MICHIGAN STATE UNIVERSITY

Biofuels, Indirect Land Use Change & Greenhouse Gas Emissions: Some Unexplored Variables (and a call to action!!)

Bruce E. Dale
University Distinguished Professor
Chemical Engineering & Materials Science
Michigan State University

Presented at:
Biorefinica 2009
Osnabrueck, Germany
January 28, 2009

Land use change (LUC) may cause large GHG emissions

U.S. corn farmer switches from corn/soy to corn/corn

U.S. soy exports go down and world soy prices rise

Additional land in Brazil (for instance) is put into soy production

Soy farmers everywhere use more inputs to increase yields

Indirect LUC emissions

Indirect process emissions

Process emissions

O' Hare, M. Jan. 17, 2008. CARB LCFS Working Group 3. *Greenhouse Gas Emissions from Indirect Land Use Change*

Argument for ILUC As Leakage

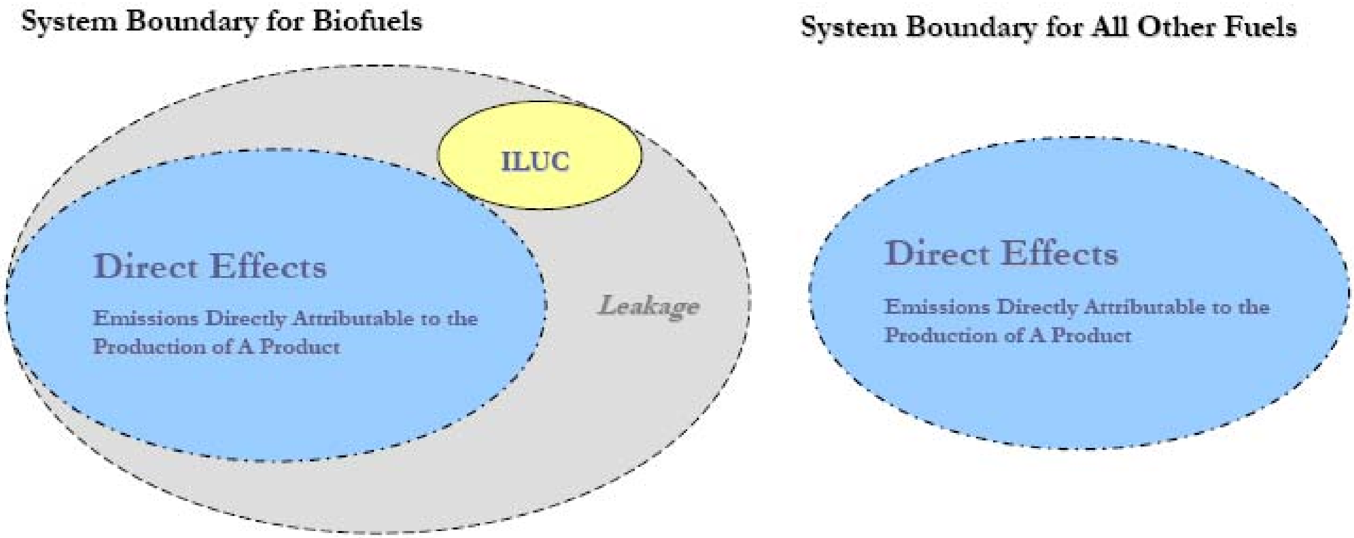
A Better Way to Define the Problem

- The term "indirect effects" is misleading
  - All effects are direct because they occur as a direct result of someone making a decision (especially true for LUC)
- ILUC is not a part of the biofuels carbon footprint
  - Indirect effects are, by definition, *directly* caused by something else
  - Even if you believe that biofuels cause land expansion, it is the decision to extract timber, graze cattle, produce food that causes the land clearing
  - If clearing occurs for biofuel feedstock, it is a direct effect & is already included
  - An indirect effect is not an inherent carbon effect of the biofuels gallon; it is an inherent carbon effect of someone else's supply chain that is being proposed for inclusion in the biofuels carbon score.
- Leakage is a better way to describe the real concern: *carbon emissions outside of the system boundary*
  - *Land use is only one part of this equation*
  - *Shuffling is another concern*
  - *Other price driven effects – including speculation – also relevant*

Coleman, New Fuels Alliances, Dec. 2008

MICHIGAN STATE UNIVERSITY

Inconsistent System Boundaries



Coleman, New Fuels Alliances, Dec. 2008

Direct vs. Indirect Land Use Change

- Direct land use change is:
  - Supply chain oriented—specific, defined system
  - Can identify/hold responsible individual actors
  - Data driven—real situations described
  - Testable in real time—grounded present reality
- Indirect land use change is:
  - Market oriented—whole world is system
  - No individual actors/no one is “responsible”
  - Model and assumption driven- hypothetical situations described: “scenarios” or WAGs (“wild ass guesses”)
  - Not truly testable– predicts future

ILUC Has Huge Intellectual Weaknesses

– Price increases drive models and LUC, therefore:
  - Any increase in agricultural prices is “bad”
  - Conservation programs that take land out of production are “bad” because they raise prices
  - Ag land should never be converted into forest/grassland
  - Agricultural communities should stay poor forever

– Global economic forecasts 10 years + from now?

– Models omit unused land (~400 million ha)

– Competing ILUC models give different results

– ILUC makes domestic industries responsible for the environmental performance of competitors

– Destroys value of real life cycle analysis

– Assumes all land use change worldwide is driven by agricultural expansion—clearly untrue

Some Life Cycle Analysis Standards: *In Plain English*

- Use the most recent/most accurate data possible
- Select the reference system/functional unit: what exactly are we comparing?
- Make it easy for others to check your data and methods= *transparency*
- Set clear system boundaries (physical & temporal)—must be equal or comparable for reference system and/or reference product of interest
- Multi-product systems must allocate environmental costs among all products
- Perform *sensitivity analysis*: how much do results vary if assumptions or data change?

