

Carbon and Bioenergy Feedstocks

Lecture 4 – Forest & Field Biomass Sources

<http://www.nasa.gov/content/goddard/seeing-photosynthesis-from-space-nasa-scientists-use-satellites-to-measure-plant-health/#.U9bq2eNdV8F>

<http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4086>

When you have a moment please visit the NASA website at the shown link. This is a very cool visualization of photosynthesis from space – one of the best we have ever created to date. It really gets you thinking about biomass carbon with a global perspective.

Week 2 – Carbon and Bioenergy Feedstocks

-Learning Objectives-

- ▶ List the major carbon resources on earth and describe both strengths and weaknesses of each in terms of availability, cost, uses, and sustainability.
- ▶ Explain the realities of the food vs. fuel argument and the environmental costs of biomass feedstocks.

What is Biomass?

- ▶ Biomass is any material that has been produced from a living or recently living organism. This usually means plants, but also includes animals. Bioenergy is predominately focused on plant sources of biomass.



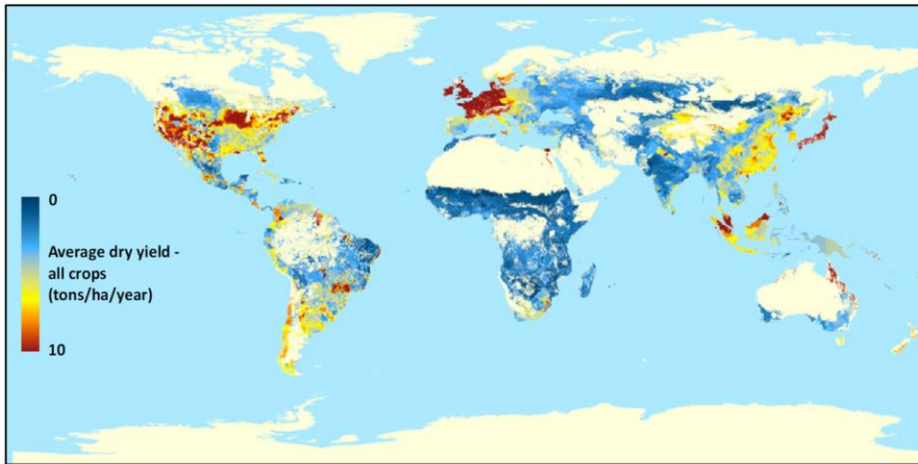
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Pictures of centurion and hyperion. Centurion is the tallest Swamp Gum (Eucalyptus) tree in the world, making it the tallest angiosperm (flowering plant) in world. The tree is located in southern Tasmania, Australia and is 99.6 meters tall. Hyperion is the name of a coast redwood (Sequoia sempervirens) in Northern California that was measured at 115.61 meters, which makes it the world's tallest known living tree and tallest gymnosperm. Biomass is very cool.

This means that a lot of things are considered biomass, humans included. Bioenergy is predominately focused on conversions associated with plants and not animals, but there are important animal sources of biomass. The important thing about plant biomass is that all plants have similar chemistry, so a chemistry that works with one type of plant biomass can at least be considered for another type of plant biomass, etc. It also means that when you look out the window, everything green you see has similar chemistry and this includes wood items we all see/use daily.

So can we use this strength



West et al. | www.pnas.org/cgi/doi/10.1073/pnas.1011078107

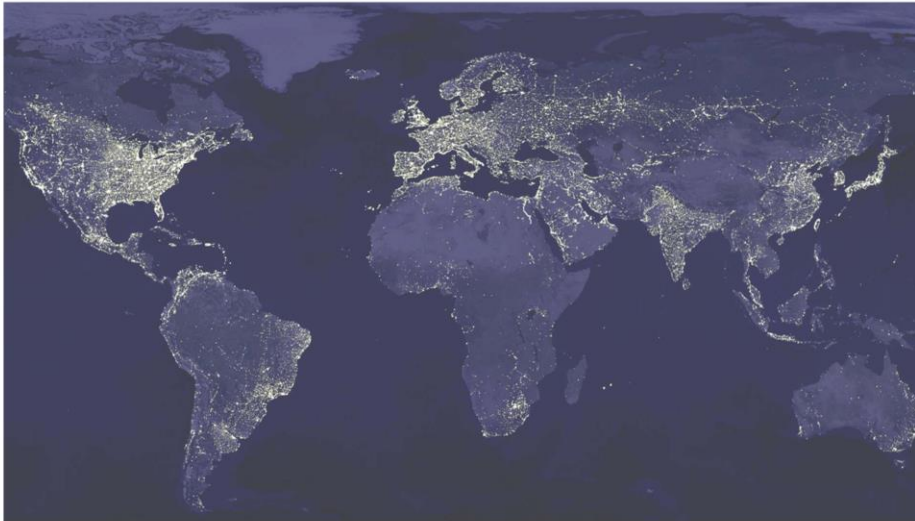
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Make me a map - <http://www.nrel.gov/gis/tools.html>

