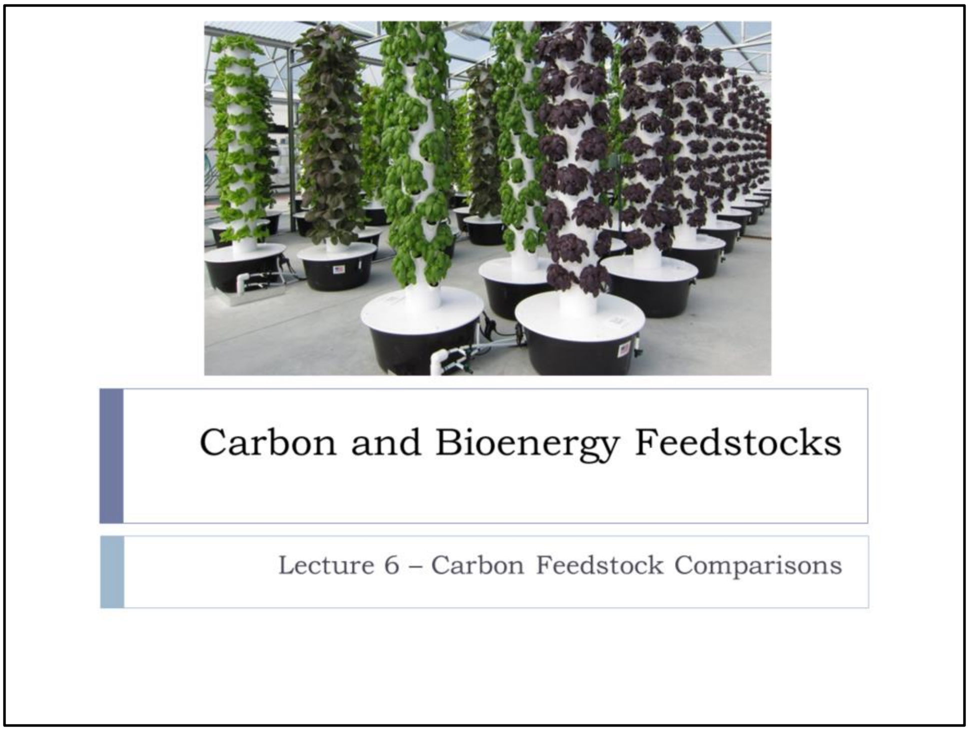


When you have an opportunity, please click on the provided link and visit the tower-garden website. Vertical gardening completely re-writes the yield/acre/year equations. They are expensive to develop, but then the yields/acre are incredible – much like algae. The Tower garden designers claim this style of agriculture can produce as much food as a 15 acre farm using about 2,500 square feet. It also requires only about 5% of the water that typical soil farming requires and can generate around 20 times more yield/acre than traditional farming.

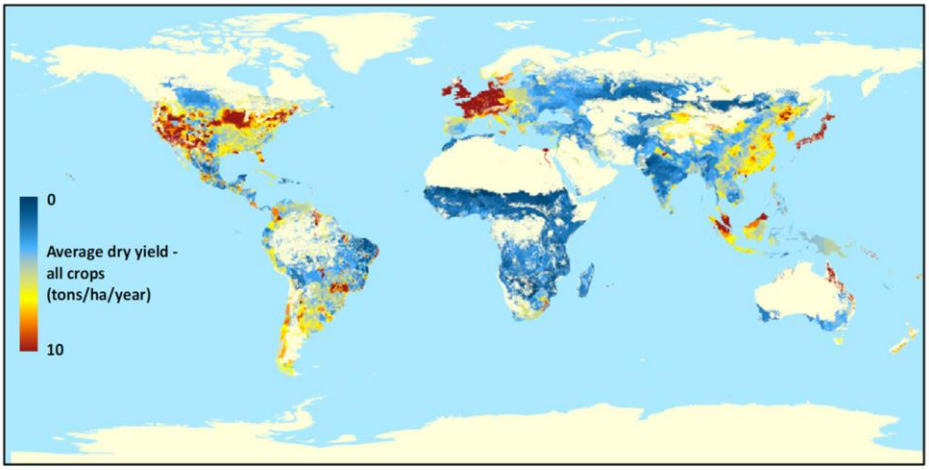
https://www.towergarden.com/

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.