Set clear system boundaries (physical & temporal)—must be comparable for reference product of interest

1. Biofuels temporal: future (forward looking)
2. Biofuels physical: entire world land for biofuels (indirect effects on GHG considered)
3. Petroleum fuels (or other alternatives) temporal: past (GREET model)
4. Petroleum fuels physical: restricted (indirect effects on GHG not considered)
5. *This gross disparity in system boundaries is the biggest intellectual weakness of ILUC—ILUC doesn't hold up to serious analysis*

Multi-product systems must allocate environmental costs among all products

1. System is land use in the entire world
2. Land produces:
   - Animal feed (roughly 10x direct human food use)
   - Human food
   - Biofuels
   - Pulp, paper, lumber
   - Clothing (cotton, linen…)
   - Environmental/recreational services
3. Searchinger allocates the entire incremental land use “cost” of biofuel production to the biofuel
4. Ignore the fact that the “replaced” agricultural production went to provide animal feed
5. Analysis unfairly advantages animal feed production from land vs. biofuel production
6. Animal feed production is “sustainable” but biofuel production is not—this is intellectually bankrupt

Perform *sensitivity analysis*: how much do results vary if assumptions or data change?

- Productive use of existing forest (or grassland) did you make furniture or flooring from the tropical hardwoods or did you just burn the trees down?
- Decreased land clearing rates and/or different ecosystems converted
- Corn yields increase both in the U.S. and abroad
- “Carbon debt” compared with oil sands GHG in 2015 vs. GREET in ~1999
- Increasing efficiency of future corn ethanol plants
- Uncertainties in global equilibrium models…test through Monte Carlo simulation
- Allocation of environmental burdens among feed and fuel uses of corn—not just to fuel (livestock are responsible for 18% of worldwide GHG emissions)
- How is land managed after conversion?
- <u>None</u> of these factors were considered in the sensitivity analysis

MICHIGAN STATE UNIVERSITY

Models in Searchinger & GTAP: Intelligent Management Scenarios

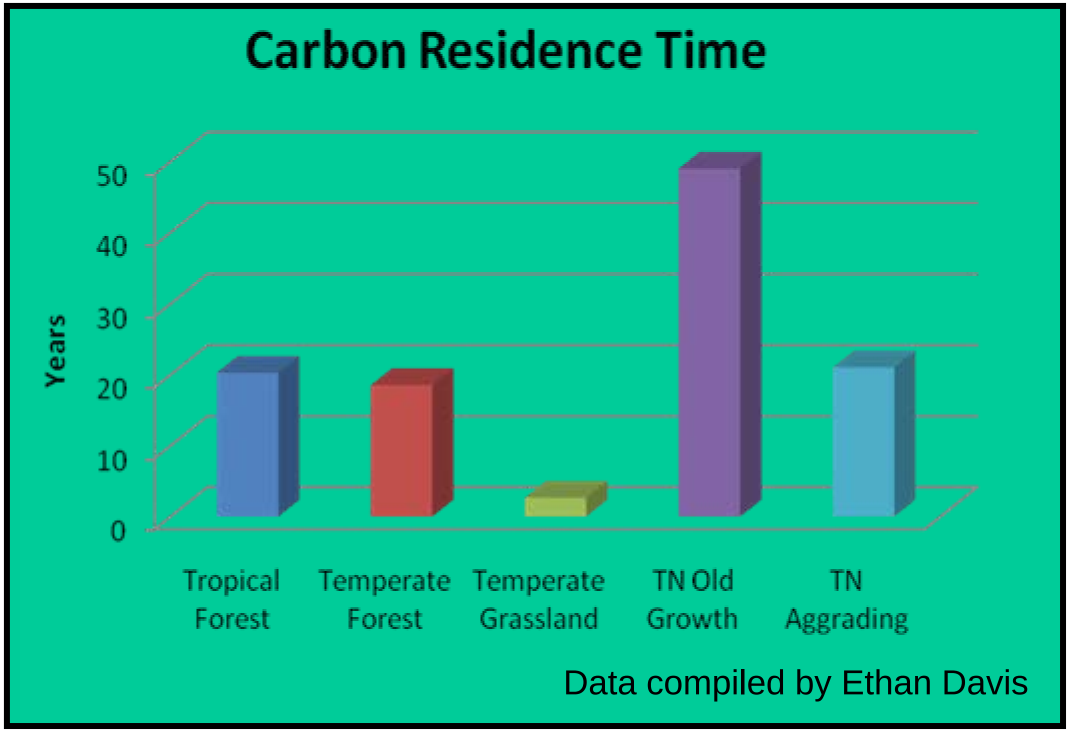
1. Ethanol demand to corn price
2. Corn price to corn or soybean supply
3. Corn or soybean supply to land use change
4. Land use change to greenhouse gas consequences
5. Management decisions:
    1. Burned standing biomass: worst case scenario
    2. Plow tillage: worst case scenario

What are effects of more intelligent/more likely management decisions?

