Optimizing bio-energy crop farm profitability with spatial distribution of bio-fuel refinery sites

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Contents

THE SCENARIO

Simply meeting the current energy demand in some "green" (i.e., "sustainable") manner is not, in the long run, ecologically sustainable.

Why?

Our pattern of consumption is always increasing [Parikh and Ramanathan, 1999].

www.

"Falling Oil Prices"- 2014-15 trends – Asia biofuels market is hit

"Policy uncertainty"- Production is hit, biofuel volume finalization could not be performed under Renewable Fuel Standard

"Broader Global Distribution":
India *looking to expand ethanol bus trial to biodiesel and biogas as well*

"Emissions": Animal fat reduces GHG emissions by 85%

"Increase in Blending"

"Go-High FFA" -Biodiesel are sourced from soybeans, palm or rapeseed, and precisely because they contain less than 0.5% free fatty acid (FFA)

(COURTESY- http://www.platts.com/latest-news/agriculture/london/asias-biofuels-prices-at-historic-lows-after-27977913

Over- Arching Goal

- The goal of a sustainable supply of energy

Aim and Objective

Formulating a Problem

Research in Bio-fuels is

1. towards producing bio-fuels or fuel materials
2. Less on feed stock production
3. The thought on meeting present energy requirements will not help future energy management

QUESTION

What is good for sustaining our own patterns of energy consumption at reduced environmental impact can be nothing but a near-perfect solution

Need of the Hour?

- Why the mathematical efficiency of large-scale bio-fuel production does not translate into efficiency and usage at the local level
- What are parameters that influence bio-fuel crop profitability while managing energy cost
- How crop selection in a particular region can effect bio-fuel production
- How transport at any level (i.e, irrigation, labor, machinery, energy feed stock) influence overall bio-fuel efficiency
- What is the say of farmer's choice and private decision on bio-crop profitability

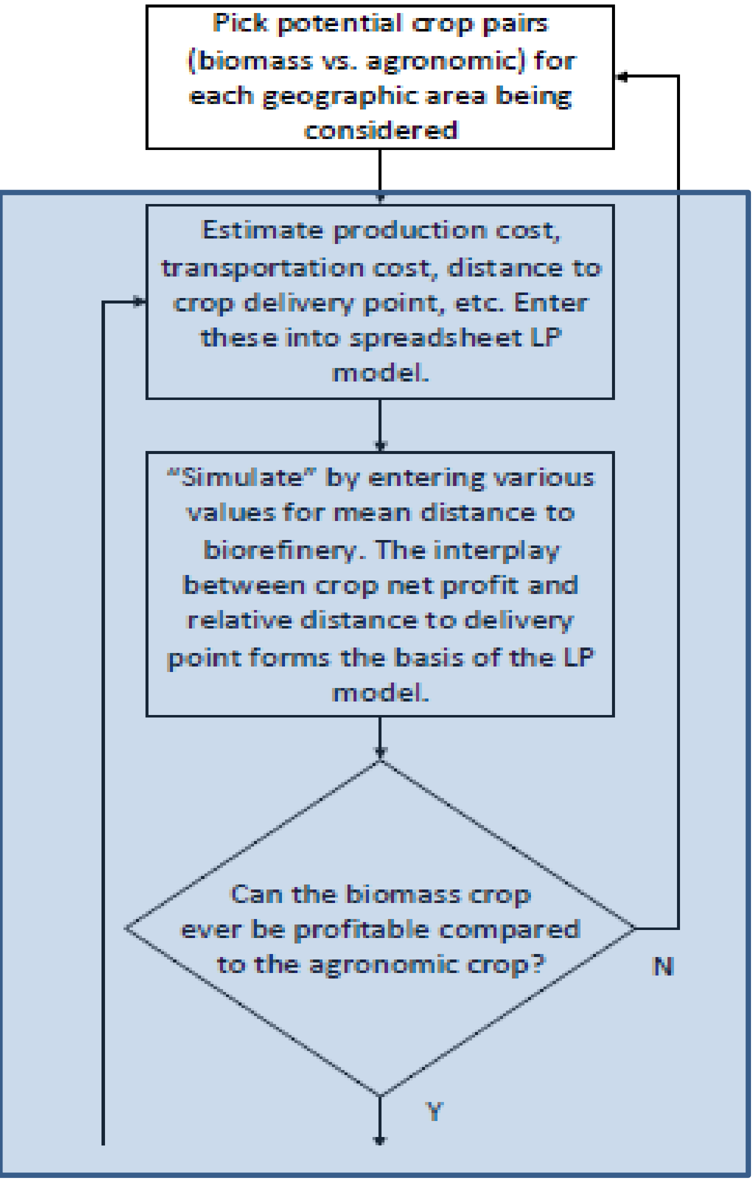
KEEPING IN MIND

To increase the biomass per unit land area is to **grow different crop varieties which are adapted to local climate in the region at a time** [Dhugga, 2007]

Swapping of crops by a farmer -social choices and private decision -role in farm profitability and management practices [Dhugga 2007].

irrigation water, manual labor, machinery utilized to carry activities such as tillage, threshing, cutting which needs to be justified [Abulfotuh, 2007, Plappally and Lienhard 2013].

