Trade-offs between biofuels energy production, land use and water use in Florida

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Federal Agency: **Department of Energy – Office of the Biomass Program**

Project Title: Hendry County Sustainable Biofuels Center

Award Number: EE0000303

Recipient: Hendry County, Florida

- Michal's work was part of a larger suite of projects done with UF under the name:

Hendry County Sustainable Biofuels

- The objective was to provide local decision makers with information and tools to evaluate the flood of biofuels related business opportunities attempting to enter the county and gain various concession.

- The project looked at biofuels from a number of perspectives:

- Life Cycle Analysis
- Cost-Benefit Analysis
- Sustainable Farming Systems
- Ecosystem Services Compensation

Objectives of this component study

Document **land use** and **water consumption implications** of **biomass production** to demonstrate the overall **resources implications** associated with **bioethanol production** for **Florida's transportation** sector needs.

Outline of the Presentation

- Biofuels – rationale, categorization, production (biomass, bioethanol), advantages and challenges
- Land use changes & water consumption – overview, relationships
- Florida case study
  - Bioethanol production
  - Bioethanol needs (transportation sector)
  - Bioethanol land requirements
  - Bioethanol water demands
  - Bioethanol trade-offs
- Conclusions

Biofuels categorization

Primary:

unprocessed biomass

Secondary:

processed biomass

Secondary BF - 3 generations:

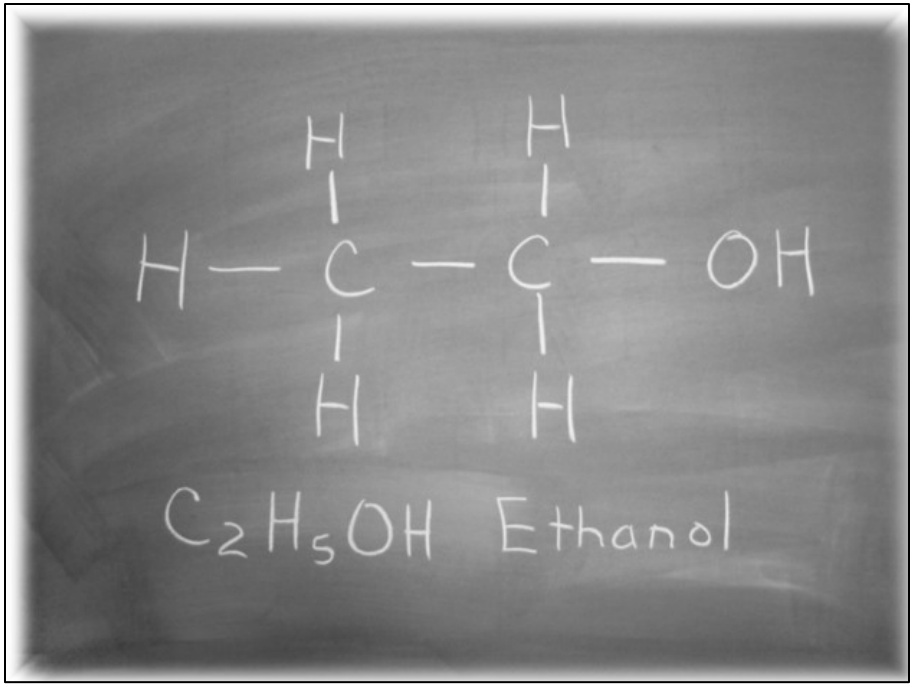
G1 - food crops (corn, soybeans), **sugars and oils biomass**

G2 - non-food crops and lignocellulosic wastes (energycane, eucalyptus), **lignocellulosic biomass**

G3 - micro- and macro-algae (Sargassum/Seaweed, Euglena), **algal biomass**

Bioethanol

- Most important biofuel
- Colorless liquid
- Replacement for fossil gas, blended at rates 10-85% (E10 – E85)
- Improves combustion
- Lowers emissions of CO



Land use changes (LUC)

Land Use Change (LUC) is a term covering two distinct (direct, indirect) means by which **land can be altered** in the pursuit (in this specific case) of biofuels production.

Direct LUC (dLUC) occurs when land previously used for other purposes is converted to biofuel crops production.