- Use standing biomass productively
- Manage land for some carbon capture

Land Conversion GHG Emissions

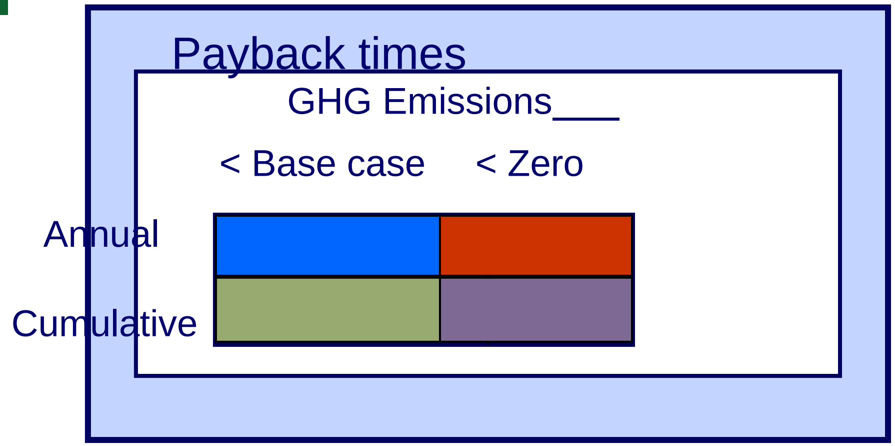
Carbon residence time: C inventory/rate of C accumulation

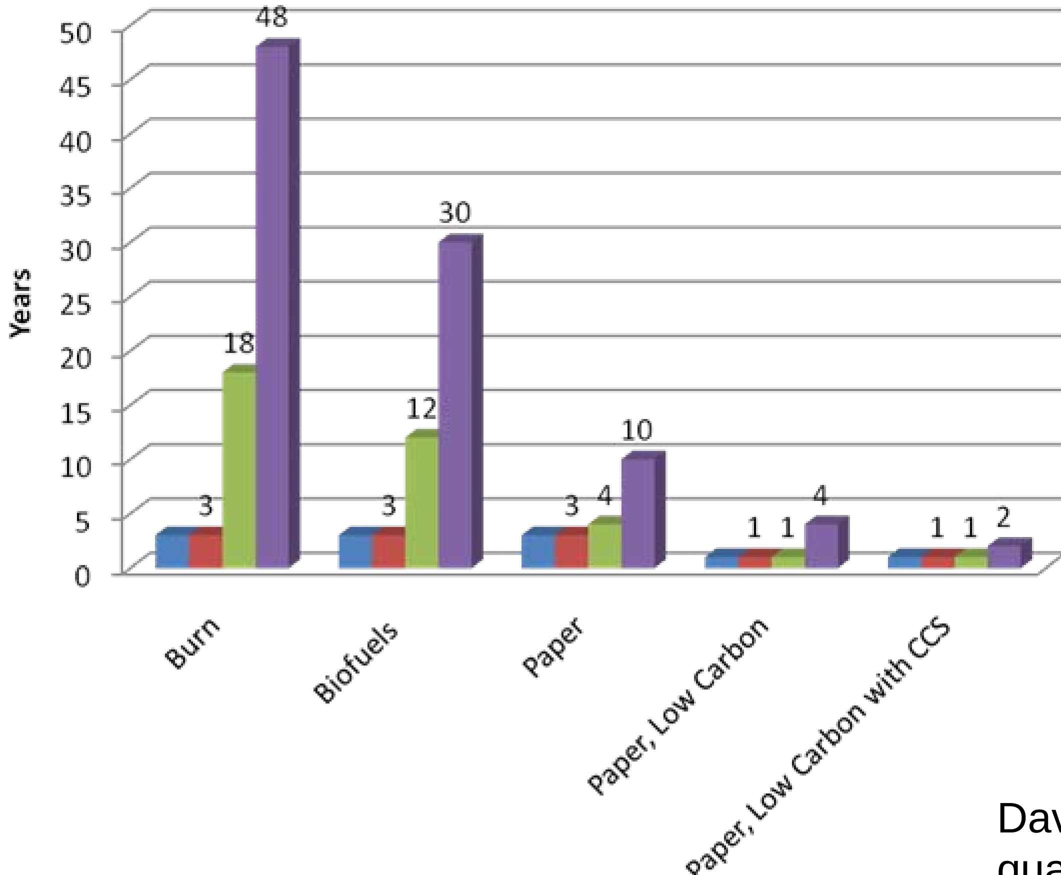


For ecosystems with a large carbon inventory, e.g. forests, land conversion may be accompanied by a large carbon debt unless:

1) **standing biomass is used to displace ghg emissions and/or**
2) **forest land is managed after conversion to minimize ghg emissions**

Grassland conversion does not generate any significant carbon debt





A large range of outcomes is possible,depending on whether or not land conversion is approached with the intent to minimize carbon debts

Even for the particularly challenging case of forest land conversion, rather small payback times result if uses are found for cleared biomass that offset ghg emissions.

Low carbon land conversion and/or carbon capture and sequestration further reduce payback times.

Davis, Laser, & Lynd - In-process analysis, quantitative results may change.