Energy Crops	Country	Climate and Geography	References
Sugarcane	Brazil, India, USA, UK	Tropical	Dhugga, 2007
Soyabean	Brazil, USA	Sub tropical	Duke 1983
Micanthus	Canada, UK, USA	Spring and Summer species	Newman 2003
Switch grass	USA	Summer	Newman 2003
Sweet Sorghum	India, USA	Semi-Arid in Tropics	GAIN 2006
Coconut	India, New Zealand, Philipines, Sri Lanka, Vietnam, Thailand, Hawaii, USA	Tropical Sandy Shorelines	Philips 1994
Japtropha	Cameroon, Carribean, China, Florida, USA, **India**, Kenya, Philipines,	Arid to Semi Arid	Gilman and Watson 1993; ICRISAT 2008; Katembo and Gray 2007; Singh 2006;
Eucalyptus	Australia, Brazil, India, Taiwan, USA	No Climate or soil barrier	Berkeley ELP 2007
Palm	Cameroon , Saudi Arabia	Tropical	Berkeley ELP 2007
Pongamia	India	Semi Arid-Sub humid	Wani and Sreedevi 2007
Croton Megalocarpus	Kenya	Semi-Arid in Tropics	Keriko 2006
Oleander	Kenya	Semi-Arid in Tropics	Keriko 2006
Rapeseed (Canola)	Argentina, Canada, Denmark, France, Italy,	Winter and Springs	Berkeley ELP 2007
Bamboo	Nigeria, india	Semi humid-Marshes	Berkeley ELP 2007
Peaches	USA	Subtropical climate	Berkeley ELP 2007
Algae	Japan , USA	Lagoon and Sea shores	Berkeley ELP 2007
Cassava	China, India	Humid Conditions	GAIN 2006
Artichokes	Argentina	Springs	Berkeley ELP 2007



Even though current literatures report that *there is an efficiency of over 50% in production of ethanol from glucose*,

Costs such as

1. transport,
2. climatic conditions,
3. demand for transportation fuels and public opinion concerning low productivity concerns

affect the final profitability from the biofuel production system [Christy and Rismani-Yazdi, 2008].