Here is the map of agricultural productivity again. The real question is, can the areas with high productivity use that strength.

To help support this demand?



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To support of the demand of the areas that are utilizing the most energy. Pictures of the earth at night are a very good way to get a feeling for where most of our energy consumption is occurring. It is very interesting that the areas of energy consumption overlap so well with the areas of intense agricultural productivity.

Types of Biomass & Urban Wastes

- ▶ **Forest Biomass**
 - ▶ Forest residues, mill residues, whole trees, etc
- ▶ **Agricultural Biomass**
 - ▶ Grasses, corn stover, grain straw, grain hulls, bagasse, etc
- ▶ **Aquatic Biomass**
 - ▶ Microalgae and macroalgae
- ▶ **Landfill Waste**
 - ▶ Municipal solid waste (MSW), refuse derived fuel (RDF), etc
- ▶ **Wastewater/Sewage Sludge (biosolids)**

For the purpose of this class, biomass will be divided up into five main types (name everything).

Types of Biomass & Urban Wastes

- ▶ **Forest Biomass**

- ▶ Forest residues, mill residues, whole trees, etc

- ▶ **Agricultural Biomass**

- ▶ Grasses, corn stover, grain straw, grain hulls, bagasse, etc

These are primarily rural distributed sources of biomass

I would like you to consider categorizing the five main sources of biomass into two categories. The first is rural distributed sources like forests and fields. These sources of biomass are generally found in country settings and they are often enormous, but spread out, requiring harvesting and consolidation.

Types of Biomass & Urban Wastes

- ▶ **Aquatic Biomass**
 - ▶ Microalgae and macroalgae
- ▶ **Landfill Waste**
 - ▶ Municipal solid waste (MSW), refuse derived fuel (RDF), etc
- ▶ **Wastewater/Sewage Sludge (biosolids)**

These are primarily urban consolidated sources of biomass

The second category is urban consolidated sources like landfill waste and wastewater sludge. Aquatic biomass is included because algae have considerably potential for becoming this kind of a biomass source. These sources of biomass are generally found in more urban and suburban settings and they have already been consolidated by us to keep our cities and towns clean.

Forest Biomass - What is it?

Woody biomass that comes out of the forest or from the production of wood products

1. Logging Residues: Slash, thinnings, stumps
2. Mill Waste: Shavings, chips, sawdust, black liquor, bark
3. Roundwood: Whole trees, logs

The tough thing about forest biomass is that there are a lot of forests and it is tempting to believe that should mean its easy to use for bioenergy. The problem is that there has been a strong market for wood for hundreds of years, so the wood that can be economically removed from the forest is removed and it is used for materials. Almost zero wood is wasted during wood processing, so while there appears to be a lot around, it is not really available or cheap in significant quantities.

Gasoline goes for about 65 cents/lb and most lumber is sold for about 40 cents/lb. So, if wood could be easily turned into gasoline, then maybe it would be more economic to turn wood into gasoline than to turn it into lumber. Unfortunately, it is not easy to turn biomass into gasoline and its very easy to turn into materials, so it is likely that a lot of forest biomass will continue to be used for primarily lumber, unless it is a tree farm.

Forest Biomass – Logging Residues

- ▶ **Logging Residues: Slash, thinnings, stumps**
 - ▶ Challenges – dirty, wet, dispersed
 - ▶ Strengths – cheap to produce, storage



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Logging residues are a very common source of forest biomass. They are what is left over after the tree has been cut and loaded onto a truck. Logging slash is the branches, roots and unwanted stem sections of the tree, along with some brush depending on the area. Slash is very cheap and can be stored in piles outside without degrading, but it is also very wet, full of rocks & dirt, and spread out in lots of little piles all over the forest. Conventional practice tells us that the forest products companies would be using it right now for fuel if it was economic to recover this source of biomass for fuel. The fact that they aren't suggests a challenge in leveraging this resource.