MICHIGAN STATE UNIVERSITY

Other Indirect Land Use Change Scenarios

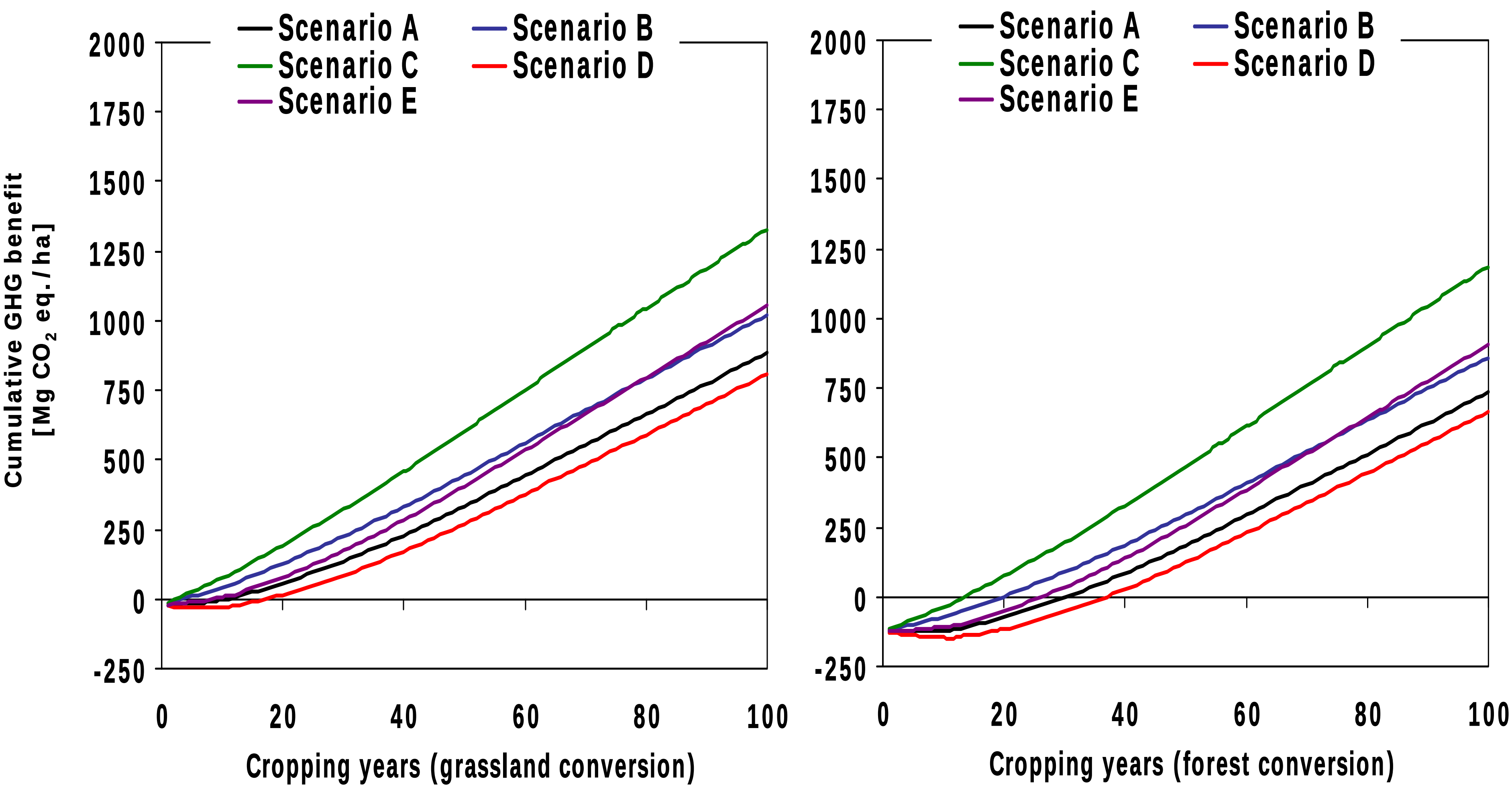
- Divert existing cornfield to ethanol production, and then convert grassland (or forest) to cornfield dedicated to animal feed production—harvest and use some corn stover as fuel for biorefinery

Scenario	Description
A	Cropping management: **current tillage practice**
B	Cropping management: **no tillage practice**
C	Cropping management: **no tillage practice combined with winter cover crop**
D	Cropping management: **plow tillage**
E	Scenario A with an assumption that ethanol would displace marginal gasoline fuel (from **Athabasca oil sands**)

* Data for DAYCENT from 8 U. S. corn producing counties, different climates,etc.

Paper published 2009 in *Environmental Science & Technology*

Cumulative GHG Benefit



MICHIGAN STATE UNIVERSITY

Some early conclusions:

Innovating on the biofuels supply chain (eg, using standing biomass instead of just burning it, and/or managing the land appropriately after the conversion) can greatly reduce or eliminate the “carbon debt”—even make it negative

- Harvesting standing biomass for biofuel production reduces payback time by 20 years (from about **50** to about 30 years)

- Harvesting standing biomass for paper production reduces payback time by 40 years (from about **50** to about 10 years)

- Applying best land management practices reduces the payback time by 25 years

- These approaches would be additive: thus the total savings could be as large as 40 + 25 years = 65 years, therefore giving a negative payback period

- Grassland conversion “debt” is essentially zero in all scenarios we have studied

- Land use conversion will involve a mix of forest and grassland, therefore the “carbon debt” ***may in fact be zero or even negative for some real systems***

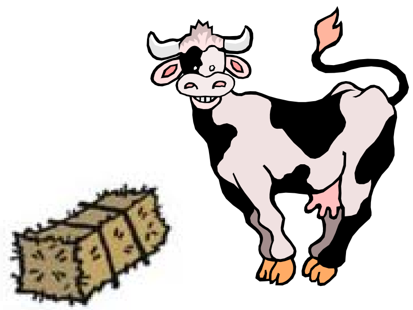
Two Technical Advances Required for Cellulosic Biofuels & Their Consequences

1. Key enabling advance: Effective, economical pretreatment to increase accessibility/digestibility of cellulose and hemicellulose (60-80% of forages) –*pretreated material will likely have value as animal feed*
2. Later advances: Complete utilization of all biomass components: carbohydrates, lignin, protein, lipids, minerals, pigments, pectin, organic acids, etc.
3. Taken together, these advances will significantly alter how we provide calories & protein to feed animals, particularly ruminant animals, with much higher land efficiencies "nega acres".
4. Use pretreated (with ammonia fiber expansion) switchgrass as animal feed and biofuel feedstock