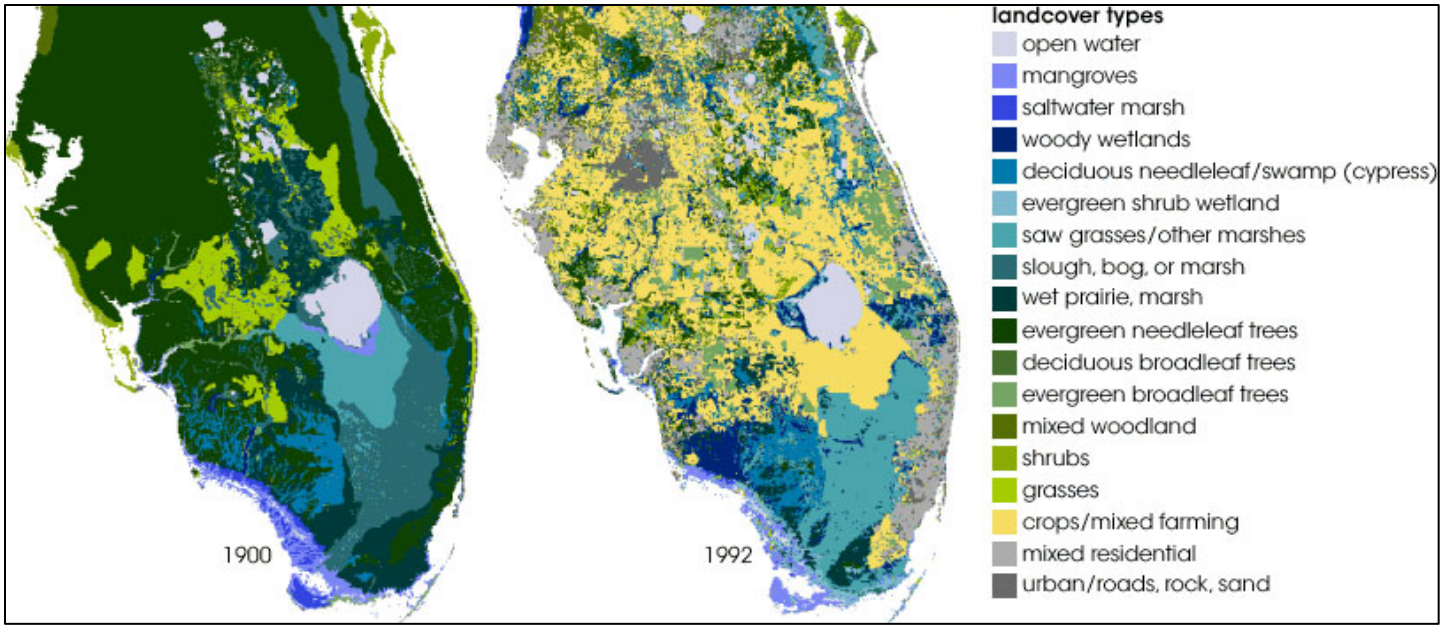
Indirect LUC (iLUC) refers to the changes in land use that take place elsewhere as a consequence of a bioenergy project.

Effects: **iLUC > dLUC**

Effects still learned about

Land & water use changes in FL - overview

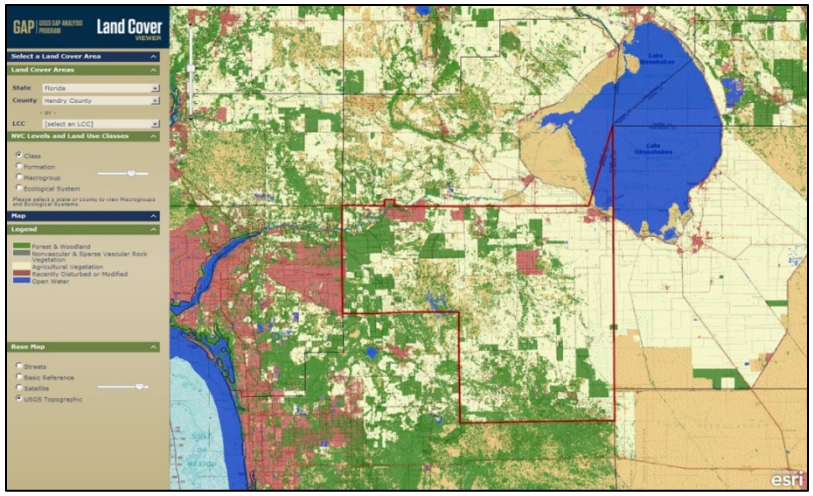
- Until the end of 19th century: more or less natural state
- Beginning of the 20th century till today: extensive residential, commercial and ag. development
- 1936 – 1995:
  - **Increase**: Population: 829%, Cropland, pastures: 59%, Urban land: 628%
  - **Decrease**: Forest land: -22%, Marsh land: -51%

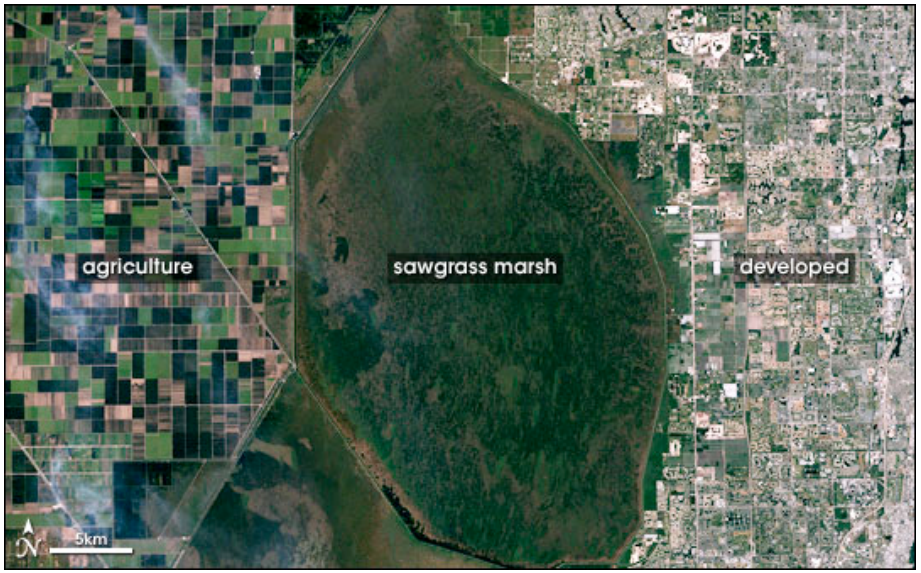


Source: *Marshall, 2004.*

Land & water use changes in FL - consequences

- Large farms, profit-driven monocultures
- Loss of biological diversity
- Regional & global climate changes
- Land management
- Water pollution





Land use availability

	Global	Florida
Population	7.1 B	19 M
ALL land	148,940k km²	170k km²
AG land/person	**1.71 ac/p**	**0.43 ac/p**
ARABLE land/person	**0.52 ac/p**	**0.16 ac/p**
PASTURES land/ person	1.19 ac/p	0.27 ac/p

Land is a **VERY limited** resource

References:

FAOSTAT, 2011; Florida Department of Transportation, 2012; United States Department of Agriculture, 2007.