Forest Biomass – Mill Waste

- ▶ **Mill Waste: Shavings, chips, sawdust, black liquor, bark, hog fuel**
 - ▶ Challenges – expensive, low availability
 - ▶ Strengths – often urban-ish, clean, consolidated



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The production of lumber from logs generates a lot of sawdust, shavings and chips. Much of the media suggests that mill waste is actually waste that could be used for biofuels, but unfortunately this is not true. The wood processing facility of today has almost no waste. Many mill residues are sold for use in wood composites and for landscaping/habitat restoration. What isn't sold at a good margin for other products is utilized by the mill for energy to produce the steam needed for drying. Mill residues are a great source of biomass for bioenergy when they can be found cheaply and with good availability, but this is not common.

Forest Biomass - Roundwood

- ▶ **Roundwood: Whole trees, logs**
 - ▶ Challenges – expensive, wet, requires processing
 - ▶ Strengths – storage, supply chain, high density



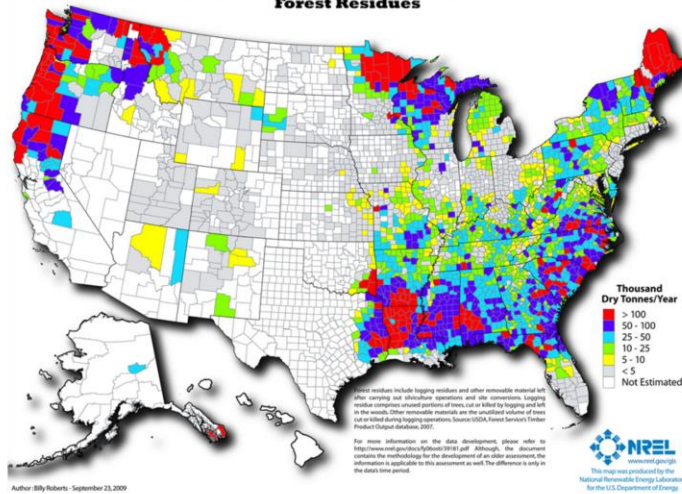
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Growing trees on tree farms and harvesting trees from natural forests is expensive and generally whole trees do not make a great deal of sense economically for biofuels. However, some tree farms grow trees so fast that harvesting them for bioenergy does make sense. This source of biomass may face stiff competition for the trees from biomaterials companies in the future, but at the moment there are some interesting developments. If you can find a cheap, large, consistent supply of logs there is a lot you can do with them from a bioenergy perspective.

Forest Biomass – Where is it?

Biomass Resources of the United States Forest Residues



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So where is the forest biomass? Primarily in the PNW and the South. Minnesota, Michigan, NH and Maine are also big forestry states.

<http://www.nrel.gov/gis/biomass.html>

Agricultural Biomass/Energy Crops - What is it?

Crops produced using intensive agricultural practices and residues from cash crop production (food, materials, chemicals)

1. Grasses: Sugarcane, Miscanthus, Switchgrass, Sorghum
2. Small trees: Poplar, Willow, Eucalyptus
3. Residues: Hulls, Corn stover, bagasse, prunings, etc
4. Grains: Wheat, Corn, Rice, Barley

Pretty much any biomass that can be grown in a field is considered agricultural. This is its own category of biomass because it often quite mechanically and chemically different than forest biomass and it is produced from manmade ecosystems using water and arable land. Biomass (trees, grass, etc.) is made primarily of carbon, hydrogen and nitrogen. It gets the carbon from the CO₂ in the air, it gets the hydrogen from water, and it gets most of the nitrogen from fertilizer. That means to make it grow fast, it must have a large supply of water and fertilizer, otherwise it doesn't have the raw ingredients to grow as fast as we want.

This is where food vs. fuel really stops making sense. Since energy crops generally require intensive practices they obviously compete with food crops. However, the food vs. fuel argument has always been political and silly because we raise plenty of non-food crops like cotton, flax, tobacco, lavender and peppermint. There is no such thing as fuel vs. food because we are not running out of food and we have massive amounts of arable land. Water is a contentious issue, but the price of food will change with or without energy crops. The chicken, beef and pork lobbies are largely behind the vast majority of food vs. fuel debates.