MICHIGAN STATE UNIVERSITY

Tale of Two Biorefineries

Mobile Cellulose Biorefinery



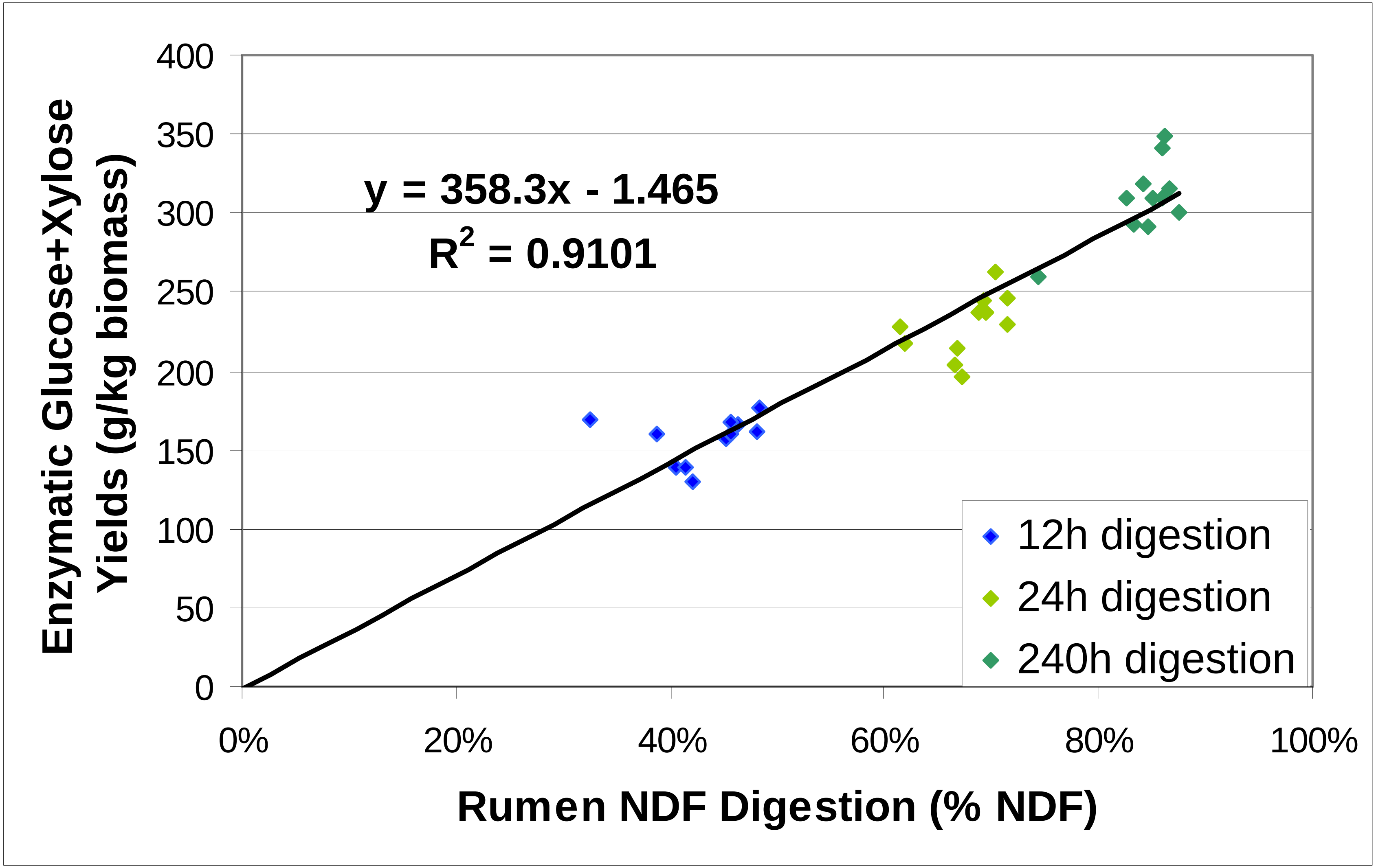
Stationary Cellulose Biorefinery

Improve Cellulose Conversion for Biorefinery = Improve Cellulose Digestibility for Cows

*Rasby, Rick. "Estimating Daily Forage Intake of Cows". University of Nebraska-Lincoln Institute of Agriculture and Natural Resources, http://beef.unl.edu/stories/200608210.shtml, 10/02/06.

