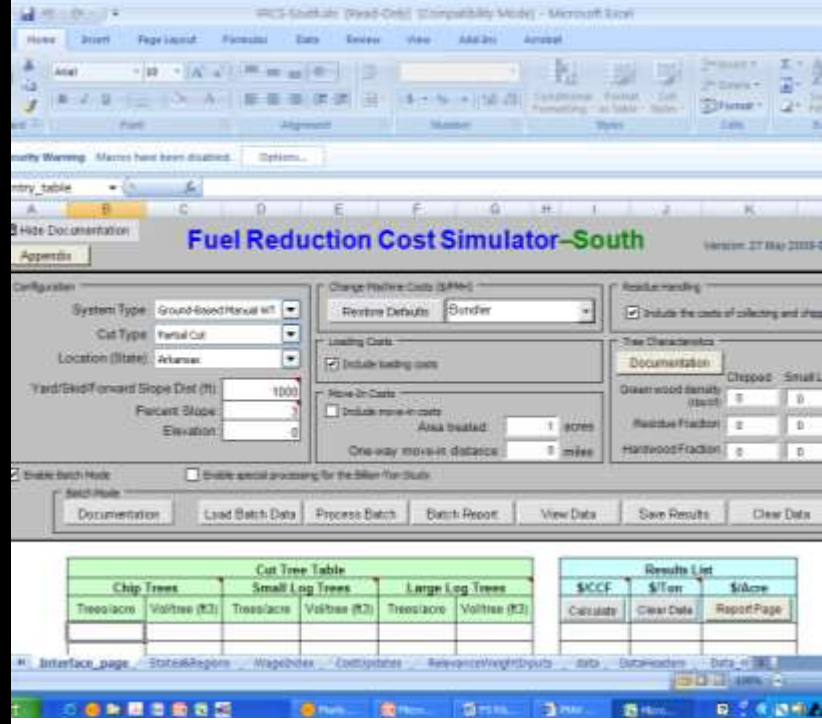


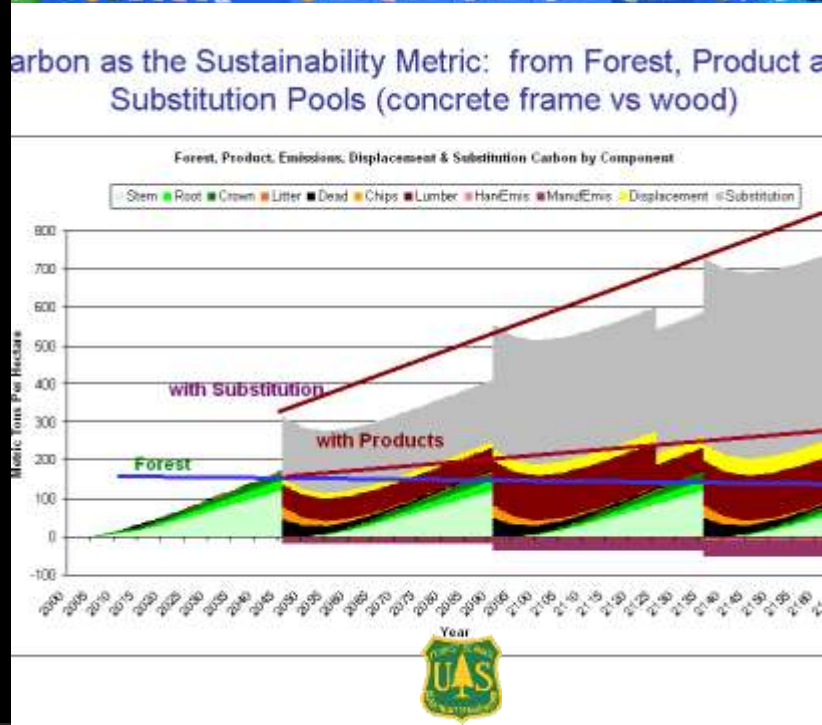
Source: Nanda, S., Dalai, A.K., Berruti, F. *et al.* Biochar as an Exceptional Bioresource for Energy, Agronomy, Carbon Sequestration, Activated Carbon and Specialty Materials. *Waste Biomass Valor* **7,** 201–235 (2016). https://doi.org/10.1007/s12649-015-9459-z

USDA United States Department of Agriculture

Decision Support and Policy Analysis Research

- Lifecycle analysis
- Siting models
- Sustainability criteria
- Operations cost reduction models
- Integrated land use and markets models





Partnerships

Ongoing research on biochar is conducted along with university and industry cooperators

- US Department of Agriculture Energy Programs
- Agricultural Research Service
- Natural Resource Conservation Service
- US Environmental Protection Agency - Center for Public Health and Environmental Assessment
- US Department of Energy — Bioenergy
- US Department of Energy — Bioenergy Knowledge Discovery Framework
- US Energy Information Administration
- Biomass Research and Development Board
- Short Rotation Woody Crops Operations Working Group
- International Energy Agency Task 43 Biomass Feedstocks for Energy Markets
- International Energy Agency Bioenergy
- Federal Woody Biomass Utilization Working Group (WBUG)
- US Biochar Initiative
- International Biochar Initiative

Michigan Technological University,
University of Idaho,
Utah State University,
Northern Arizona University,
Humboldt State University
Boise State University
Chico State University
Colorado State university,
Montana State university,
Oregon State university,
Washington State university,
University of Georgia
North Carolina State University
universities among other many partners from the Departments of Natural Resources, NGOS and established biochar industry.

Thank you!

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