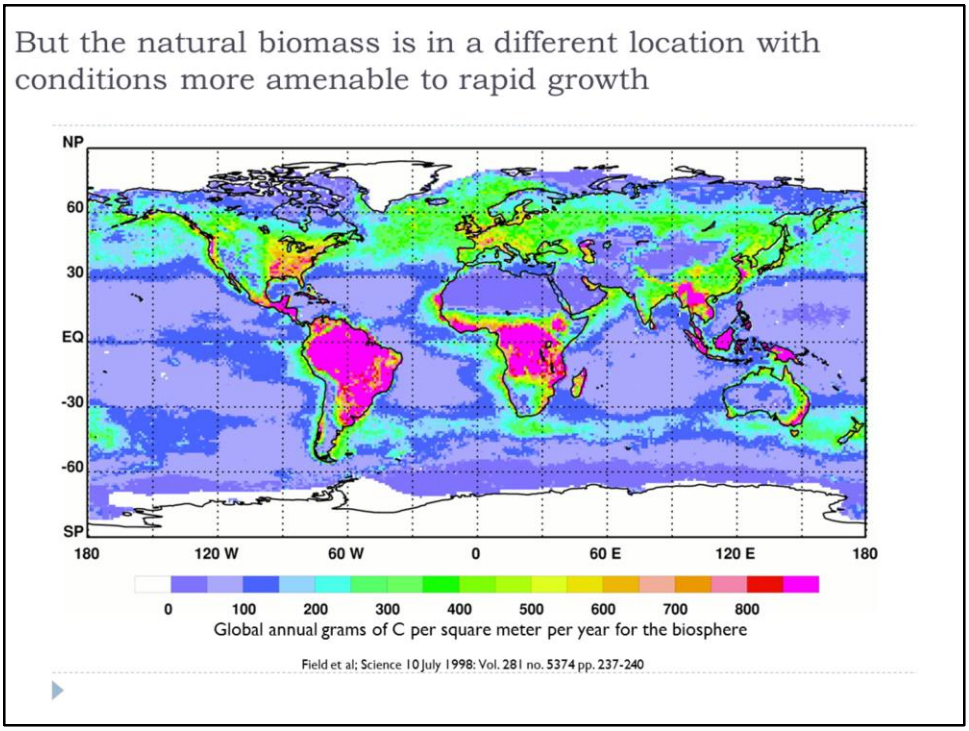
- Explain the realities of the food vs. fuel argument and the environmental costs of biomass feedstocks.

Now back to the plants and the crops - the developed world is very good at growing crops because it's got the $$$ .....



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

Here is the ag prod map again. Remember how well it overlapped with the lights at night? That relationship has a lot to do with money. So, its not unrealistic to say that one of the big reasons we are so productive is because of the money we have had to develop the appropriate infrastructure to supply water and fertilizer to the crops, as well as develop the technologies necessary to get high yields/acre.



The value of this infrastructure becomes even more apparent when you consider the contrast between where agricultural productivity is highest and where natural biomass grows the most. The most favorable growing conditions on earth are not where the most agriculture productivity is happening.

Must remember that biomass is carbon but also hydrogen, nitrogen, and phosphorous

- Elementally biomass is approx. 50% Carbon, 40% Oxygen, 5% Hydrogen
- Nitrogen is often around 1% and Phosphorous is around 0.5%
- Only source of hydrogen is water and water use efficiency is ~ 2.5% for field crops
- Every ton of biomass we generate requires ~ 10,000 gallons freshwater