Water consumption in BF production

Increased biofuels production → higher water use

- **feedstock production (irrigation, evapotranspiration) - significant water volume**
- **industrial processing (fermentation, distillation, etc.) - relatively small water volume**

- BLUE water - volume of surface and groundwater evapotranspiration as a result of the production of a product or service
- GREEN water - volume of rainwater evapotranspiration during the production process

Why BF in Florida?

Favorable subtropical to tropical **climate**

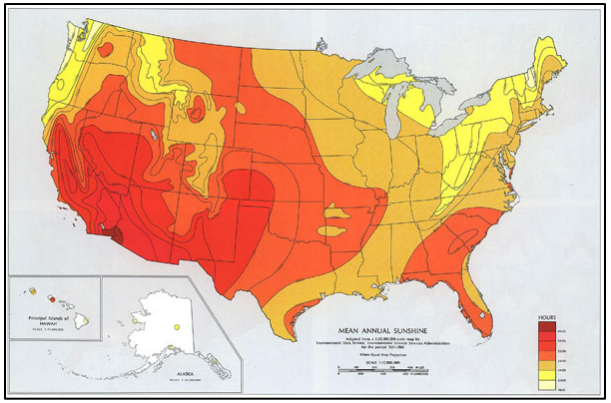
Abundant, though limited **water** resources

Advanced **research**

Traditional leading **ag. role**

Minor oil reserves, no refineries

Increasing **energy demands**



Bioethanol production – FL case

- 500k+ acres used for potential BF crops
- Currently no large scale bioethanol facilities
- Cellulosic bioethanol (G2) a possible way forward?

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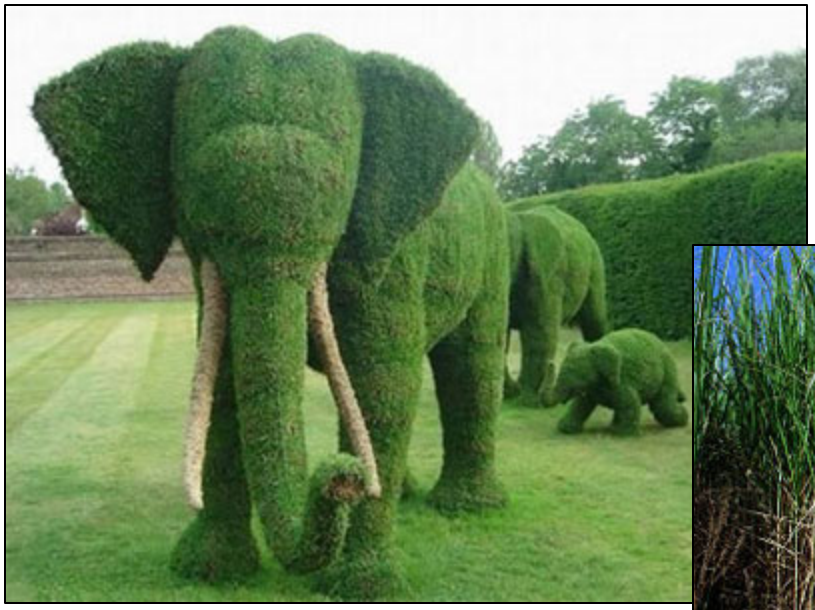
- Analytical Tools Development
- Life Cycle Analysis
- Cost-Benefit Analysis
- Sustainable Farming Systems
- Ecosystem Services Compensation
- Economic Development
- Youth Development

