Carbon and Bioenergy Feedstocks

Lecture 5 – Aquatic Biomass & Urban Wastes

This micro lecture is about ….

When you have an opportunity, I would like you to click on the provided links and read about the algal housing project in Germany. It is a fascinating applied utilization of algal bioreactor technology.

http://biomassmagazine.com/articles/9341/real-green-heat

http://www.iba-hamburg.de/en/themes-projects/the-building-exhibition-within-the-building-exhibition/smart-material-houses/biq/projekt/biq.html

Algal bioreactor house in Germany

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.

Aquatic Biomass- What is it?

Crops produced using aquaculture or harvested from lakes & oceans

1. Macroalgae: Kelp and other seaweeds
2. Microalgae: Spirulina, Chlorella, Botryococcus, etc
3. Floating plants: Salvinia, Duckweed, Water Hyacinth, etc

For our purposes aquatic biomass is defined as crops produced ….

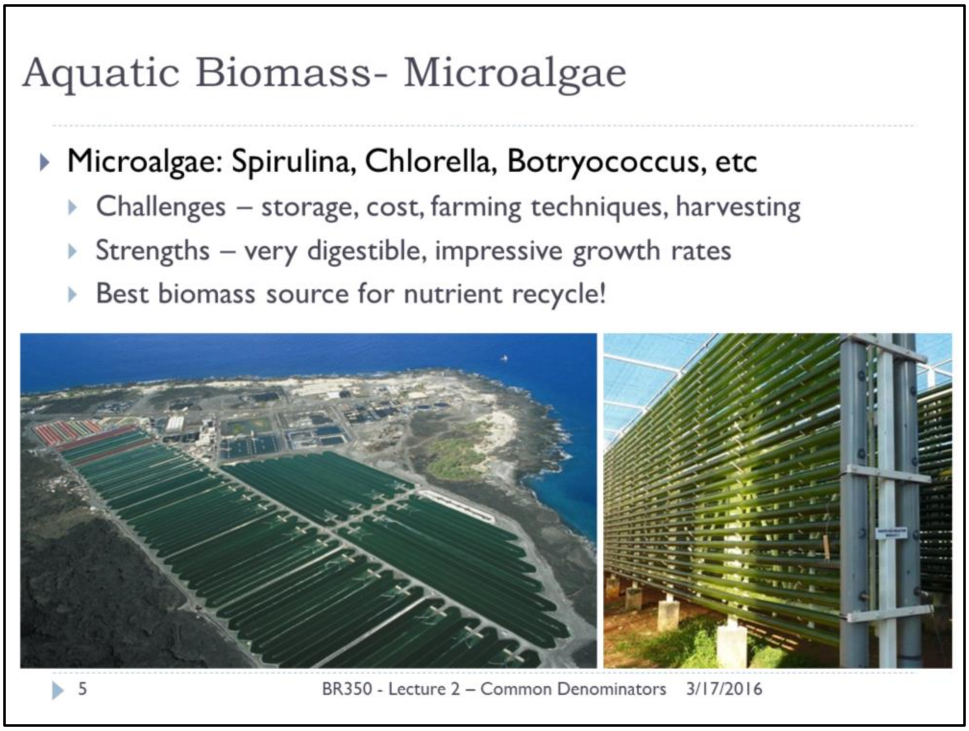
We will focus on three main types; macroalgae, microalgae, and floating plants. The difference between macroalgae and microalgae is that macroalgae are big organisms, like seaweed and kelp, but microalgae are single celled organisms, like spirulina and chlorella.

Aquatic Biomass- Macroalgae

- Macroalgae: Kelp and other seaweeds
  - Challenges – storage, cost, farming techniques
  - Strengths – very digestible, impressive growth rates

4 BR350 - Lecture 2 – Common Denominators 3/17/2016

Even though we like to think of algae as being advanced, macroalgae like kelp and seaweed have been cultivated at larger scales for centuries. Kelp and seaweed are commercially harvested from the ocean and commercially farmed all over the world. This algae is largely used for food, chemicals and cosmetics, but not yet as an energy source. As a potential source of biomass for bioenergy it has some interesting attributes. It grows very fast. Kelp is one of the fastest growing photosynthetic organisms on earth. It is also very digestible because it has no lignin and it has the potential to be grown at high densities in very small areas due to its ocean habitat. However, at the moment it is quite expensive, stores badly and isn't cultivated at the scales that would be necessary for it to make sense as a bioenergy crop.