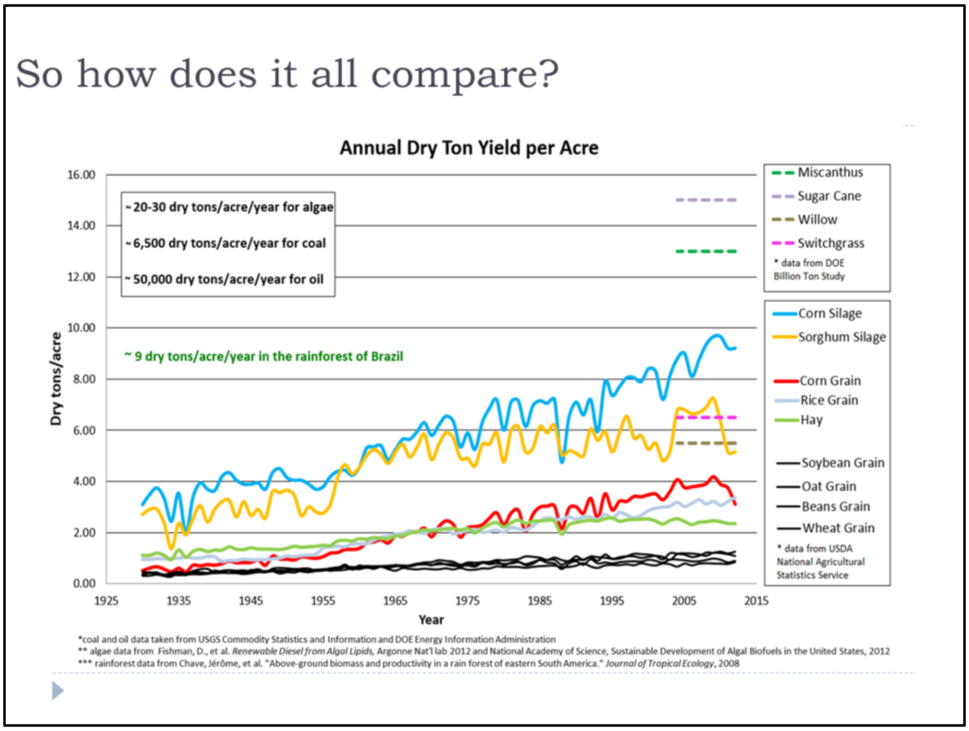
Like we have discussed previously, biomass is ….

It is mostly carbon and oxygen, but that 5% hydrogen and 1% phosphorous carries a significant cost. Watering efficiencies for field crops are pretty bad. So, it takes a whole lot of water to grow a metric ton of biomass. Likewise, phosphorous utilization efficiencies aren't very high in a field setting, so we see a lot of phosphor runoff that pollutes our lakes and streams. Biomass must have these things to grow, and to grow fast it requires even more of them than normal. When you consider that the utilization efficiencies for H2 and P are so low, you really have to think carefully about what crops actually make sense, where to grow them, and how much to grow.

The food vs. fuel argument is distorted and has been led by the beef and chicken industry that wants lower corn prices

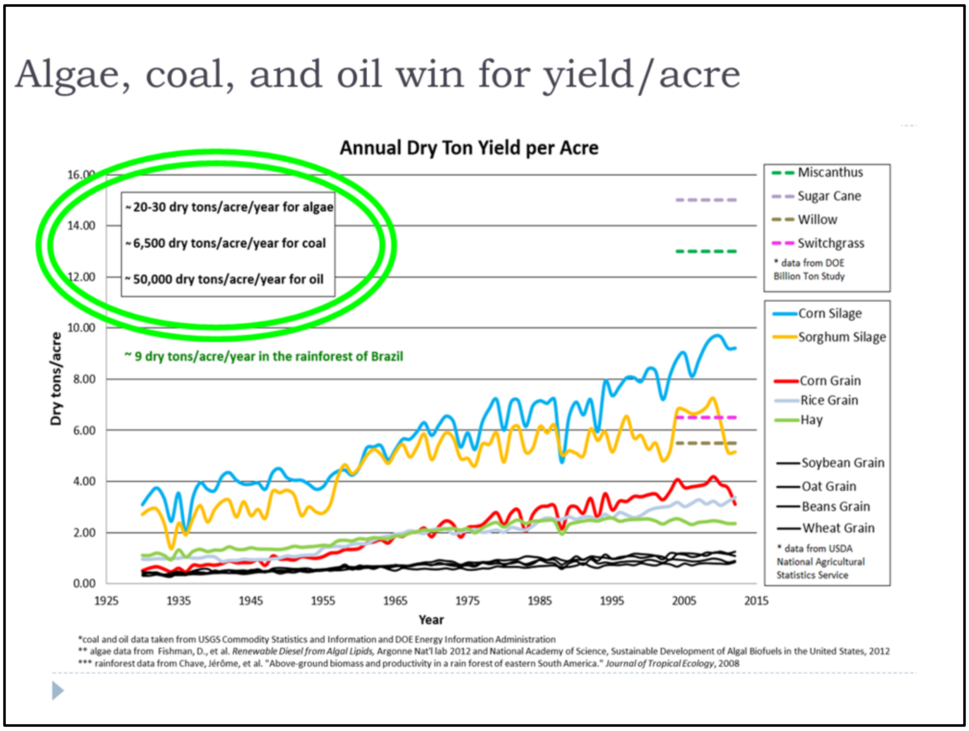
- Fast growth on minimum land requires intensive agriculture
- Intensive agriculture whether for food or bioenergy is still intensive
- Intensive agriculture requires huge levels of water and fertilizer for growth rates
- It is nearly impossible for food and bioenergy agriculture to not compete