FL BF production - crops

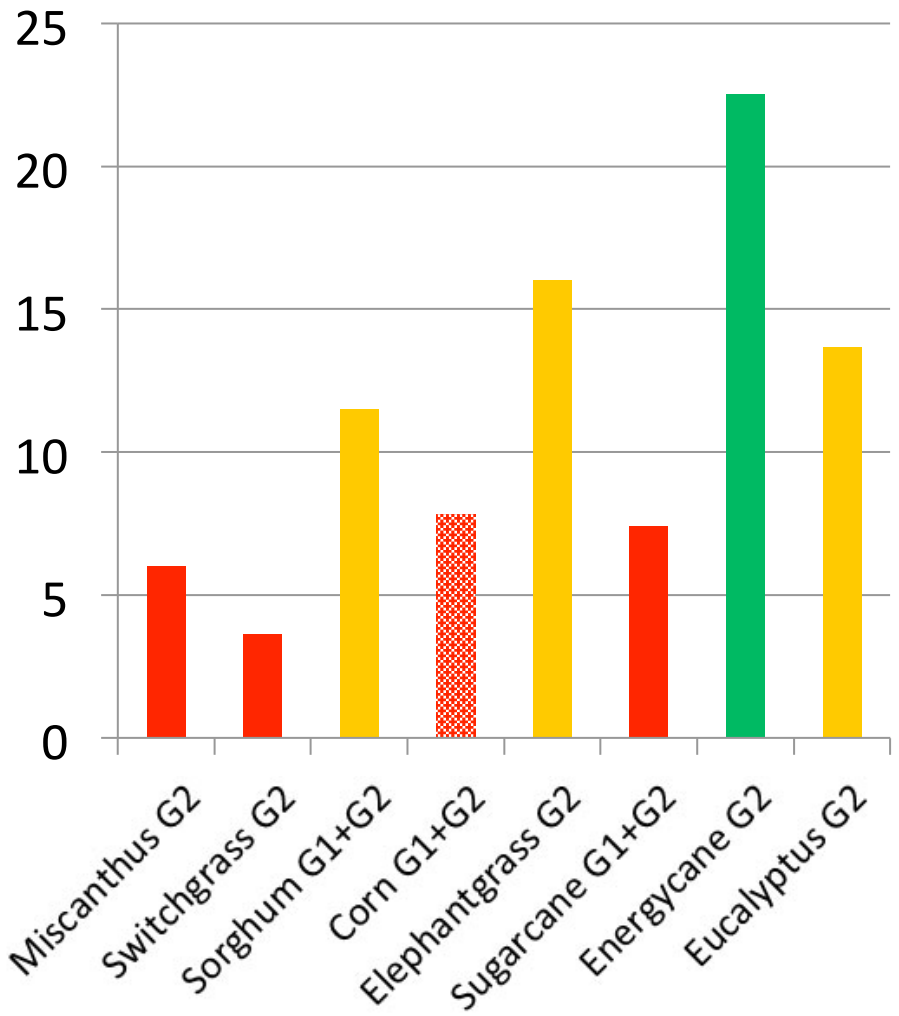
8 various bioethanol crops considered:

- Miscanthus
- Switchgrass
- Sweet Sorghum
- Corn
- Elephantgrass
- Sugarcane
- Energycane
- Eucalyptus



FL BF crops – biomass yields (ton/ac)

	Medium yield (ton/ac)
Miscanthus G2	6.0
Switchgrass G2	3.6
Sorghum G1+G2	11.5
Corn G1+G2	7.8*
Elephantgrass G2	16.0
Sugarcane G1+G2	7.4
Energycane G2	22.5
Eucalyptus G2	13.7



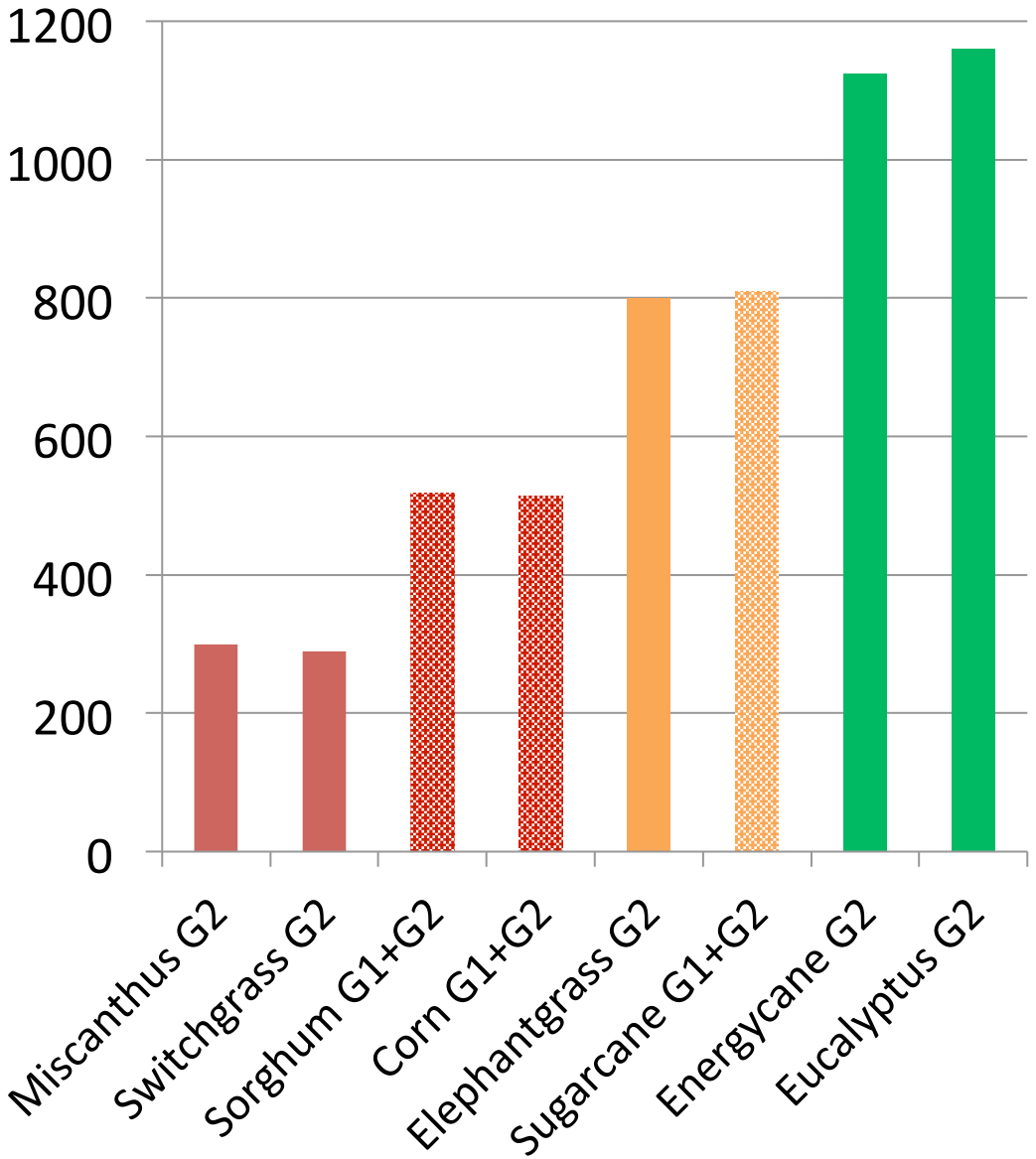
** grain only (G1) is 4.2 tons, the rest is stover*

