NARA
Northwest Advanced Renewables Alliance

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Soil monitoring equipment

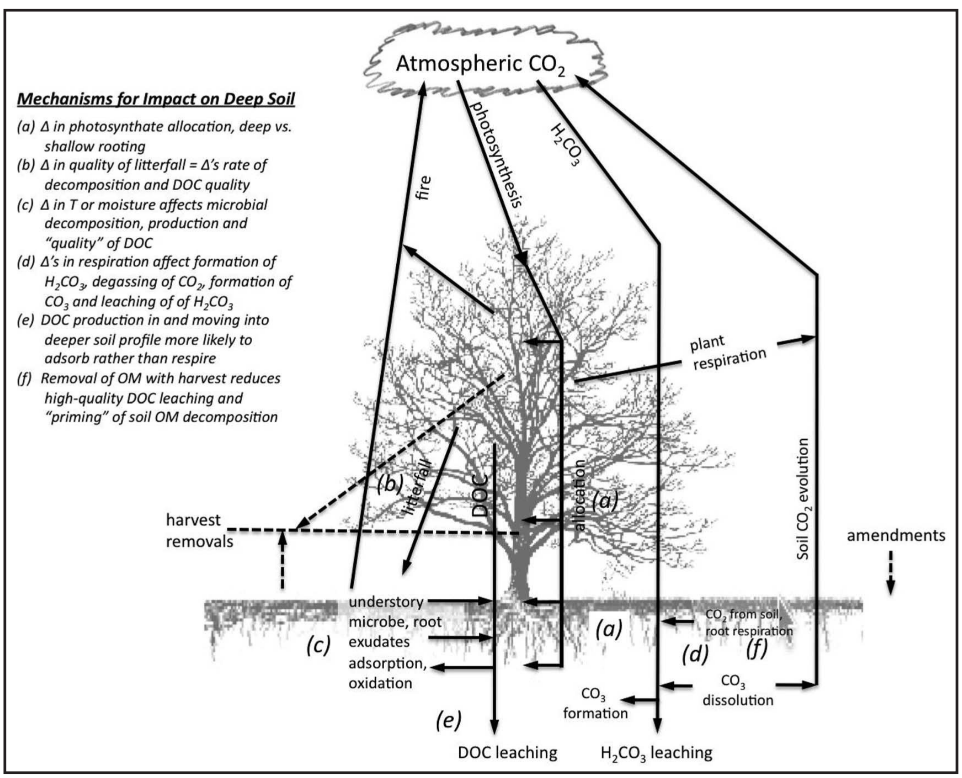
Measuring soil nutrient levels of intensively harvested forests

Those who consider the use of port-harvest forest residuals as a feedstock for biofuel or energy production are interested to know how biomass removal affects soil temperature, water retention and nutrient levels. These effects are being measured at Long-Term Soil Productivity Sites (LTSP) throughout the U.S including the NARA LTSP site in southern Oregon. As the name implies, these are long-term studies, and a complete understanding of the relationship between biomass removal and soil productivity is developing.

> For more information, watch the webinar [Long-term soil productivity and sustainability of forest harvest residual harvesting]

For these studies to be fully relevant, an accurate baseline measurement and understanding of soil nutrient levels in varied forest soils needs to be established. Traditionally, soil samples used to evaluate nutrient supplies and carbon pools were taken at the upper 15-20 cm (6-8 inches) of soil, recent weathering measurements have detected soil nutrient levels to as much as 100 cm (~ three feet) below the surface.

In a recent peer-reviewed paper, partially funded by the USDA-NIFA through NARA, researches review prior techniques used to monitor soil nutrient levels and explore recent knowledge that supports the need to measure nutrient levels at a



Mechanisms for differential changes in C changes in the soil profile with depth. Reprinted from "Deep Soil Horizons: Contributions and Importance to Soil Carbon Pools and in Assessing Whole-Ecosystem Response to Management and Global Change", by Harrison, R.B., Footen, P.W. and Strahm, D., 2011, Forest Science, 57(1), pp. 67-76.

level equal to root depth, which for some managed forests in the Pacific Northwest can extend well below 100 cm.