Maybe someday, someone will make me remove this statement, but thus far most of the political pushes for food vs. fuel are led by politicians openly supported by livestock lobbies. Like we have previously reviewed, there have always been non-food crops grown and they have always competed with food crops for resources because both are produced using the same intensive ag methods. Energy crops are no different. They too will require the same resources as other intensive ag crops and they will all share NA’s resources and work under the same market economics that drive every commodity crop. The food vs. fuel argument is heavily distorted and primarily driven by politics, not logic.

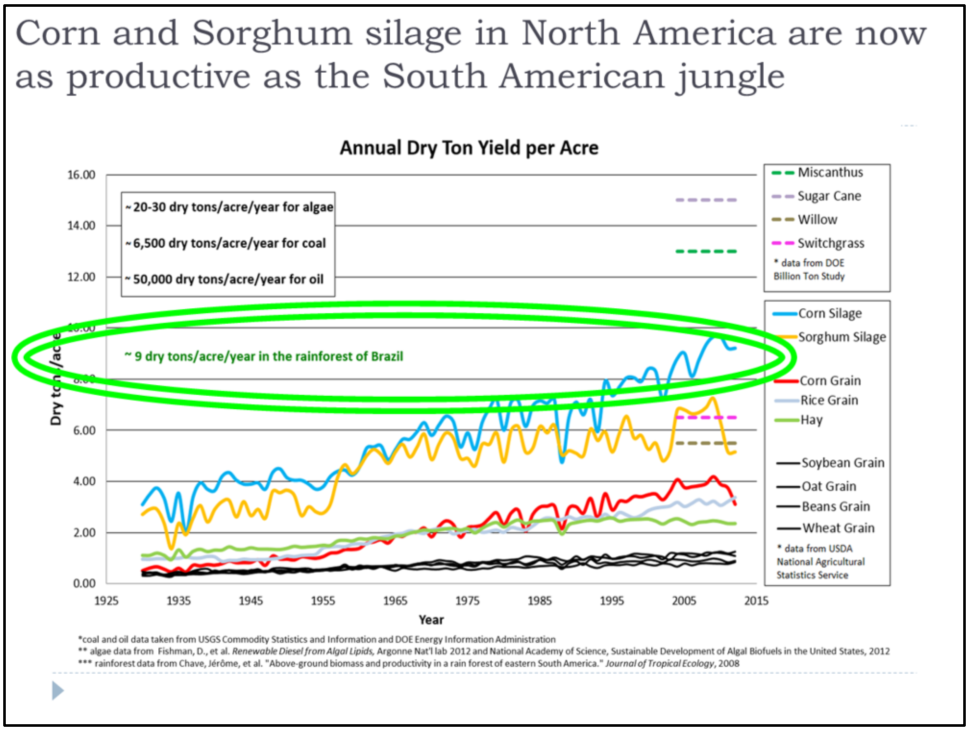


So, how do all the biomass and carbon resources compare? You will hear a wide variety of yield data in today's media because the marketing guys are never really questioned. The data I am presenting here is based on USDA statistics since the 1920's. It's fairly objective compared to anything else out there. It is an overall look at the annual dry ton yield per acre for most of the largest commodity crops and bioenergy crops in the U.S. Please take a moment and familiarize yourself with this graph before we discuss it further.