References:

Erickson, 2012; Newman, 2011; Rahmani, 2009; Woodard, 2012; Rainbolt, 2010; Hinchee, 2011; Stricker, 2000.

FL BF crops - bioethanol yields (gal/ac)

Medium yield	Gal/ac
Miscanthus G2	300
Switchgrass G2	290
Sorghum G1+G2	518
Corn G1+G2	514
Elephantgrass G2	800
Sugarcane G1+G2	809
Energycane G2	1125
Eucalyptus G2	1160



References:

Rainbolt, 2010; Helsel, 2011; Rahmani, 2009; Vermerris, 2011; Woodard, 2012; Shapouri, 2006; Gonzalez, 2011.

FL transportation - bioethanol needs

Annual mileage in FL = 191,854,954,745 miles/14,372,807 vehicles = **13,348 miles/vehicle**

Fuel (*E*10) *mileage in FL* = 191,854,954,745 miles/8,152,702,000 gal E10 = **23.5 miles/gal *E*10**

Fuel (*E*10) *needs in FL* = 13,348 *miles/vehicle / year* /23.5 *miles/gal E*10 = **567 gal *E*10/vehicle / year**

Reference:
Florida Department of Transportation, 2012.

FL transportation- bioethanol needs (cont.)

$$Fuel\ (E100)\ needs\ in\ FL\ per\ vehicle = 567\ gal\ E10/vhl\ /\ year + 31\% * 567 gal\ E10/vhl\ year = \mathbf{743\ gal\ Et/vhl\ year}$$

$$Number\ of\ vehicles\ per\ person\ in\ FL = 14{,}372{,}807\ vhl / 18{,}905{,}048\ people = \mathbf{0.76 vhl/person}$$

$$Fuel\ (E100)\ needs\ in\ FL\ per\ person = 743\ gal\ E100/vhl\ year * 0.76 vhl/person = \mathbf{565\ gal\ E100/person\ year}$$

Reference:
Florida Department of Transportation, 2012.

FL – bioethanol needs (gal/person/year)

	Fossil fuel	Ethanol	Total fuel
E0	416	0.0	416
E10	**388**	**43**	**431**
E15	373	66	439
E20	357	89	446
E85	81	461	542
E100	0	**565**	565

Absolute numbers for all Floridians:

E10 – **815 M gal** of ethanol/year

E100 – **10.7 B gal** of ethanol/year

FL - bioethanol land requirements

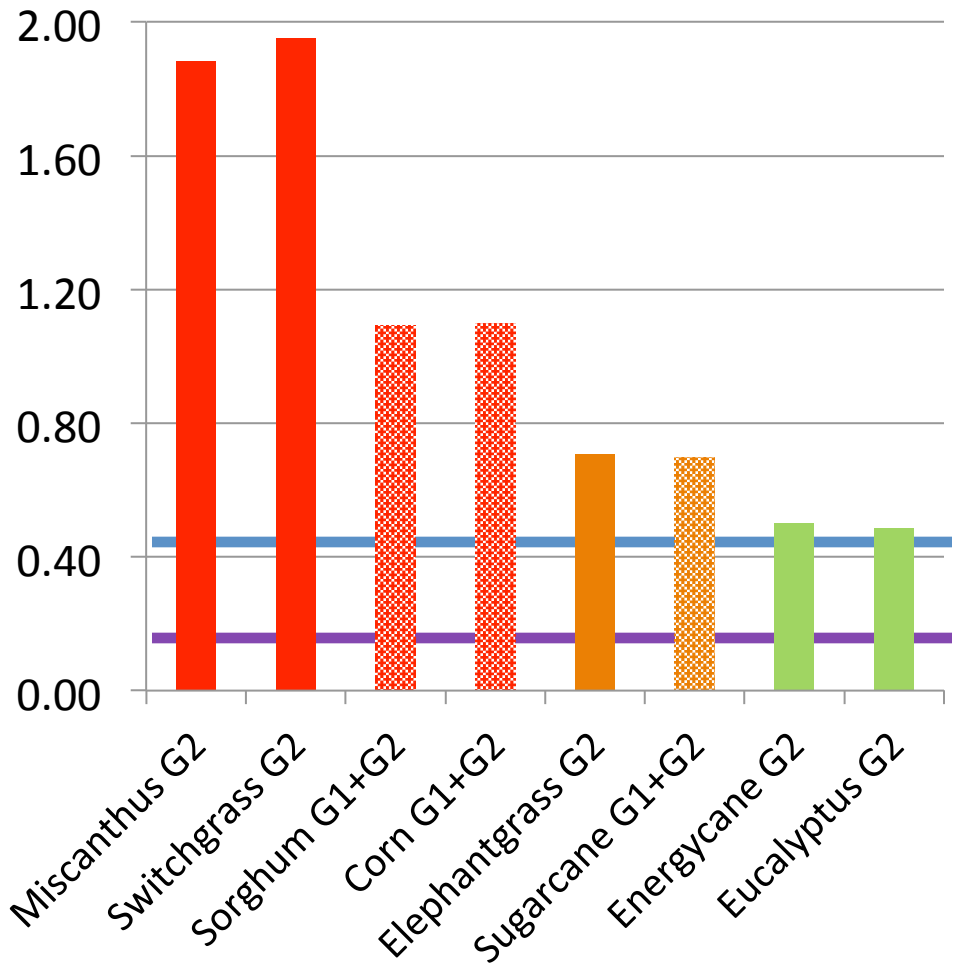
*Fuel (E*100*) needs in FL per person*=**565gal E100/person year**