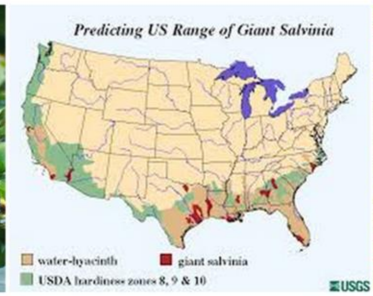


Microalgae are a little more advanced than macroalgae because it is harder to cultivate and harvest at large scales. That said, just like macroalgae it's still a very old crop since Spirulina was a food source for the Aztecs and other Mesoamericans until the 16th century; the harvest from Lake Texcoco and subsequent sale as cakes were described by one of Cortés' soldiers.

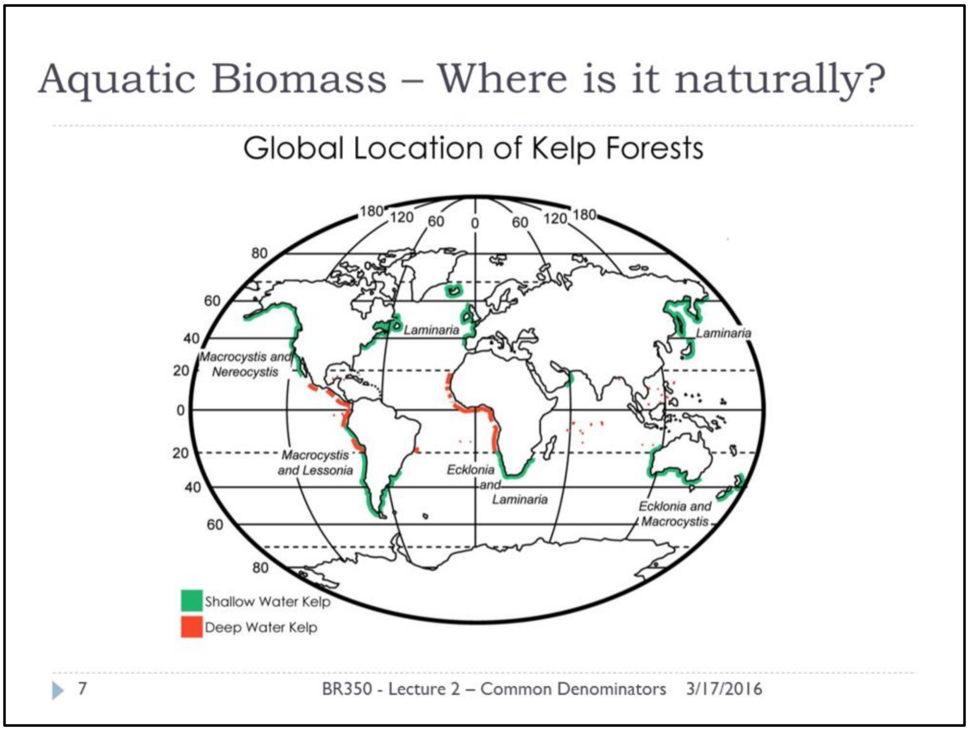
Macroalgae like kelp and seaweed may be easier to grow commercially, but microalgae has been in the spotlight because their potential strengths are very notable. They currently support the highest estimated biomass yield/acre, they are one the most digestible sources of biomass, they are fairly easy to pump/process without size reduction, and they are one of few biomass sources with the potential for total nutrient recycle – we could harvest algae, remove the products we want, and then just return the nutrients right to ponds all at the same location. However, growing algae right now is extremely expensive, so expensive that those potential strengths don't make up for it yet. As we improve our methods of cultivation, harvest and product recovery this will be a source of biomass to watch closely.