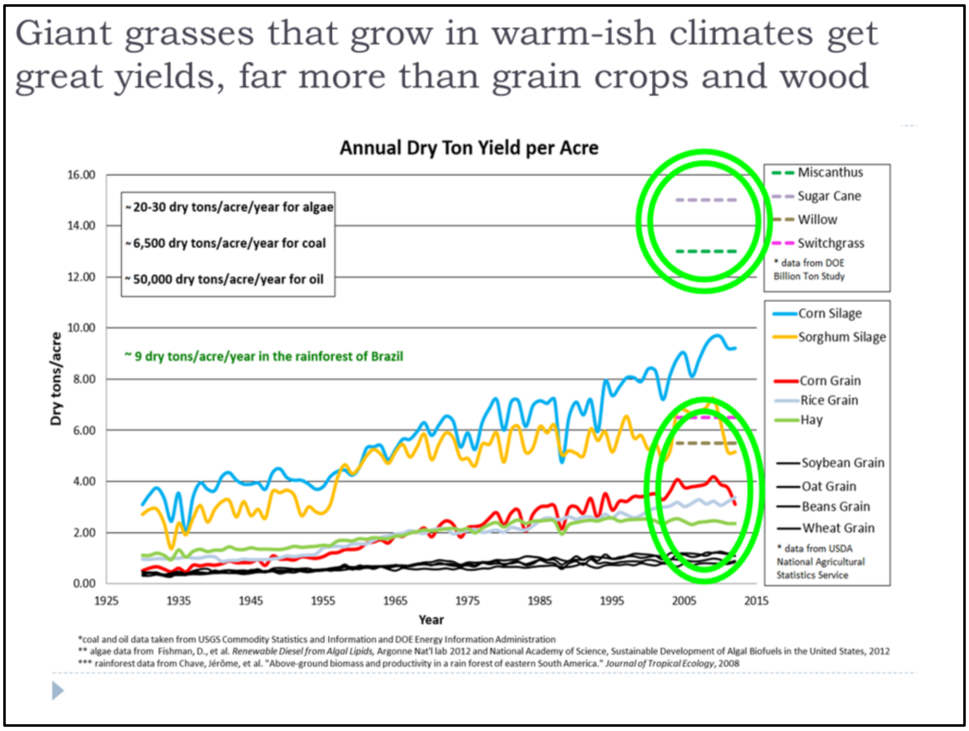
Also, for those that are not familiar with silage, I would like you to google this term. Silage is when we harvest the entire plant for its biomass, not just the grain portion. We put this biomass in a silo and then we let it ferment a little and we feed it to animals in the winter. Silage is pretty close to the types of biomass we consider when we think about cellulosic ethanol



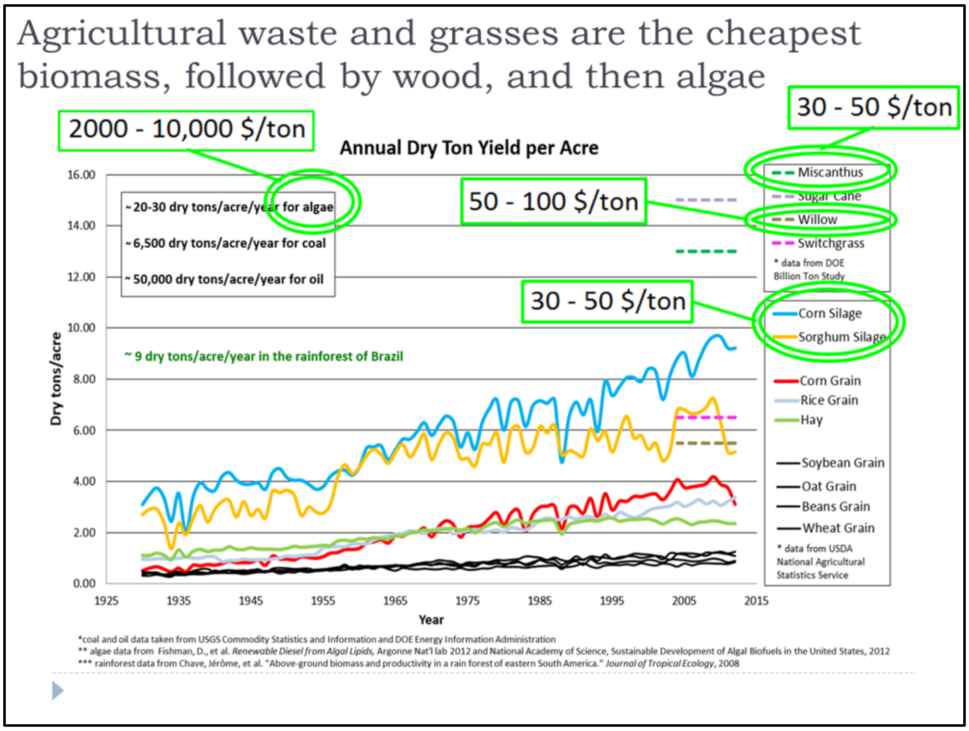
The first comparison I want to draw is between conventional biomass, algae and fossil fuels. There is no question that if we can make algae work at large scale, it will be the highest yielding biomass per acre on Earth. However, no source of biomass even comes close to the dry carbon available from oil and coal. Fossil fuels are super concentrated sources of carbon and this has led to businesses, markets and infrastructure based on a centralized resource. This is different than the distributed nature of biomass, where its found everywhere, but rarely in high concentrations.