> Read *Carbon storage and nutrient mobilization from soil minerals by deep roots and rhizospheres*

Soil organic carbon

Much of the paper focuses on soil organic carbon (SOC). SOC is claimed to be the largest pool of terrestrial carbon, and tree roots play a role in putting it there. The amount of SOC in soils vary due to soil type and biological activity, but can often be accounted for at depths up to 300 cm and greater. In one study, soils sampled at 20 cm contained an average of 59 Mg C/ha, sampling at 50 cm showed 113 Mg C/ha, and sampling at 300 cm showed 202 113 Mg C/ha. The results suggest that shallow measurements for carbon can dramatically underestimate the level of available SOC to the ecosystem. And during a time when carbon stocks are being monitored due to climate change, a rethinking to how we measure SOC is suggested.

Soil processes and roots

The paper points out that roots provide water and nutrient uptake plus they help anchor the plant. Acidity due to root respiration and chemicals released by roots are shown to promote chemical weathering of mineral components deep in the soil. The fact that soil nutrients at deep levels change seasonally, suggest that tree roots uptake nutrients in deep soil when growing and that mineral weathering, root systems and soil carbon levels are linked.

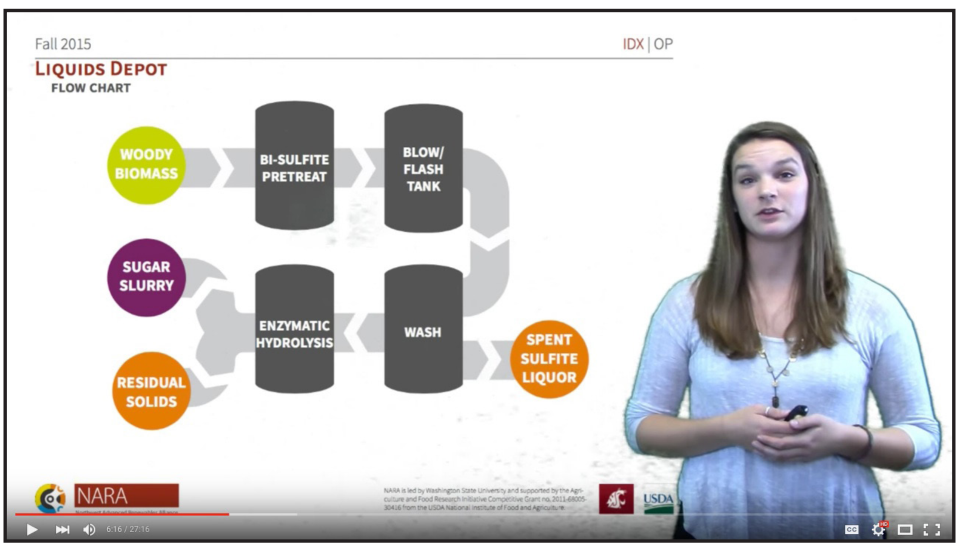
Methods to measure soil nutrient levels

The “base mineral index” was used for many years, which relied on a heavy liquid called “Thoulet solution” to separate out minerals for evaluation. The “Thoulet solution”, due to its toxicity, has been replaced with either sodium polytungstate or an agua regia analysis. Measuring the amount of nutrients in a soil sample is rather straightforward using these tools. Measuring the timescale from when a nutrient is released to when it becomes available for uptake in plants has been difficult. The paper releases new data that measures the release profiles of potassium and phosphorus over time in varied soils. The results show that nutrient release times and amounts vary depending on the parent materials (i.e. rocks) at varied soil depths. These data suggest that the amount of nutrients made available through deep root actions can be dependent on the soil mineralogy, which is at times, left out of soil quality assessments.

Conclusion

The paper emphasizes that in order to understand the amount of soil nutrients available with an ecosystem, samples should include soils at greater depths that are currently being measured. In addition, the type of minerals in soil can affect the amount of nutrients made available and should therefor be considered when evaluating a soil’s potential for plant productivity.

The work represented in this paper provides insight to how we assess a soil’s capacity to provide, store and replenish nutrients. A fuller understanding in this area should help researchers determine the impact of biomass harvesting on soil productivity.



IDX student Destry Seiler describes liquids depot siting strategy during the IDX webinar November 16th, 2015.

NARA students present findings for Olympic Peninsula biomass users

Students enrolled in the Integrated Design Experience (IDX) course at Washington State University are working with NARA to explore potential solid and liquid depot sites in the Olympic Peninsula region. These potential depots would fit into a supply chain that converts post-harvest forest residuals (material generally burned in slash piles) into chemical products like bio-jet fuel. In late November and early December, 2015, the IDX students conducted four webinars to distribute their results. Two of the webinars provide a rational for the sites.