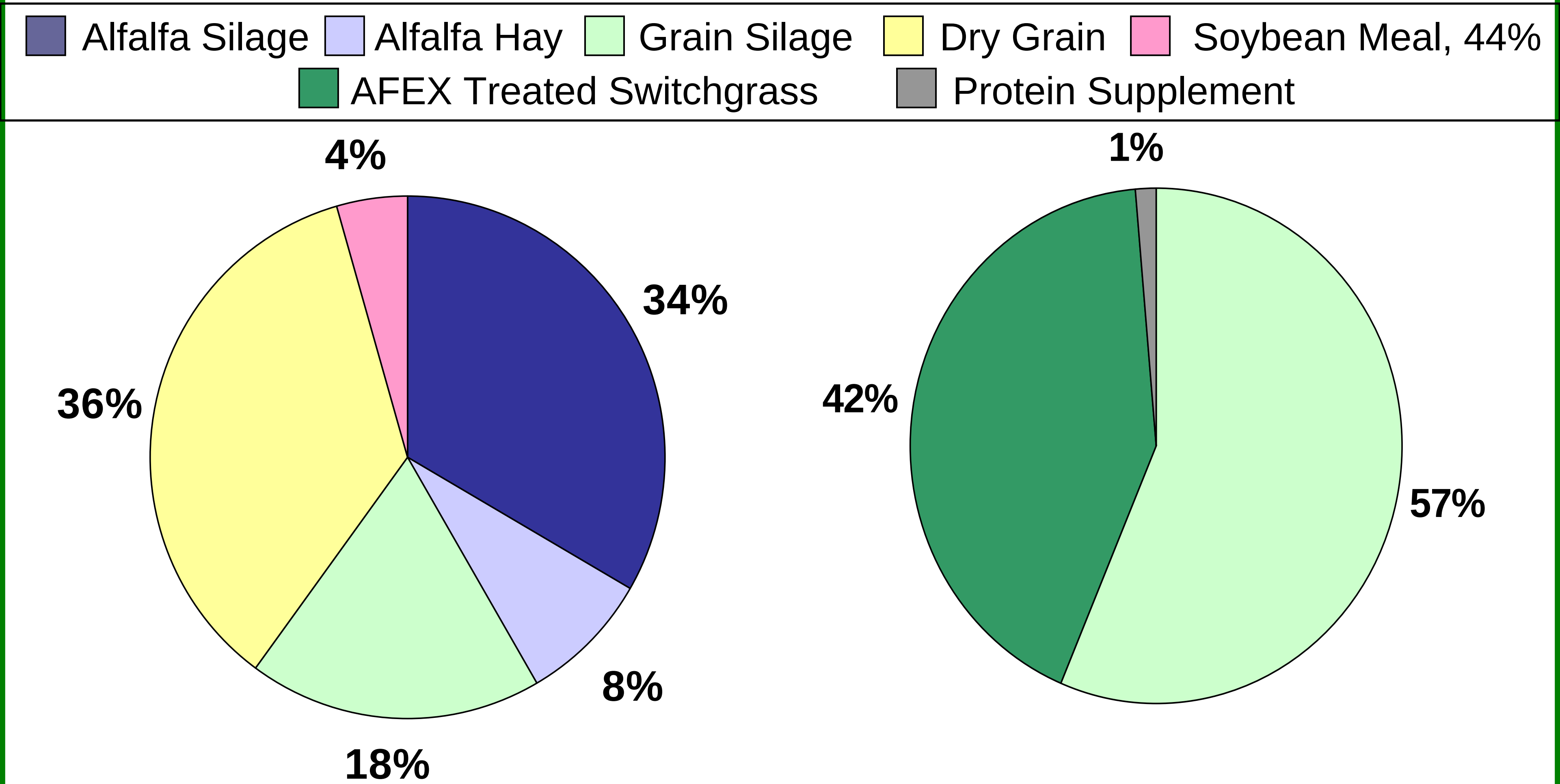
MICHIGAN STATE UNIVERSITY

Enzymatic and Rumen Fluid Digestion of AFEX-Treated Grass



MICHIGAN STATE UNIVERSITY

Dairy Diet- Black Hawk County Iowa Farm



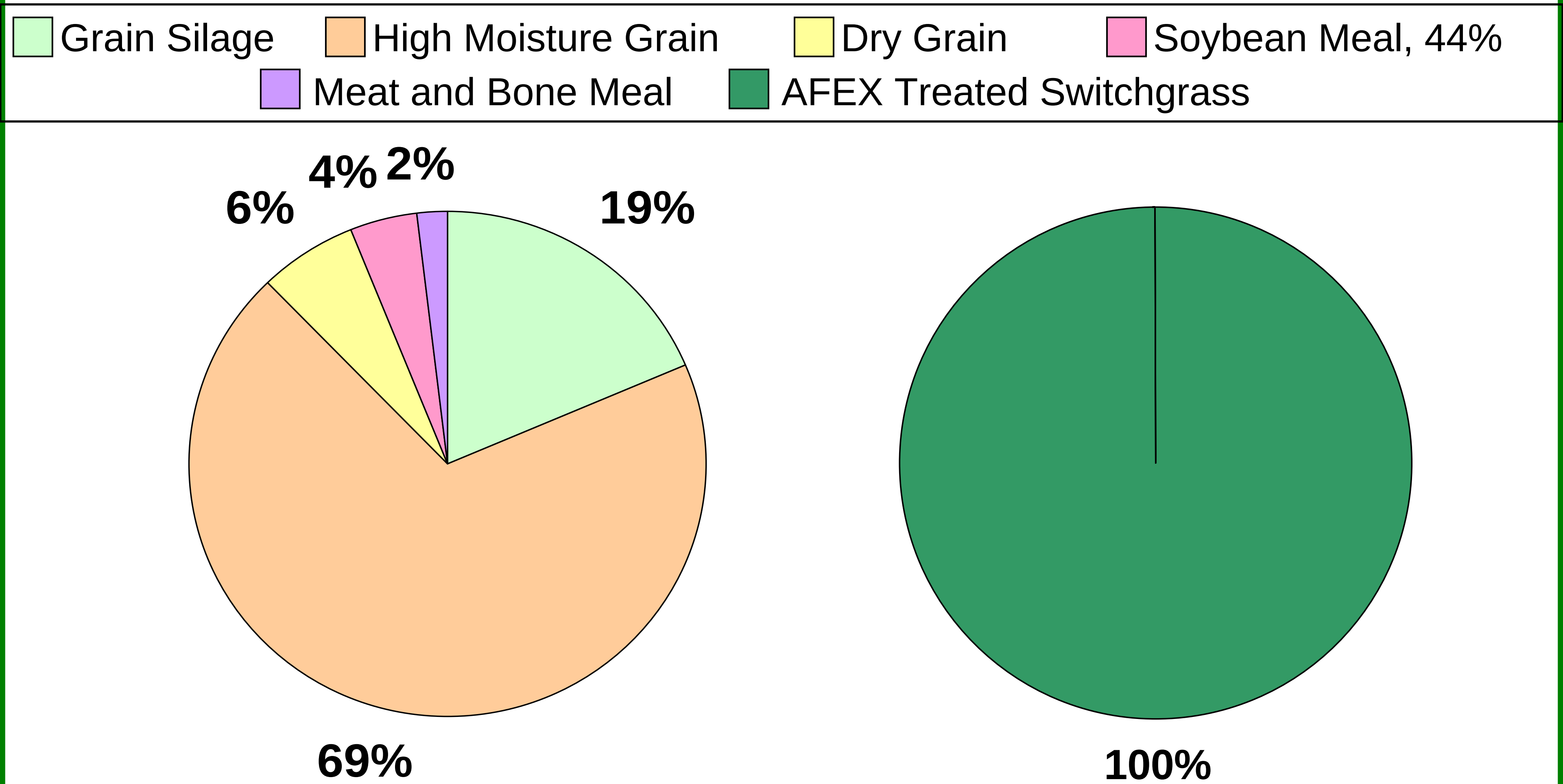
$150,242/yr
265 acres/yr

$92,388/yr
167 acres/yr

Using high digestibilty grass feeds reduces land requirements by 1/3 and GHG due to removal of corn from the animal diet—assumes 6 ton/acre switchgrass