CROP PAIRS- SELECTION

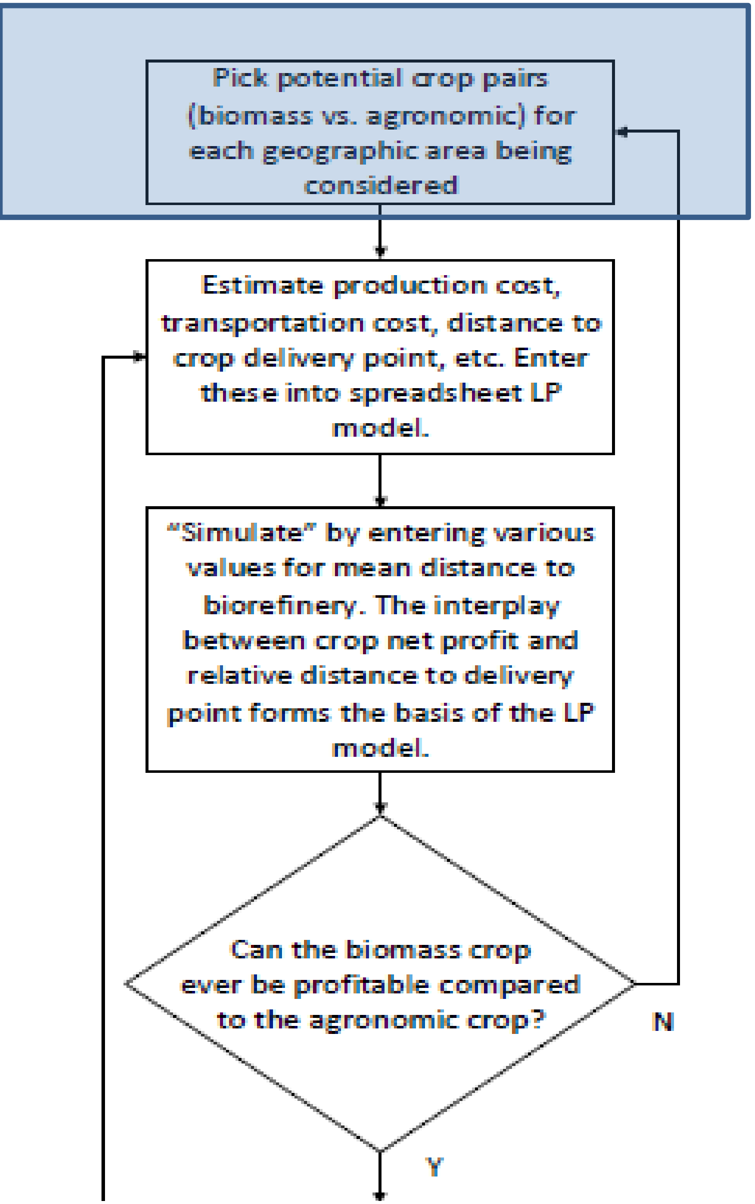
Eucalyptus-peaches

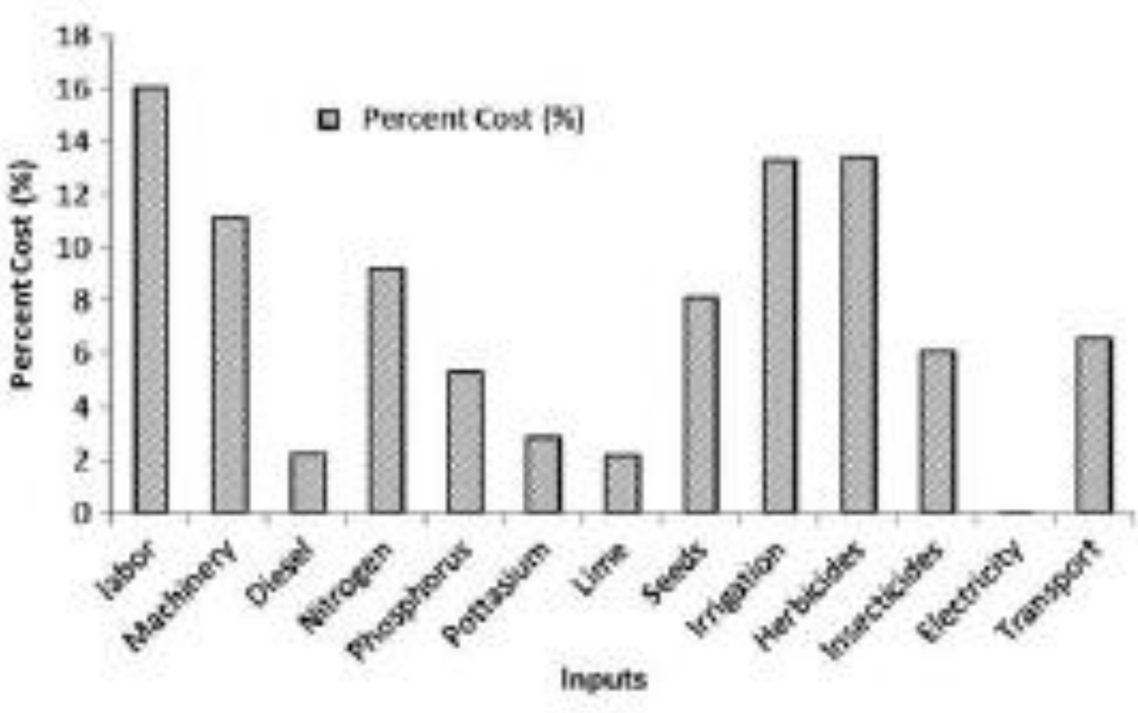
Maize and switch grass

Source: https://www.google.co.in/maps/place/United+States/@31.7860603,-132.0853276,3z/data=!3m1!4b1!4m2!3m1!1s0x54eab584e432360b:0x1c3bb99243deb742

Coconut citrus

Jatropha and Corn





Cost percentage contributions towards Maize Production in the United States for a hectare field (Source: Plappally and Lienhard 2013)

Working of the LP model

Source: Personal communication, John Binns, Madison County, Ohio Cash Grain Producer gave his farm input values

Grain Crop	Maize	Exp. Yield (bu/ac)	140	Weight/bu (lbs)	66	Bushels/ton	30	Exp. Yield (tons/ac)	4.62
Biomass Crop	Switchgrass	Exp. Yield (tons/ac	4						
Region	Midwest USA								

Grain Crop Production Inputs:		Prob.	Exp. Cost ($/ac)
Apply Fertilizer ($/ac)	$250.00	0.8	
No Fertilizer ($/ac)	$0.00	0.2	$200.00
Apply chemicals ($/ac)	$180.00	0.5	
No chemicals ($/ac)	$0.00	0.5	$90.00
Machinery Used ($/ac)	$50.00	0.95	
No machinery used ($/ac)	$0.00	0.05	$47.50
Hire Labor ($/ac)	$12.00	0.2	
No hired labor ($/ac)	$0.00	0.8	$2.40
Irrigation Cost ($/ac)	$5.00	0	
No irrigation ($/ac)	$0.00	1	$0.00
Govt. Subsidies used ($/ac)	-$1.00	0.1	
No Govt Subsidies ($/ac)	$0.00	0.9	-$0.10
Buy New Seed ($/ac)	$75.00	0.99	
Seed from previous crop ($/ac)	$3.00	0.01	$74.28