Ethanol yield in FL = ***x*** **gal Et/acre year**

*E*100, *Land requirement Sugarcane*=565 *gal E*100*/yr per /*809 *gal Et/acre yr*
=**0.70*acre/year person***

Land use requirements (ac/person) for E100

	Medium yield (ac/person)
Miscanthus G2	1.88
Switchgrass G2	1.95
Sorghum G1+G2	1.09
Corn G1+G2	1.10
Elephantgrass G2	0.71
Sugarcane G1+G2	0.70
Energycane G2	0.50
Eucalyptus G2	0.49

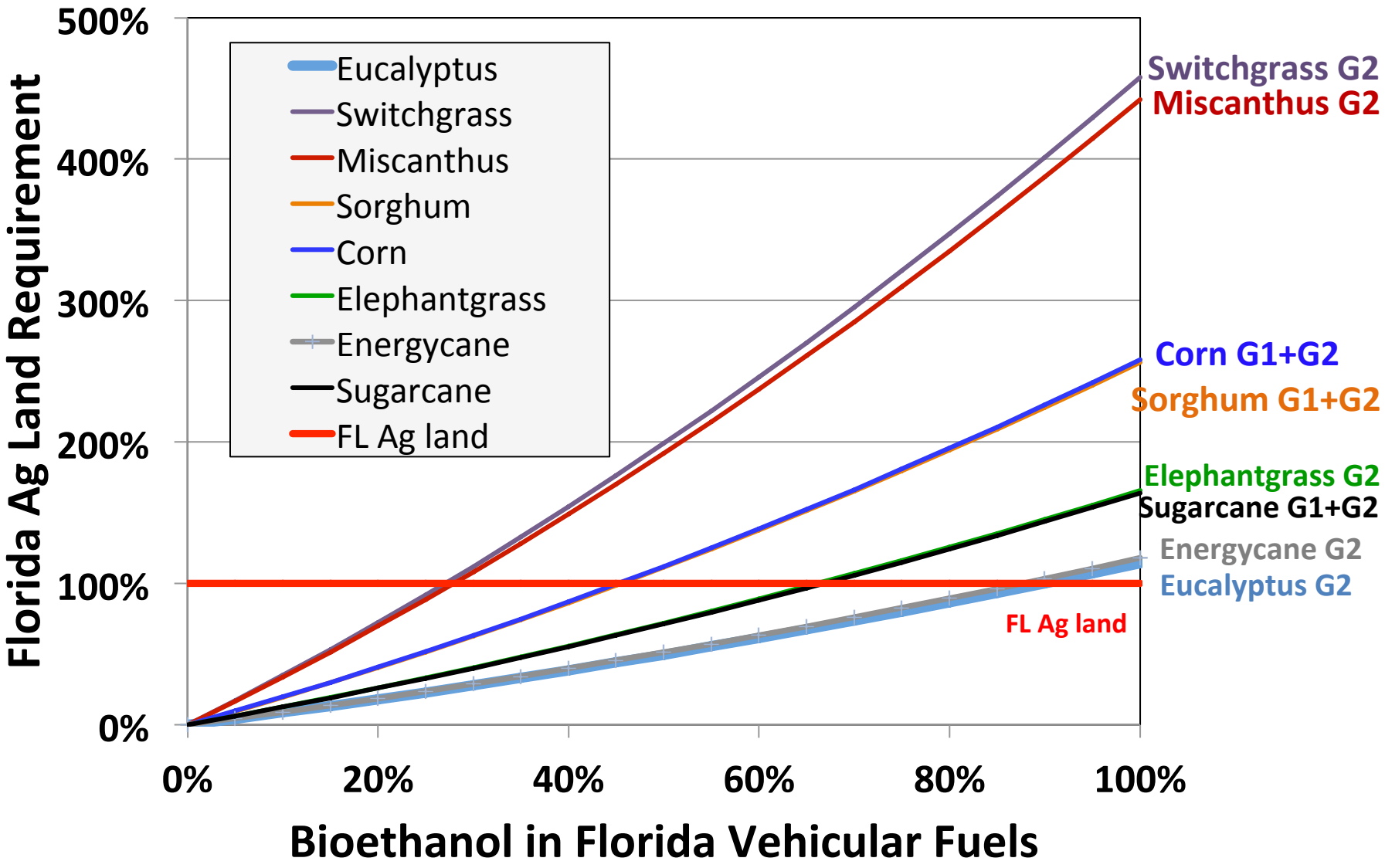


Availability: **0.43** ac ag. land/person, **0.16** ac arable land/person

Ag land (% use) - land use trade-offs for BF

	E10	E15	E20	E85	E100
Miscanthus G2	34%	51%	70%	361%	442%
Switchgrass G2	35%	53%	72%	374%	458%
Sorghum G1+G2	20%	30%	40%	209%	256%
Corn G1+G2	20%	30%	41%	211%	258%
Elephantgrass G2	13%	19%	26%	135%	166%
Sugarcane G1+G2	13%	19%	26%	134%	164%
Energycane G2	9%	14%	19%	96%	118%