Aquatic Biomass- Floating plants

- Floating plants: Salvinia, Duckweed, Water Hyacinth, etc
  - Challenges - seasonal, storage, low density, high ash content
  - Strengths – cheap, simple harvesting, fast growing invasive

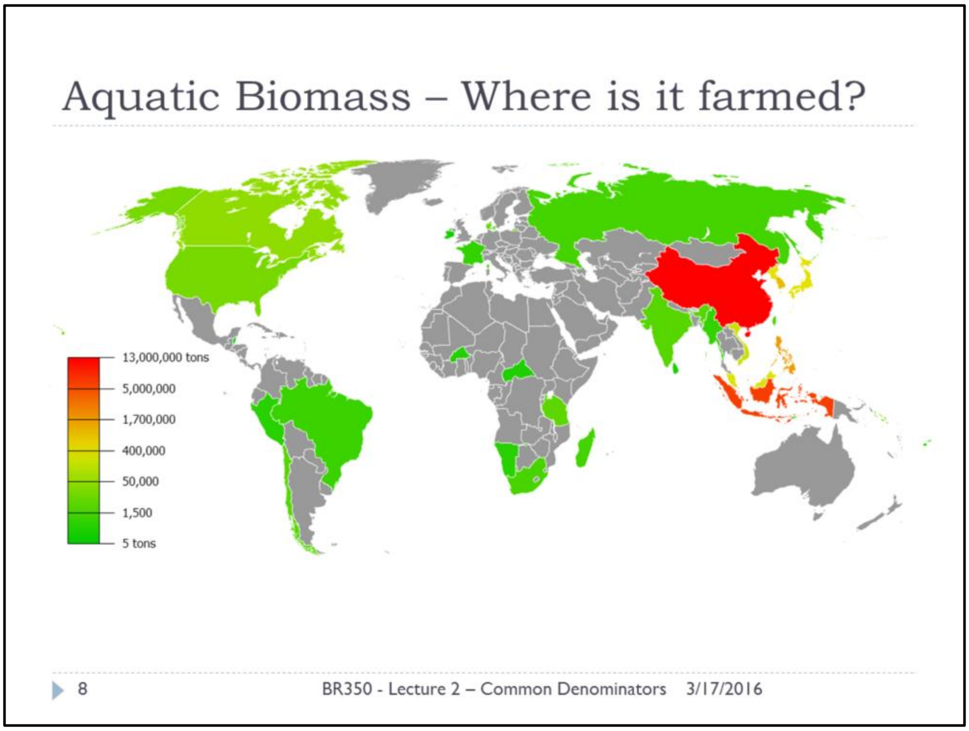


Floating plants are an interesting biomass to consider insomuch as they are invasive, they grow fast, and they are fairly easy to harvest. Many of the waterways and shallow water bodies in the United States struggle with floating plants. If they could be leveraged as a source of biomass for bioenergy it would be a constructive development. The primary challenges that would have to be overcome are related to storage, density and size of resource. Any solution taking advantage of floating plants would have to be appropriately sized to fit the resource and the speed it was growing. Despite these challenges, the strengths make floating plants important as a potential regional source of biomass in some places.



http://prattf10.wordpress.com/2010/09/27/pin-up_9-27-2010-michelle/

So where does kelp grow? Kelp grows in pretty much all of the coastal regions on earth, particularly the ones that have cold water or cold water/warm water mixing. It is the bamboo of the sea in terms of growth rates.