MICHIGAN STATE UNIVERSITY

Beef Diet- Aberdeen South Dakota Ranch



$248,381/yr
436 acres/yr

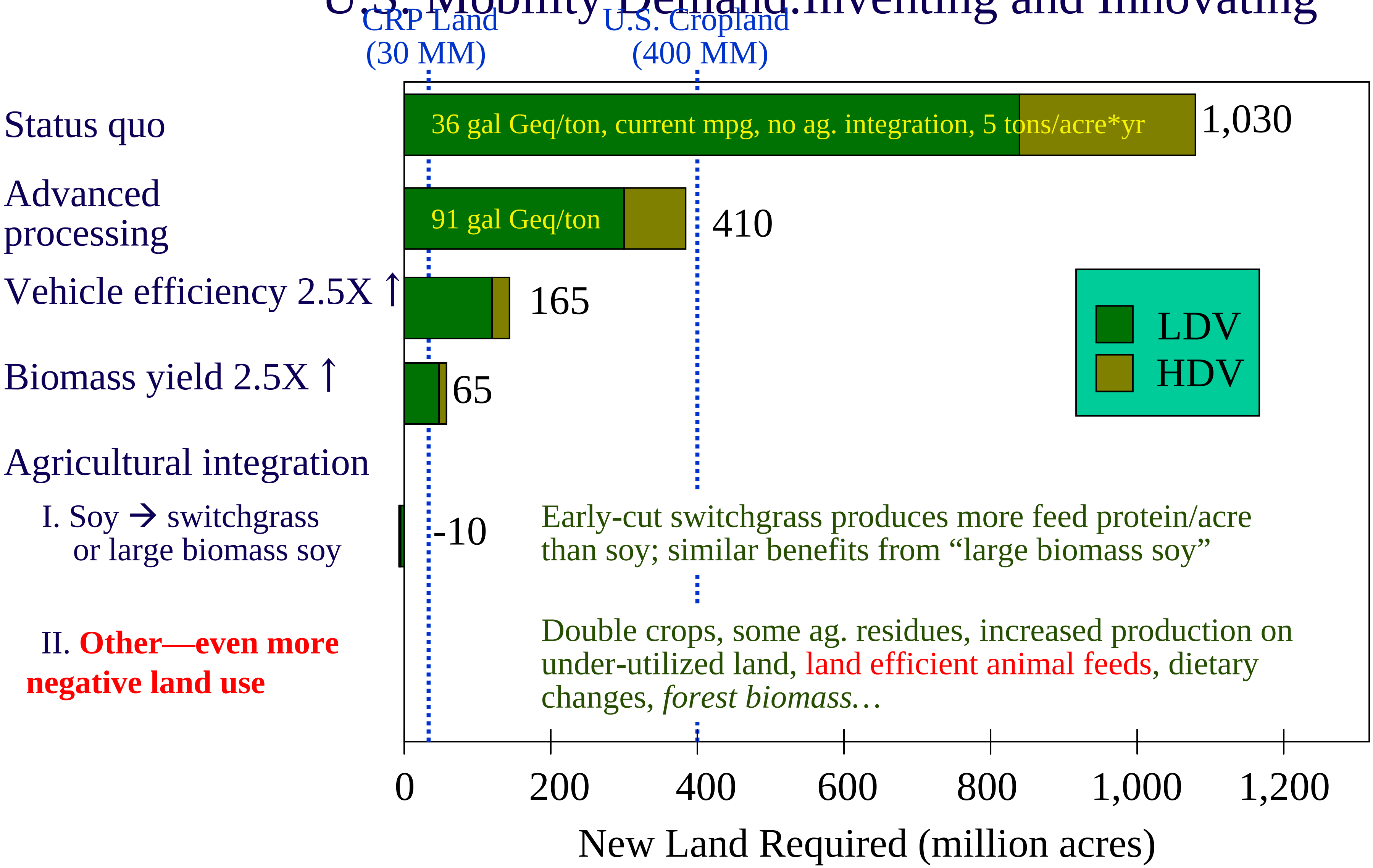
$134,897/yr
227 acres/yr

High digestibilty grasses reduce land needed for animal feeds by almost 50% & reduces GHG by replacing corn in diet.

MICHIGAN STATE UNIVERSITY

Grasses: Sustainable Sources of Protein & Calories for Animal Feed-- & Biofuel Feedstock

New Land Required to Satisfy Current U.S. Mobility Demand:Inventing and Innovating



When new land requirement = 0, the land conversion carbon debt = 0, displaced food production = 0

An Appeal to European Biofuel/Bioproduct Researchers I

- If you believe in what we are doing to create a more sustainable world, then fight for your beliefs!
- Conquer your guilt reflex—not everything you are accused of is true
- Stop accepting trivial/stupid/dishonest critiques of biofuels/bioproducts without protest and without analysis
- Learn the facts--then communicate them
- Talk to the media, your grandmother, etc.