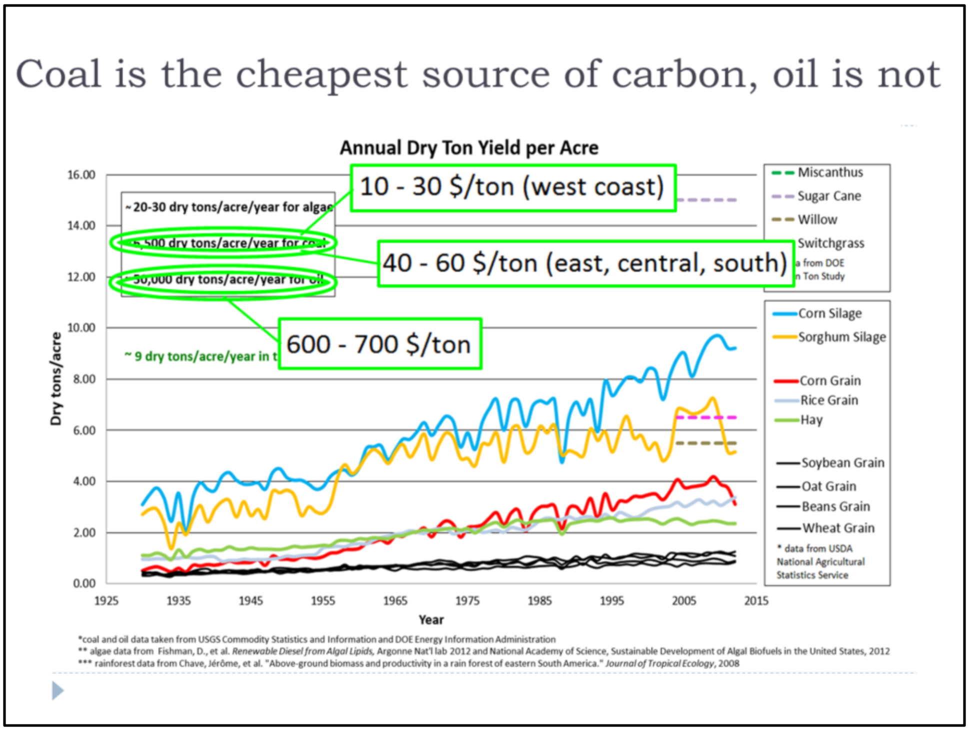
We are getting very impressive in our yields. Remember that map of where the best natural growing conditions where and how NA was not really included? Well, despite that limitation, our current yields of corn and sorghum biomass are pretty much as high as what the rainforest in Brazil achieves. That is quite a biomass yield and something we should be proud of, however it does call into question how much higher it can go. If billions of years of evolution have suggested a pseudo-upper limit for land-based biomass productivity in the rainforest, how much higher can we go? Clearly it is not an actual limit because sugar cane and miscanthus have been grown at a higher yield, but at what cost? And what is a reasonable upper limit? It’s safe to say we aren’t sure yet, but we are certainly entering new territory in terms of biomass yields/acre and, good or bad, it’s very impressive.