Expected Cost of Grain Crop Production ($/ac) NON-LAND: $414.08

Biomass Crop Production Inputs:		Prob.	Exp. Cost ($/ac)
Apply Fertilizer ($/ac)	$200.00	0.8	
No Fertilizer ($/ac)	$0.00	0.2	$160.00
Apply chemicals ($/ac)	$50.00	0.5	
No chemicals ($/ac)	$0.00	0.5	$25.00
Machinery Used ($/ac)	$40.00	0.95	
No machinery used ($/ac)	$0.00	0.05	$38.00
Hire Labor ($/ac)	$12.00	0.4	
No hired labor ($/ac)	$0.00	0.8	$4.80
Irrigation Cost ($/ac)	$5.00	0	
No irrigation ($/ac)	$0.00	1	$0.00
Govt. Subsidies used ($/ac)	-$5.00	0.7	
No Govt Subsidies ($/ac)	$0.00	0.3	-$3.50
Buy New Seed ($/ac)	$75.00	0.05	
Seed from previous crop ($/ac)		0.95	$3.75

NON-LAND Expected Cost of Biomass Crop Production ($/ac): $228.05

BIOMASS CROP FAILURE RISK	Prob.		Exp.cost of Prod. ($/ac)	Expected Transportation Cost ($/ac)	Gross Profit ($/ac)	Net Profit, NON-LAND ($/ac)
Successfully produce BIOMASS crop	0.95	Deliver to Biorefinery	$228.05	1 $4.00	$560.00	$327.95
		Deliver Biomass Crop to Intermediate	$228.05	$4.00	$504.00	$271.95
BIOMASS Crop fails (total loss)	0.05					

GRAIN CROP FAILURE RISK:	Prob.					
Successfully produce GRAIN crop	0.95	Deliver to Grain Elevator/Market	$414.08	$190.48	$840.00	$235.44
GRAIN Crop fails (total loss)	0.05					

Break even point

TRANSPORT:	
Fuel cost rate ($/km)	$0.50
Maint Cost($/km)	$0.30
Trip (truck) Delivery Size(tons)	20
DISTANCE:	
Mean Distance to Biorefinery (km)	2 1
Mean Distance to Grain Elevator/Market (km)	55
PRICES:	
Price of Grain Crop at elevator($/bu)	$6.00
Price of Grain Crop at elevator($/ton)	$181.82
Price of Biomass Crop ($/ton)	$140.00
Penalty for Delivery to Intermediate (%)	10

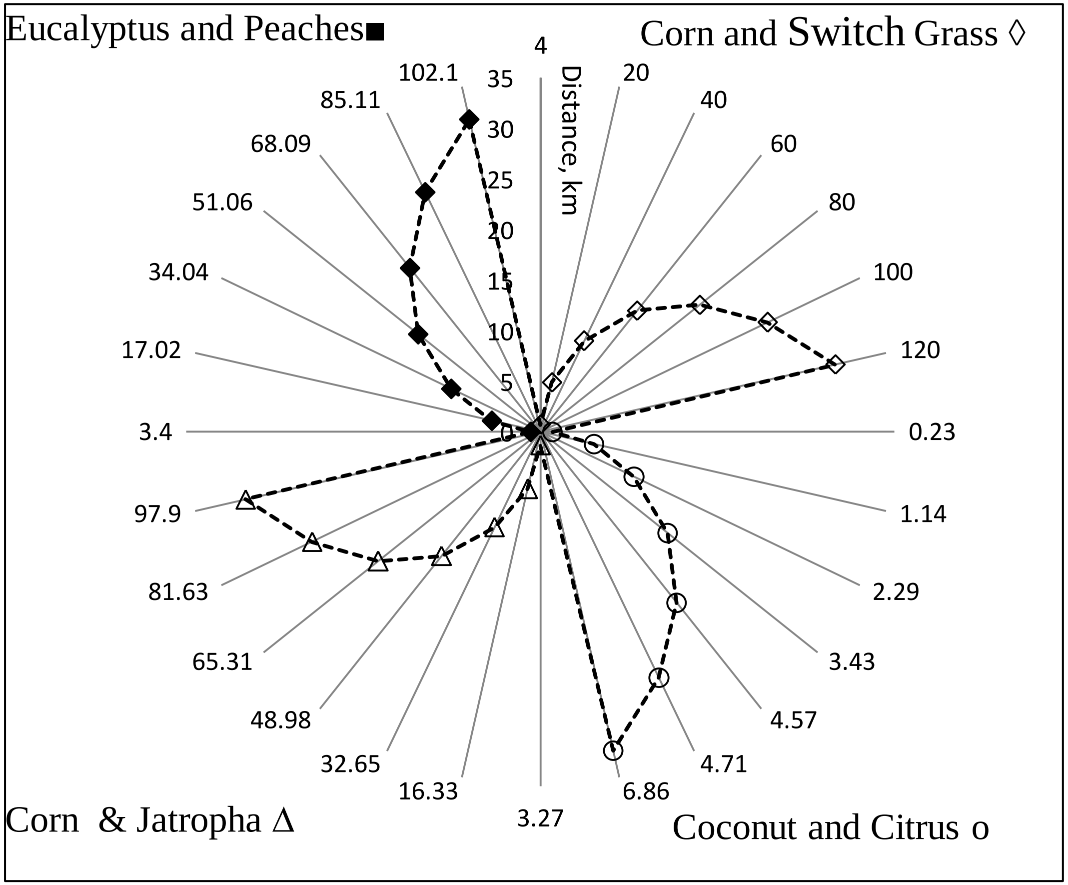
Useful Indices:

Fertilizer Cost to Crop Value Ratio		
Grain	Biomass, direct del.	Biomass, intermediate del.
4 0.24	0.49	0.59

Distance Ratio (biorefinery to grain elevator)	3 0.02
Price Ratio (before penalty, biomass/grain)	0.77

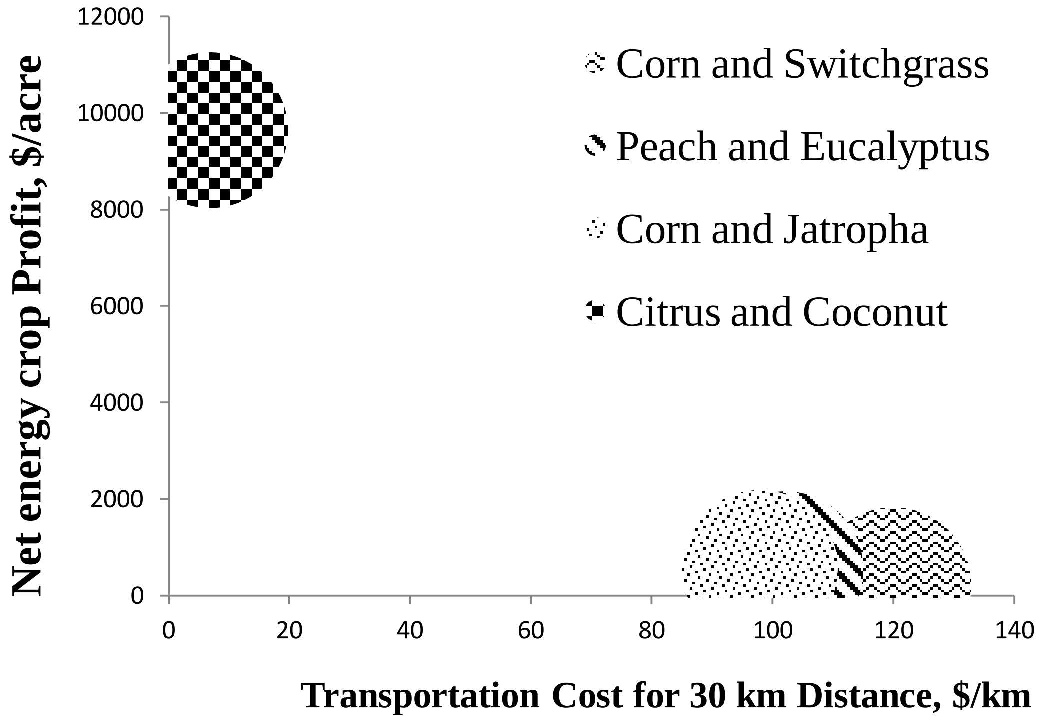
KEY:

(yellow)	INPUT CELLS
(orange)	OUTPUT CELLS

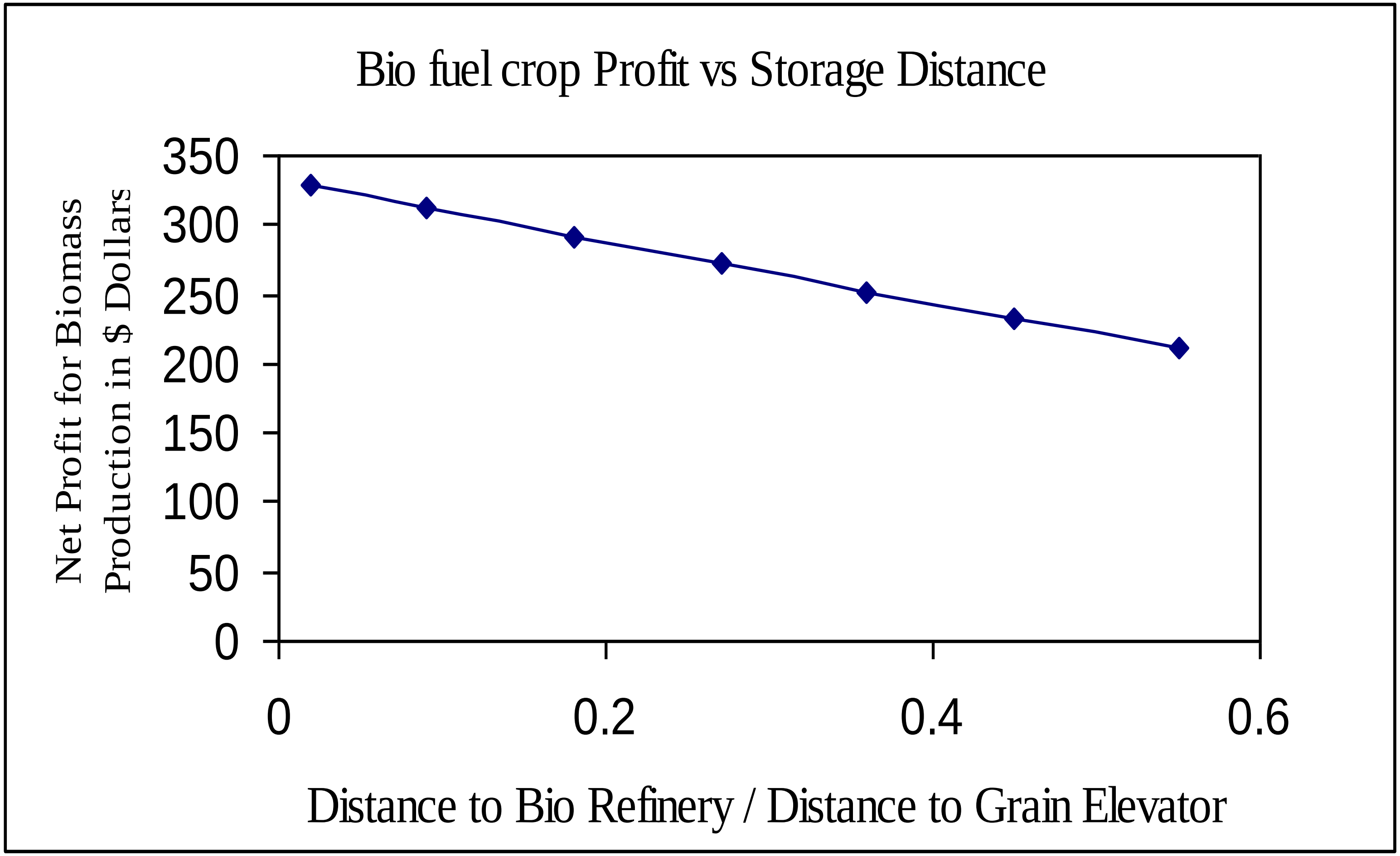


Expected expenditure (in US dollars) to transport crops as a function of distance to the bio-refinery (in km)

bio-material transport cost , M_1



Net Energy crop profit vs.
Transportation cost for a 30 km radial distance from the crop field to the bio-refinery.



M_2 is defined

The Storage place of feedstock for animals (feed corn) should be greatly localized to reduce cost. This will help bio-fuel production benefits to soar.

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Fertilizer to Crop Value M_3

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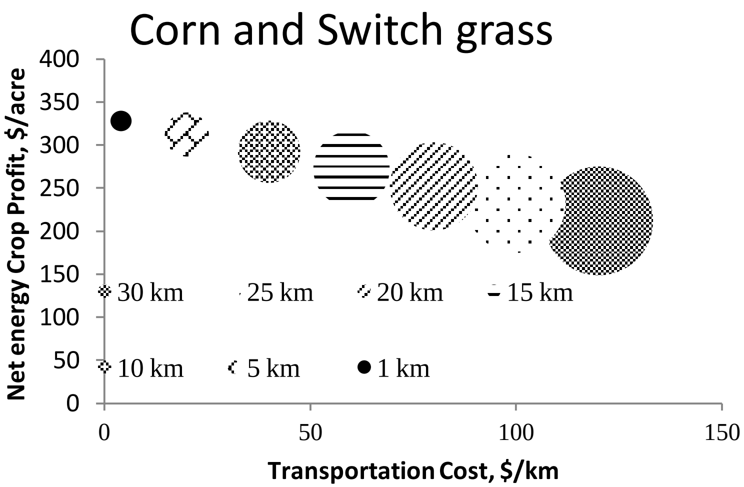
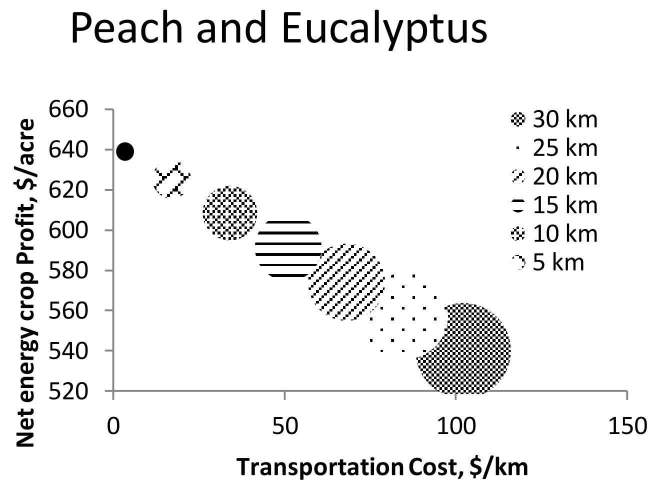
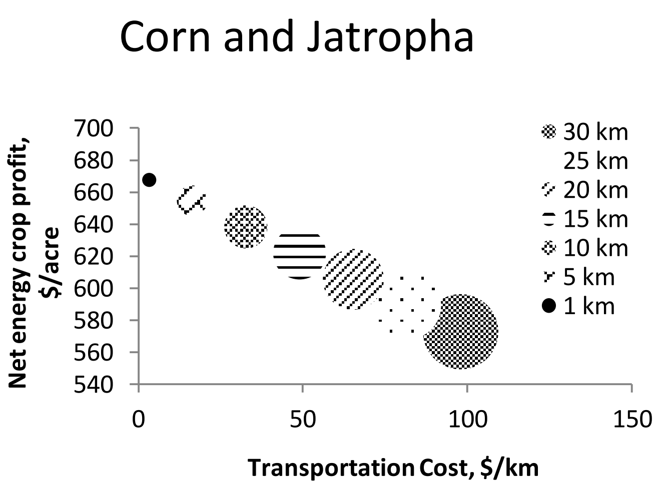
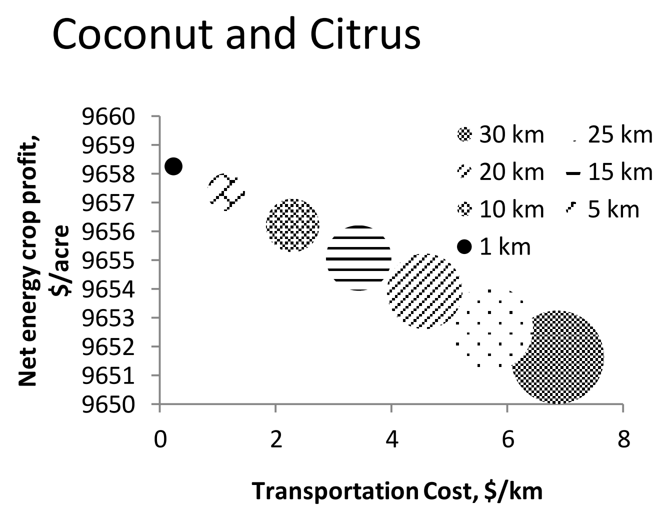