> View webinar *Pilot Plant at Port Townsend*

> View webinar *Micronized Wood Product Plant at Hermann Brothers*

Whereas an additional set of webinars provide schematic designs for each site.

> View webinar *Liquid Depot Facility at Port Townsend Paper Company*

> View webinar *Micronized Wood Facility at Hermann Brothers site*

These webinars are the product of work generated after visiting select forest products companies last October.

Pilot plant at Port Townsend

The IDX students selected the Port Townsend Paper mill as a potential site to include a liquids depot. A liquids depot would process post harvest forest residuals into a sugar syrup and also produce a lignin-rich co-product. The sugar syrup could then be transported to bio-refineries for further conversion into biochemicals, biofuels and/or livestock feed. To do this, a liquids depot would be capable of performing a pretreatment and enzymatic hydrolysis process. The pretreatment step uses heat and chemicals to break apart the wood structure to expose sugar polymers. Exposure of the sugar polymers is necessary for the enzymatic hydrolysis step: a process where applied enzymes reduce the sugar polymers (like cellulose and hemicellulose) into simple sugars. Paper mills are ideal sites to include a liquid depot facility as they already have infrastructure to handle wood biomass storage and transport. In addition, they already process and market lignin as a byproduct.

In the webinar, the students estimated that a viable liquids facility would need 100,000 bone-dry tons (BDT) of post-harvest forest residual material annually to be economically viable. This amount would produce 4000 tons of glucose and 40,000 tons of lignosulfonate annually. The Port Townsend Paper mill already uses 120,000 BDT of post-harvest forest residuals annually for energy production, so the total amount of woody biomass needed annually to supply both energy and sugar syrup would be 220,000 BDT.

While this number represents a significant amount of wood biomass, it is estimated that only 14% of forest residuals generated annually after timber harvest in the Olympic Peninsula are currently used; the rest is either left on site or burned.

Using a biomass supply model generated by NARA researchers, the IDX students illustrated on maps the amount of sustainable post-harvest biomass available based on a set delivery price. Delivery price included all acquisition, processing and transport fees from the harvest site to the liquids depot. At $73 average per BDT delivered, 246,000 BDT would be available annually under averaged timber harvest scenarios. The students also estimated that 60 new jobs would be created.

The webinar presenters described three sites and provide detailed schematics within the Port Townsend Paper mill property that could potentially host the added liquids depot facility.

Micronized wood product plant at Hermann Brothers

For a potential solids depot in the Olympic Peninsula, the IDX students used the Hermann Brothers Logging and Construction site in Port Angeles for their case study. A solids depot would process and store post-harvest forest residuals for energy use or for distribution to a liquids depot or bio-refinery. Hermann Brothers already supplies post-harvest forest residuals for a variety of uses and thus already functions as a solids depot. The added feature explored by the IDX students is to incorporate a micronized milling capacity to the business.

Micronized milling is a process that grinds wood material into a wood flour with average particle size of 50 microns. The advantage gained using this technology is that the pretreatment step (and costs) used to expose the sugar polymers for enzyme hydrolysis is avoided. The wood particles are so small that the enzymes, when added, have access to the polymers and can generate simple sugars. Efficient wood milling relies on electric energy, which is relatively inexpensive in some Pacific Northwest locations.

In the webinar, the IDX students estimated that a sustainable micronized milling plant would require 50,000 BDT of post harvest forest residuals annually. Using NARA biomass models, the students predicted that 122,000 BDT of post-harvest forest residuals could be sustainably delivered at a $63 cost per BDT. Three sites within the Hermann Brothers wood yard property were evaluated for accommodating the micronized wood infrastructure.

Student professional development and stakeholder benefit

The IDX students perform critical data gathering and analyses for the NARA project and for regional stakeholders. Their research results to date can be found on the NARA website.

Nearly 100 undergraduate and graduate students with varied majors including law, engineering, and design have participated in the IDX research for NARA. These students leave with an amazing understanding of biomass and biofuel supply chain issues. Already, the students are getting jobs in the region as planners, architects, and engineers and are becoming the bioenergy experts in their communities and in business.

The impact from these students entering the bioenergy workforce is a desired outcome of NARA's bioenergy literacy goal. An additional benefit is that data and outreach accomplished through their efforts educates Pacific Northwest stakeholders and provides a solid foundation of information for investment and planning purposes.