An Appeal to European Biofuel/Bioproduct Researchers II

- Here are some relevant facts:
  - There is no land shortage- 400MM ha unused
  - Agricultural <u>overproduction</u> is the problem- there is plenty of food in the world
  - Agricultural surpluses in the EU/US are so large as to make bioproducts irrelevant for food concerns, biofuels are self correcting
  - A modest increase in agricultural prices is generally a good thing for poor rural people
  - Powerful forces want to destroy biofuels & they are not particularly honest

MICHIGAN STATE UNIVERSITY

To (Mis)quote the Godfather: "It's Not Business, It's Personal"

MICHIGAN STATE UNIVERSITY

"The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil."

Sheikh Zaki Yamani
Former Saudi Arabia Oil Minister

MICHIGAN STATE UNIVERSITY

Questions ??

MICHIGAN STATE UNIVERSITY

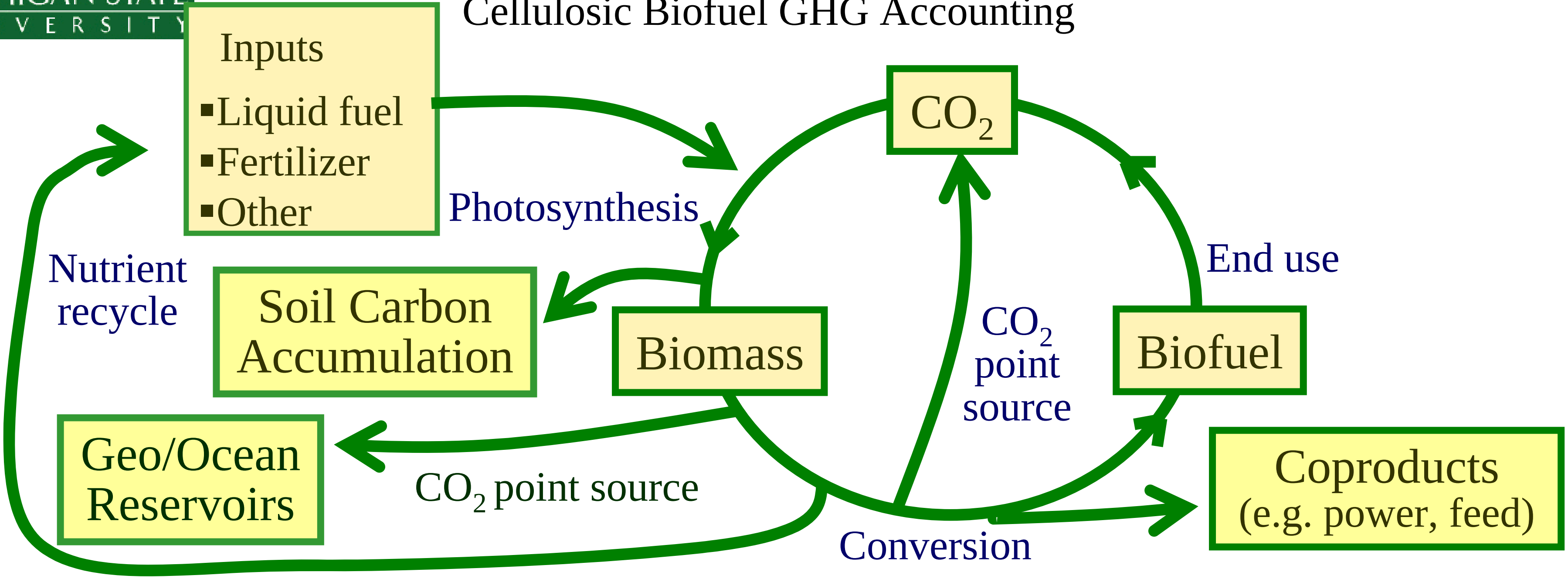
Land Use Change is Almost Never Driven by Agricultural Expansion Alone

Table 1. Frequency of broad clusters of proximate causes in tropical deforestation.

	All cases (n = 152)			Asia (n = 55)		Africa (n = 19)		Latin America (n = 78)	
	abs	rel (%)	cum (%)	abs	rel (%)	abs	rel (%)	abs	rel (%)
Single-factor causation									
Agricultural expansion	6	4	4	2	4	1	5	3	4
Wood extraction	2	1	5	0	–	2	11	0	–
Infrastructure expansion	1	1	6	0	–	0	–	1	1
Other[a]	0	–	–	0	–	0	–	0	–
Two-factor causation									
Agro-wood[b]	22	15	20	12	22	2	11	8	10
Agro-infra[c]	30	20	40	3	6	2	11	25	32
Agro-other	5	3	43	1	2	3	16	1	1
Wood-infra	1	1	44	0	–	0	–	1	1
Wood-other	1	1	45	0	–	1	6	0	–
Three-factor causation									
Agro-wood-infra	38	25	70	21	38	2	11	15	19
Agro-wood-other	6	4	74	4	7	1	5	1	1
Agro-infra-other	8	5	79	0	–	0	–	8	10
Wood-infra-other	1	1	80	0	–	0	–	1	1
Four-factor causation									
All	31	20	100	12	22	5	26	14	18
Total	152	100	–	55	100	19	100	78	100

H. J. Geist & E. F. Lambin. 2002. *BioScience,* vol. 52, #2, p. 143-150

Cellulosic Biofuel GHG Accounting



CO_2 Equivalent Emission

(% Gasoline base case, per mile, not cumulative)

	EtOH & Power	EtOH & FT Fuels & Power
Primary Cycle	0	0
Inputs	+10	+8
Coproducts	-56	-4
N recycle	-3	-2
Soil carbon accumulation	-130 (-19 to -240)	-101 (-15 to -186)
CO_2 capture, sequestration	-128	-98
Land conversion	+, potentially large	