Grain crop transport is much low compared to other bio-fuel crops.





This would main that we have to reduce distance of transport of bio-fuel crops tp get profits at par to grains.

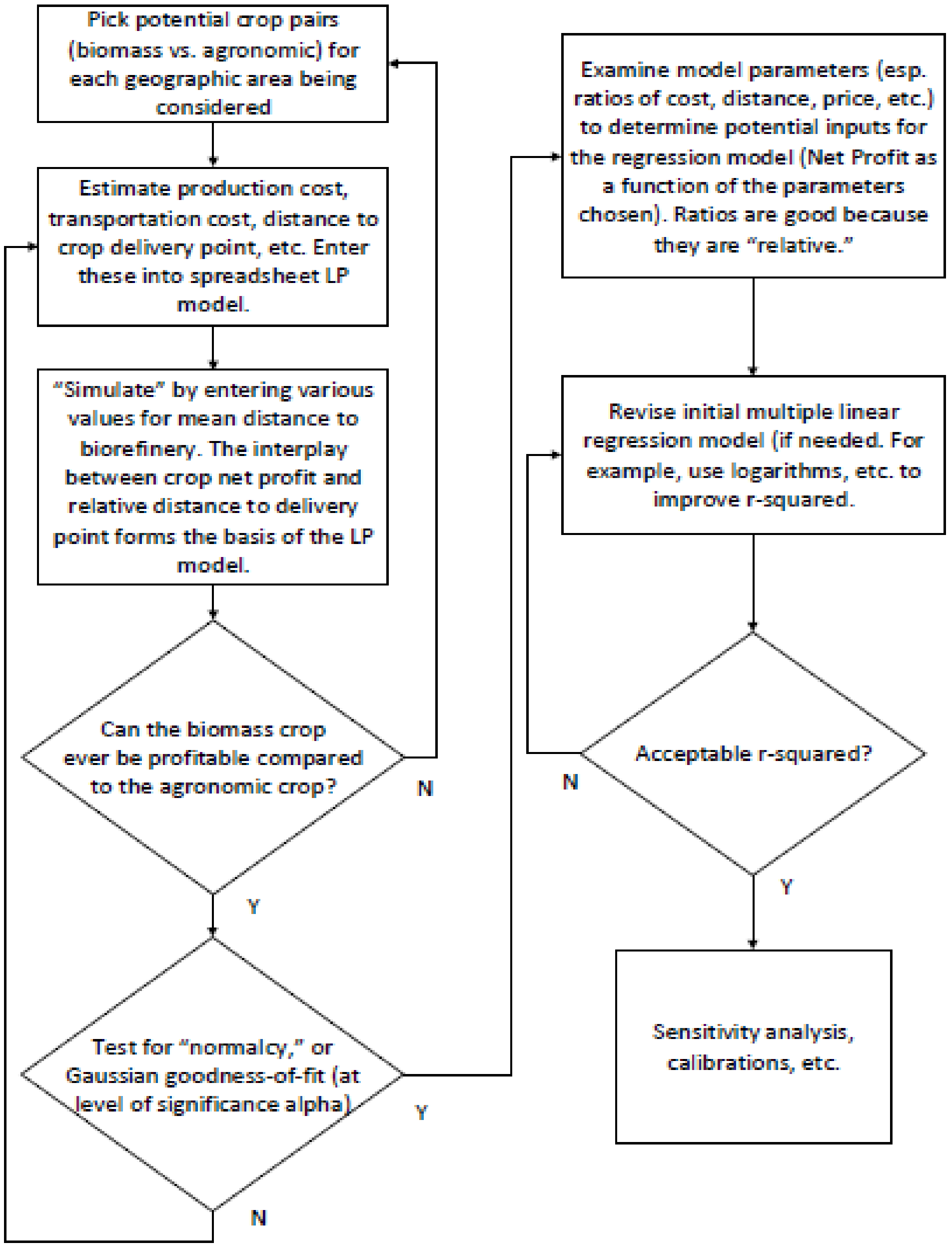
Correlation Chart – M_1 (T-bio), M_2 (Disratio). M_3 (Distance) , M_4 (F/bio)