http://www.fao.org/fishery/statistics/global-aquaculture-production/en

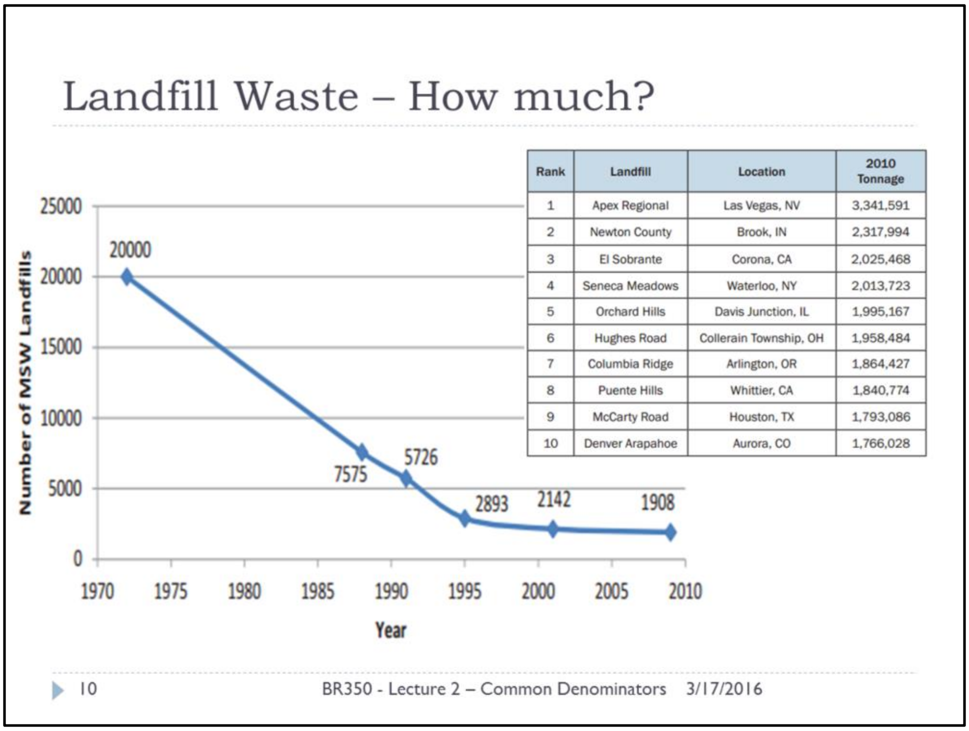
This map was generated based on global aquatic plant harvest data from 2012. Most of what is shown on this map this is seaweed and kelp (or macroalgae). Comparatively global microalgae production is more on the order of about 100,000 TPY. Microalgae is very expensive stuff at around $2,000/ton compared to the $70/ton for forest & field biomass.

http://www.algaeindustrymagazine.com/special-report-spirulina-part-5-development-of-a-spirulina-industry-production/

Landfill Waste – What is it?

- Trash: MSW (municipal solid waste), RDF (refuse derived fuel), yard & food waste, paper products, plastic, etc
  - Challenges – dirty, unpredictable, mixed, toxic
  - Strengths – cheap, consolidated, massive reserves

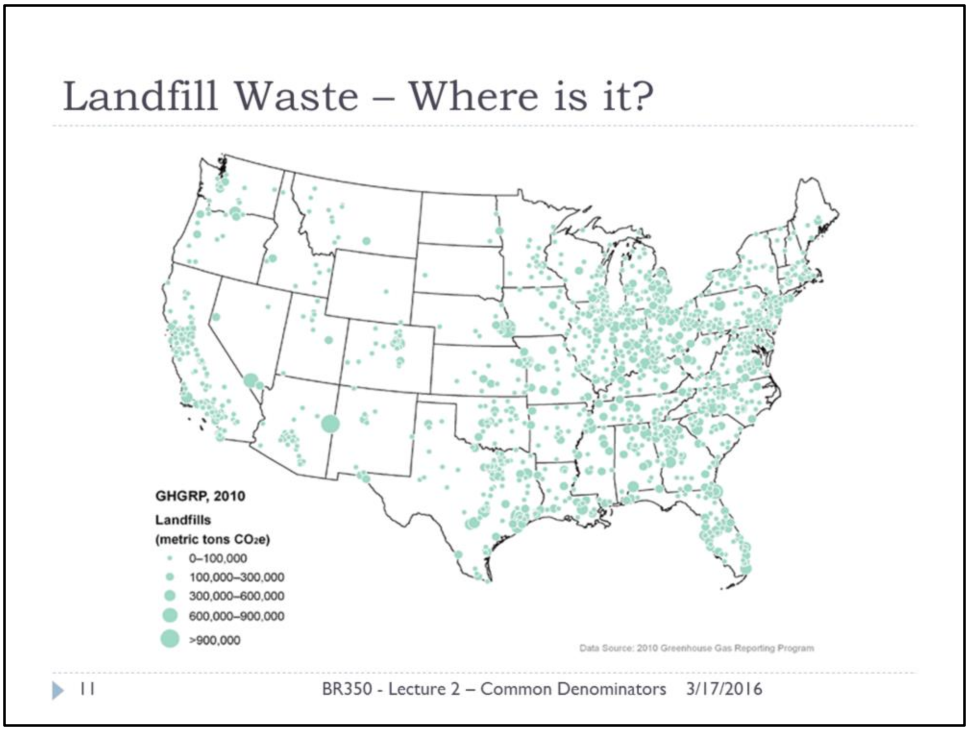
Landfills are frequently in the news because no one wants them to be nearby. However, we all generate trash and to keep our cities and towns clean, landfills have been a necessary development. From a bioenergy perspective they are also an excellent source of biomass and carbon, if you can engineer a way to deal with its unpredictable composition and level of contaminants. The only solution for trash for decades has been to landfill it or incinerate it, but this is changing. The size of the carbon reserve, the fact they are so consolidated, and their frequent presence near urban areas is making landfills the target for a variety of bioenergy companies. Like microalgae, this will be an area to watch closely.