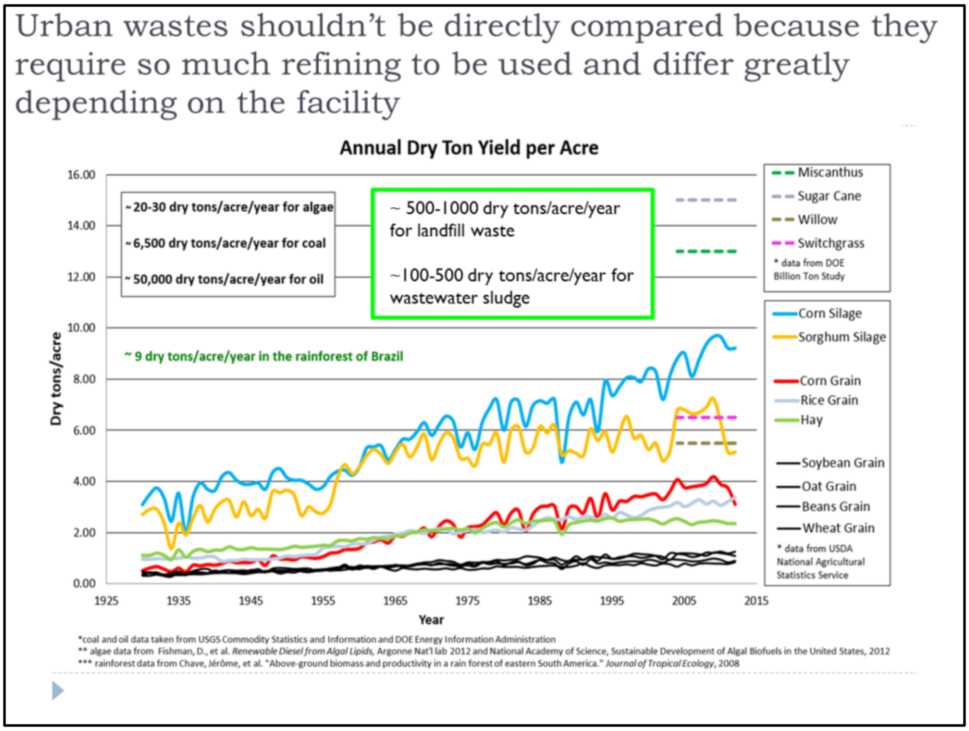
As previously mentioned sugar cane and miscanthus grown in warm climates get exceptional yields. They yield almost twice as much biomass as the nearest competing crops and three times the biomass a hay field will yield. In the race for the fastest, largest growing energy crops, giant grasses have set a high bar. That said, it is important to keep in mind that plants capable of this level of growth are often defined as invasive, so we need to measure the risks responsibly.



Yields are fascinating because they are so inflated in the media, and costs are equally fascinating because they are so deflated in the media. Biomass is pretty expensive carbon compared to coal, but not so when compared to gas and oil. As a rule, generally grassy biomass and things like silage are cheaper than woody biomass, like willows and eucalyptus. There are tradeoffs and both are good depending on the project, but if we are simply talking about costs, grasses are cheaper. Both of these pale in comparison to algae on cost. By this metric, algae could be considered one of the most expensive sources of carbon discussed so far – it probably won't always be, but right now it is.



If you recall from the previous fossil fuels lecture, coal is the cheapest fossil fuel, then gas, then oil. While these are fair comparisons based on cost/ton, they do not take into account the complications around using a solid form of carbon. It is no coincidence that the two most expensive forms of carbon are liquids/gasses compared to solids. They are easier to concentrate, easier to transport, and easier to use in industrial processes for good thermodynamic reasons. If the best carbon source argument was based on cost alone, we would probably be using more sources of carbon, but it's more complicated than that.



Landfill yield is around 500-1000 dry tons/acre/year depending on facility. WWTP sludge is around 100-500 dry tons/acre/year depending on facility. We shouldn't really compare urban wastes directly to biomass, or even fossil fuels, because they are such a mixture and so facility dependent, but for the sake of discussion let's do it anyways. The facts are that these sources of carbon really are quite concentrated. At these levels and given their close proximity to the places where the carbon is needed for fuels/chemicals, these should be some of the most treasured sources of carbon for the bioenergy community. They are extremely challenging to work with, but given all the lessons being learned about the economics of more distributed sources of biomass, there needs to be more focus in this area.

Next Lecture – Biomass Chemistry

When you have a chance, I would like you to read the posted link from the cutting edge news about a pilot gas station test occurring in Israel. They are testing methanol and ethanol blends to see what consumers think since methanol is easier to make than ethanol. This is a development worth following to see what happens.

http://www.thecuttingedgenews.com/index.php?article=74973