Eucalyptus G2	9%	13%	18%	93%	114%

Florida Ag Land demand for E0 to E100



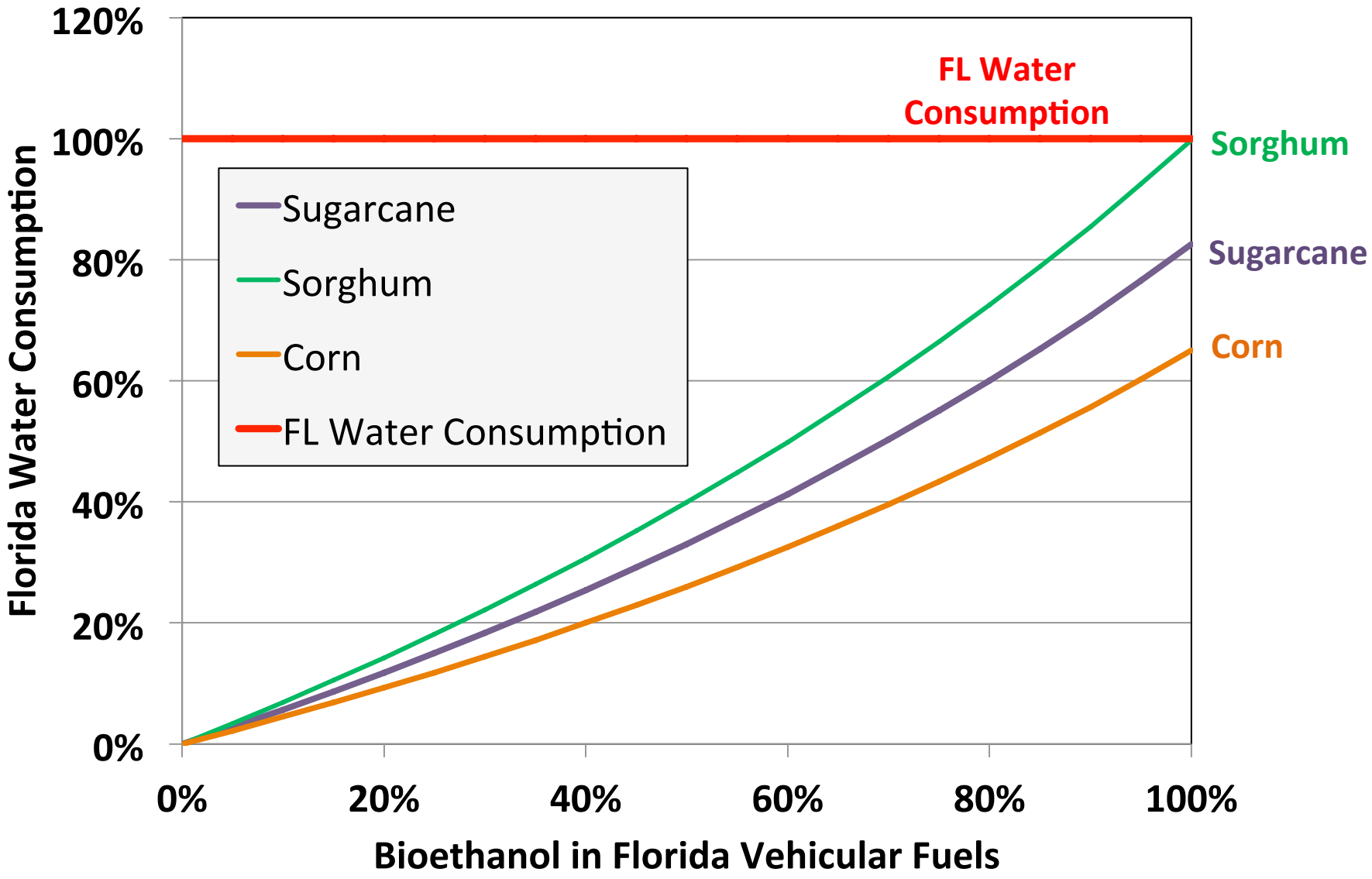
Florida – Water demand for BF production

L of water needed for 1L of bioethanol	Blue water	Green water	TOTAL Water
Sugarcane	518	1587	2105
Sorghum	291	2253	2544
Corn	523	1134	1657

- **Current overall FL water consumption: 1.14E+14 L/y**
- **Known needed ethanol volumes for various blends**

FL water demand	E10	E15	E20	E85	E100
Sugarcane	6%	9%	12%	65%	83%
Sorghum	7%	11%	14%	79%	100%
Corn	4%	7%	9%	51%	65%

Florida – Water demand for BF production



Conclusions

- Land use requirement for production of **all ethanol needed for E85** in Florida is roughly **the same as the total available Ag land** in Florida for **the best yielding biofuels crops** (energycane, eucalyptus).