Rank	Landfill	Location	2010 Tonnage
1	Apex Regional	Las Vegas, NV	3,341,591
2	Newton County	Brook, IN	2,317,994
3	El Sobrante	Corona, CA	2,025,468
4	Seneca Meadows	Waterloo, NY	2,013,723
5	Orchard Hills	Davis Junction, IL	1,995,167
6	Hughes Road	Collerain Township, OH	1,958,484
7	Columbia Ridge	Arlington, OR	1,864,427
8	Puente Hills	Whittier, CA	1,840,774
9	McCarty Road	Houston, TX	1,793,086
10	Denver Arapahoe	Aurora, CO	1,766,028

https://wasterecycling.org/images/documents/resources/pocket-facts.pdf

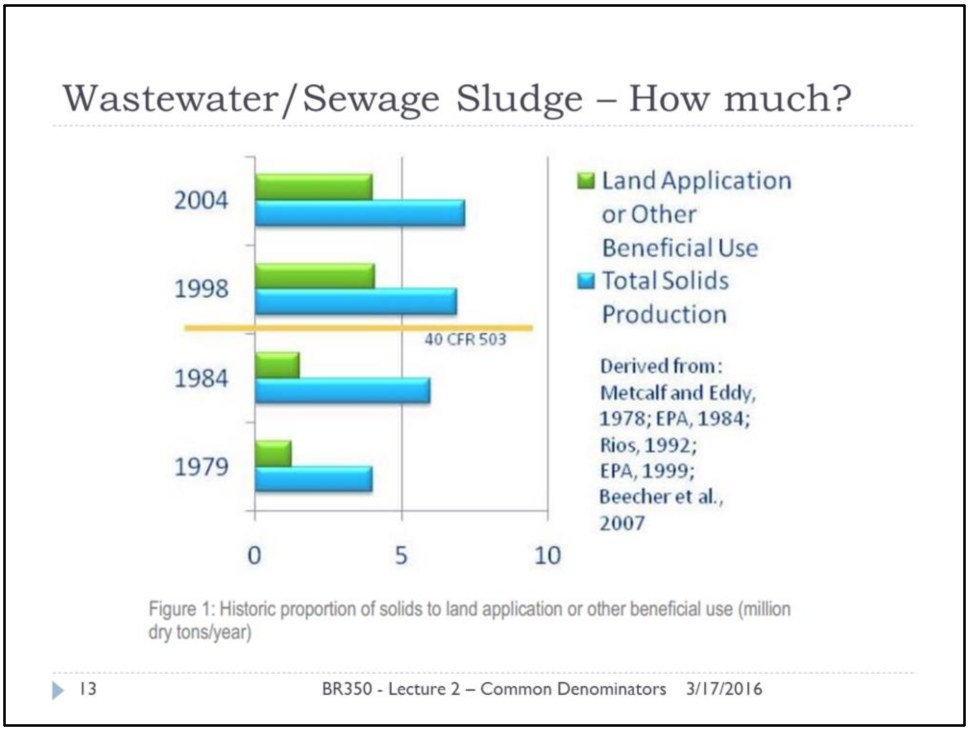
The largest landfills in America bring in about 3 million tons/year trash. The table shown above is 2010 data so it is dated, but it provides a good reference point for what big landfills are doing these days. In some ways landfill represent the largest consolidation of biomass that developed nations undertake. There is no other source of biomass that compares on a tonnage/acre/day scale other than maybe food. It is also important to remember that this is wet weight and the waste is probably very wet, so more than half the weight is water.



http://www.epa.gov/ghgreporting/ghgdata/reported-2010/landfills.html

It is extremely difficult to find a good map of the location of all the landfills in the US. It is even harder to find current size data so that you could make a map. As a result we will have to settle for an EPA landfill map based on CO2 emissions. It is interesting to note that the highest density of landfills is located with the highest population density, but the largest landfills are located in areas with very low population. This is because the nearby areas of high population are paying to have their trash transported to these remote locations. That is worth thinking about.