NARA introduces Webinar Series

The Northwest Advanced Renewables Alliance (NARA) is concluding its final year under the contractual terms with the United States Department of Agriculture's National Institute of Food and Agriculture (USDA-NIFA). Many of the outputs generated from this project are recorded in peer-reviewed journals or documents in various NARA reports.

Another format used to rapidly introduce NARA outputs to a wide audience is through webinars. In October 2015, NARA launched a Wood-to Biofuels Webinar Series. Each webinar features NARA researchers describing their research contributions to the NARA project.

Completed webinars have been posted on the NARA YouTube channel. The next webinar will be on January 19th and is titled "Pretreatment of Woody Biomass for Biofuel Production". J.Y. Zhu will present the webinar. He is the scientific team leader at the U.S. Forest Service's Forest Products Laboratory in Madison Wisconsin and adjunct professor at the University of Wisconsin-Madison.

Listed below are links to and a brief description of the webinars presented so far. These webinars focus on feedstock logistics, sourcing, and availability plus environmental sustainability. Additional webinars, presented in the near future, will address other areas of the NARA project such as co-product development, conversion into bio-jet fuel and education.

WEBINARS AS OF DECEMBER 7, 2015

Estimating forest residue for biomass production

By Kevin Boston, Associate Professor, Oregon State University

The webinar describes the biomass supply chain and various techniques used to measure biomass piles. It describes the logging process that are common in the Pacific Northwest and how they can influence the amount and location of biomass produced from harvesting operations. It review the operations used to collect and process this biomass and suggests other equipment that might be useful to increase the amount of biomass available for energy production.

Decision support for forest harvest residue collection

By John Sessions, University Distinguished Professor and Rene Zamora-Cristales, Post Doctorate, Oregon State University

A forest residue collection model using forwarders and excavator loaders is presented to estimate the potential cost of biomass extraction from the forest to roadside landings. Tradeoffs between increasing collection costs and increasing road transportation are examined. The impact of tax credits and site preparation savings are discussed.

Characterization of forest residuals for bio-jet fuel production

By Gevan Marrs, Feedstock Sourcing, NARA

Softwood feedstock samples collected throughout the Pacific Northwest have been characterized for carbohydrate, lignin, and extractives content. Some of the samples have received exhausting testing through pretreatment, hydrolysis and fermentation into alcohols. In addition, the cost impacts associated with various feedstock processing options have been quantified in order to evaluate the economic impacts to deliver a "standard sized" feedstock product for conversion into bio-jet fuel and co-products.

'Woods-to-Wake' life cycle assessment of residual woody biomass based jet-fuel

By Indroneil Ganguly, Assistant Professor, Research, University of Washington

Utilizing a 'woods-to-wake' (WTWa) Life Cycle Assessment (LCA) methodology, which is comparable to well-to-wake for its fossil based counterpart, this webinar assesses the environmental implications of recovering these harvest residues to produce woody biomass based bio-jet fuel.

Long-term soil productivity and sustainability of forest harvest residue harvesting

By Jeff Hatten, Assistant Professor, Oregon State University; Scott Holub, Silviculture Research Scientist, Weyerhaeuser NR Company

This webinar examines the effects of removing forest floor and harvest residues on soils and sustainable production in intensively managed Douglas-fir forests of the Pacific Northwest. The amount and types of biomass being removed and how biomass harvesting impacts various nutrients (e.g. nitrogen, phosphorus, calcium) is discussed. Nutrient removals may impact long-term production or growth in these forests, simple thresholds and nutrient budgets are used to examine this trend. Finally, the limitations of this approach and opportunities for further research are discussed.

Incorporating Timber Product Output (TPO) harvest residue information and forest market models to evaluate biorefinery siting potential

Todd Morgan, Director, Forest Industry Research, Bureau of Business and Economic Research, University of Montana
Greg Latta, Assistant Professor, Senior Research, Forest Engineering, Resources & Management, College of Forestry, Oregon State University

Since the NARA study began in 2011, BBER researchers have measured more than 2,500 felled trees within 108 logging sites. The NARA project uses this data to characterize how current forest harvest residues vary by region, county, ownership source, pulp removal, logging systems employed, and tree attributes such as species. To evaluate how that supply might change over time NARA utilizes spatially explicit economic models of forest products markets, which balance harvests on FIA plots with demand for logs at regional mills. The resulting spatial allocation of logging operations for products such as lumber, plywood, and paper products is then further refined with the TPO data to assess future potential harvest residue availability.

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