- **Water demand** for production of **all ethanol needed for E100** would **increase** current **overall water consumption** in Florida between **65% and 100%** for the most common biofuels crops.

Conclusions

- **Vehicular energy** is only **33%** of Floridians energy consumption - so even if we **re-allocate ALL our ag land (and its associated water use)** for biofuels, we still produce **only 33% of FL total energy needs**.

- **Bioethanol** (particularly **G2 and G3**) produced in Florida has the **potential** to make a net contribution to Florida's energy needs and security, so continued R&D is justified.

Conclusions

- **Various issues** need to be addressed:
  - **technology** and infrastructure
  - negative effects on **biodiversity**
  - **climate** change
  - **land use** change
  - **water** availability
  - **trade-offs** for limited resources

Conclusions

- Assuming no change in food production and consumption habits in Florida, the likely result of **biofuels sector expansion** would be the **conversion of natural lands** or **low-intensity agricultural lands** into **high-intensity biomass production** and the associated **increased water consumption** and **water quality implications.**

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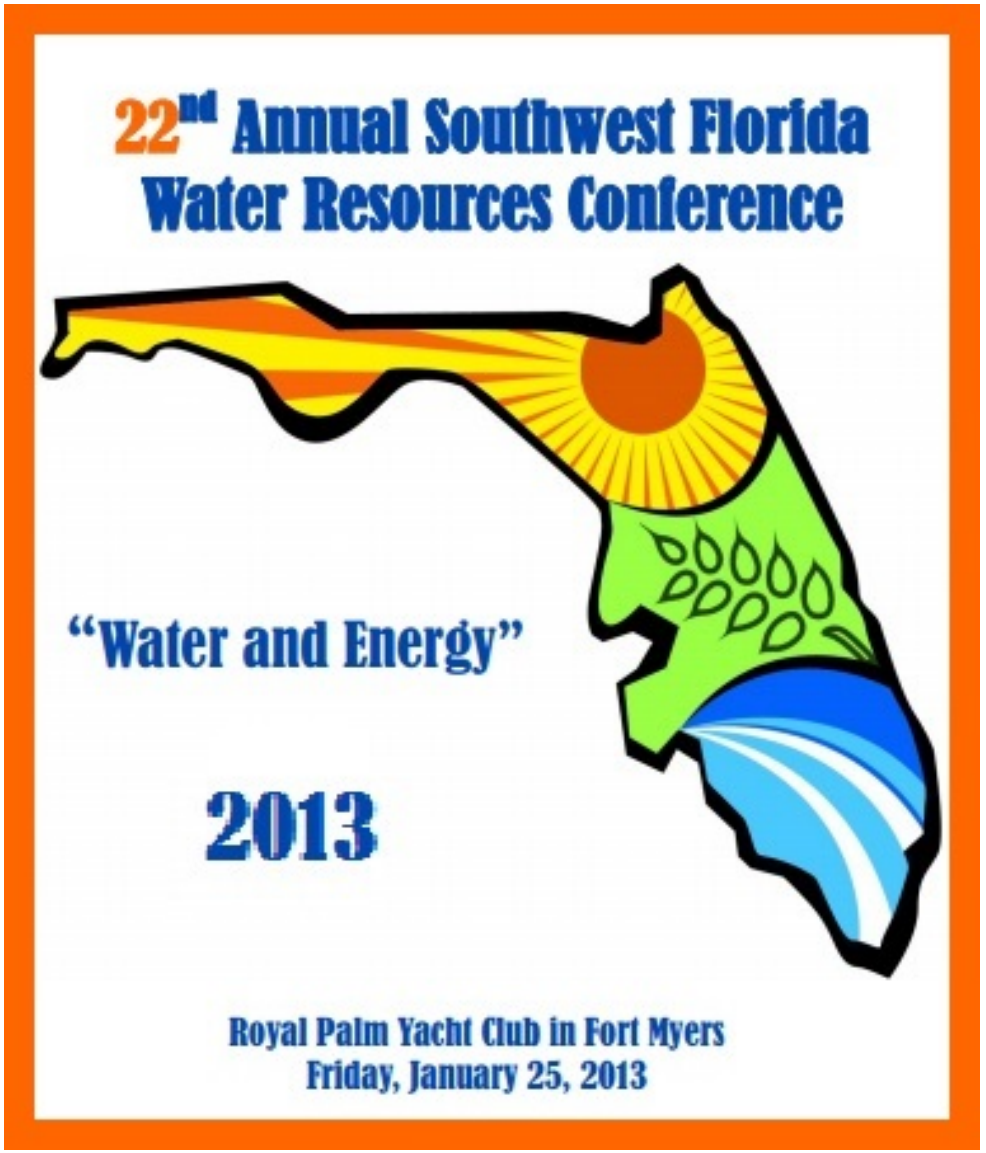
- Life Cycle Analysis
- Cost-Benefit Analysis
- Sustainable Farming Systems
- Ecosystem Services Compensation



Questions and Comments?

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