We all use the bathroom because, surprise! We are unable to convert 100% of the biomass we consume into energy and human mass. This actually leaves quite a bit of leftover biomass that we flush and send to the WWTP. At the WWTP much of the biomass is converted into bacterial biomass, so the solids remaining are primarily bacteria and indigestible biomass (wood, paper, etc.). This is a great source of biomass that is utilized for biogas and gets a lot of interest. It is always interesting to consider that wastewater sludge may be the only easily available, large scale source of bacterial biomass. Far from being gross, this could actually be quite useful because bacterial cell walls are very unique, giving this source of biomass potential for unusual conversions. There are a lot of parallels between landfill waste and wastewater sludge, so lessons learned in one area may be able to be applied to the other.



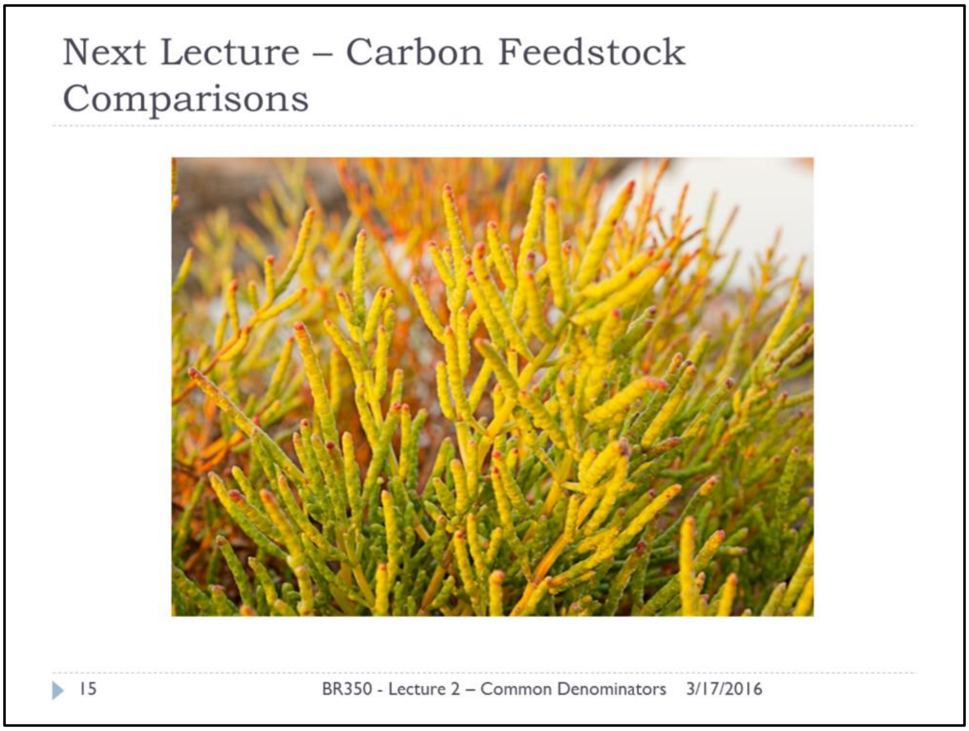
http://www.wef.org/uploadedFiles/Biosolids/PDFs/ENABLING%20THE%20FUTURE.pdf

Bio solids are a fairly concentrated source of biomass somewhere on the order of 7-8 million dry tons/year these days. That isn’t nearly as much as landfills, but it is a significant source of fairly homogenous biomass generally next to urban centers.

Aquatic & Urban Biomass things to consider …

- Aquatic biomass is very expensive and urban wastes are extremely cheap (but difficult to work with)
- Unconventional sources of biomass
- These are some of the most concentrated sources of biomass available to us
- Even more expensive to process into correct shape & composition
- High potential for carbon & nutrient recycling

In closing … read the slides



This is a picture of the halophyte Salicornia Bigelovii. When you have an opportunity please go to the provided link and read about some of the recent bioerngy developments using crops that grow in saltwater. Imagine not needing freshwater to water your crops – this would dramatically change our agricultural paradigm.

http://www.technologyreview.com/news/417390/biofuels-from-saltwater-crops/

http://www.greenprophet.com/2014/01/boeing-etihad-and-masdar-biofuel-desert-plants/