Agricultural Biomass/Energy Crops Grasses

- ▶ **Grasses: Sugarcane, Miscanthus, Switchgrass, Sorghum**
 - ▶ Challenges - seasonal, storage, low density, high ash content
 - ▶ Strengths – digestible, impressive growth rates



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High yield grasses and energy crops are often the same thing with the exception of a few trees. These sources of biomass are the fastest growing source we have available. Grown in a warm place, with lots of water and some fertilizer, they will out produce the jungles of SA in biomass production. They also have much less lignin than trees, so they are much more digestible. This is why cows can eat grass, but not wood.

While they grow incredibly fast, they are tough to store, seasonal and have some challenges around conversion. It is very likely that energy crops like this will play a big role in the future of bioenergy.

Agricultural Biomass/Energy Crops Small Trees

- ▶ **Small trees: Poplar, Willow, Eucalyptus**
 - ▶ Challenges – growth rate, low density
 - ▶ Strengths – storage, fiber & composite materials, low ash



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The small trees that are considered energy crops are poplar, willow and eucalyptus. They have the same strengths as forest biomass, but less of the weaknesses. They are a cleaner, cheaper source of wood and because they are higher density they have better transportation economics than grasses. They also have the potential to be used for other markets if the bioenergy markets are not strong for some reason.

Agricultural Biomass/Energy Crops Residues

- ▶ Residues: Hulls, Corn stover, bagasse, prunings, etc
 - ▶ Challenges - seasonal, storage, low density, high ash content
 - ▶ Strengths – cheap, consolidated



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Ag residues are a very exciting potential source of biomass because they aren't really used for any high dollar products right now. There are a lot of them and they have many of the same challenges as the grasses/crops they are produced from, but they are also cheaper and have already been consolidated. Ag residue conversion shows promise of being one of the best sources of biomass for bioenergy conversions.

Agricultural Biomass/Energy Crops

Grains

- ▶ **Grains: Wheat, Corn, Rice, Barley**
 - ▶ Currently the largest source of biomass for biofuel (ethanol)
 - ▶ Often not considered in today's biomass assessments
 - ▶ Very expensive, but very useful biomass
 - ▶ Consider the value of grains vs grasses for farming



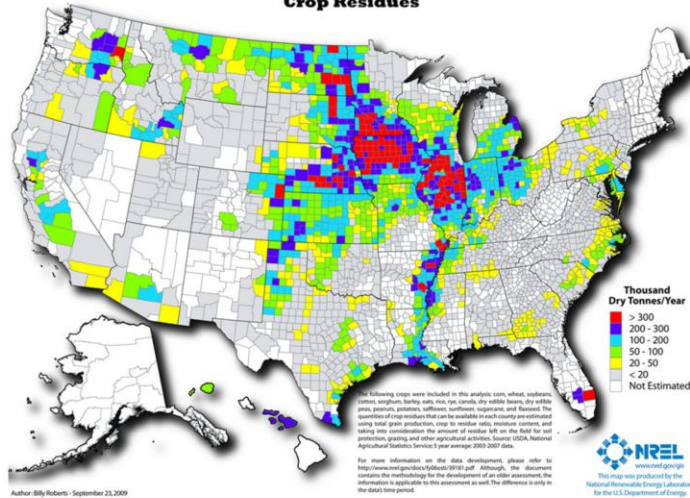
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It wouldn't be fair to not include grains in the discussion. Grains do not get anywhere near the yield/acre that grasses get, but as a source of sugars/oils, they require very little processing compared to grasses, so there is a tradeoff. Despite the constant discussions about yield, there are other considerations. It is important to think about the objective in deciding what the appropriate biomass is.

Agricultural Biomass – Where is it?

Biomass Resources of the United States Crop Residues



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So where is the Ag biomass? Primarily in the Midwest. Everyone has some, but the Midwest really has a lot

<http://www.nrel.gov/gis/biomass.html>

Land Based Biomass things to consider ...

- ▶ Generally sells for about \$60-70/ton (except grains)
- ▶ Most conventional source of biomass
- ▶ Must collect & transport, very spread out resource
- ▶ Expensive to process into correct shape
- ▶ Solids are difficult to feed into reactors

Next Lecture – Aquatic Biomass & Urban Wastes



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http://www.sdnews.com/view/full_story/298437/article-Kelp-harvester-leaving

Kelp harvesting is big business and ships like this used to roam the CA coast collecting it for processing. When you have a moment please visit the news website at the shown link to read more about.