	T-bio	Distance	Disratio
Distance	0.710		
	0.000		
Disratio	0.710	1.000	
	0.000	0.000	
F/bio	0.376	0.084	0.084
	0.048	0.671	0.670

Bio-material transport cost (T-Bio) , M_1,
M_2 is defined the ratio of distance to bio-refinery site to agronomic crop delivery point

These are correlation show that distance M3 is very less correlated to the ratio of fertilizer cost to crop value M_4 (ratio F/bio)

M_1 and M_2 have the capacity to reflect individual grain crop & bio-fuel crop pair property for a specific region



$$P_i = r \prod_{i=1}^{2} M_i^{q_i}$$

$$r = P_0 \left\{ \prod_{i=1}^{k} M_{io}^{q_i} \right\}^{-1}$$

For any energy crop-food crop pair irrespective of any specific region in the United States can be expressed as

$$P_i = r' \prod_{i=1}^{3} M_i^{q_i}$$

M_3 is the natural logarithm function of r specifically for each specific energy crop-rotation food crop pair (Plappally et al 2011)

Corn and Switch grass

$$P = e^{5.59} V_1^{-0.0994} V_2^{-4.71}$$

Peach and Eucalyptus

$$P = e^{6.38} V_1^{-0.0389} V_2^{-1.71}$$

Corn and Jatropha

$$P = e^{6.43} V_1^{-0.0355} V_2^{-1.57}$$

Coconut and Citrus

$$P = e^{9.18} V_1^{-0.0001} V_2^{0.007}$$

V_1 and V_2 represent the independent form of M_1 and M_2.

The Power values of V_1 tells that the importance of transportation cost decreases from bottom to top, i.e from a less grain pair to a more grain dominated pair

$$P = e^{6.89} V_1^{-0.701} V_2^{0.896} V_3^{1.29}$$

Predictor Variables\ Model Coefficients	r’	q_1	q_2	q_3	R^2	S
M_1	8.72	-0.629	-	-	56.1	0.935
M_2	12.0	-1.12	1.10	-	96.4	0.274
M_3	10.7	-0.855	0.824	0.0608	99.7	0.075

The above equation basically attests the importance of the ratio of distance to the bio-refinery site to the agronomic crop delivery point (V_2 or M_2) and

Secondly the importance of the type of crop in a local or nearby region.

Conclusion

1. For bio-fuel profits, bio-refinery should be closer than actual grain elevators
2. A new model of energy crop profit as a function of transport cost and ratio of the distance from the bio energy crop farm to bio-refinery and radial distance from food grain farm to grain elevator.
3. Production and Storage of bio-fuel crop should be localized and near to bio-fuel production centers. This means that bio fuel is to be produced from local crops.

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Corn and Switch grass

Predictor Variables\ Model Coefficients	r	q_1	q_2	R^2	S
M_1	6.03	-0.118	-	77.7	0.082
M_2	-9.15	2.74	-2.94	96.6	0.035

Corn and Jatropha

Predictor Variables\ Model Coefficients	r	q_1	q_2	R^2	S
M_1	6.54	-0.0461	-	80.4	0.029
M_2	1.07	0.991	-1.07	97.3	0.012

Peach and Eucalyptus

Predictor Variables\ Model Coefficients	r	q_1	q_2	R^2	S
M_1	6.54	-0.0461	-	80.4	0.029
M_2	1.07	0.991	-1.07	97.3	0.012

Coconut and Citrus

Predictor Variables\ Model Coefficients	r	q_1	q_2	R^2	S
M_1	9.18	-0.00019	-	81.8	0.00011
M_2	9.16	0.0043	-0.0046	98.1	0.00004

The Multivariate Framework (Source: Plappally et al 2011, JEMT, ASME.

$\left[\rho x_{i,j}\right]$ is a square matrix, $k \times k$, and if $\left[\theta_{i,j}\right]$ is a vector in the null space of $\left[\rho x_{i,j}\right]$ and exist in the n dimensional space of the predictor variable $X_{i,j}$ data set, then [4]

$$\left[\rho x_{i,j}\right]\left[\theta_{i,j}\right] = \lambda_{i,j}[I]\left[\theta_{i,j}\right] \quad \text{(A1)}$$

$$\left[\lambda_{i,j}[I] - [\rho x_{i,j}]\right]\left[\theta_{i,j}\right] = 0 \quad \text{(A2)}$$

Here $\left[\theta_{i,j}\right]$ is the null space of the characteristic equation term and left hand also represents two orthogonal vectors in the inner product space. It should be noted that $\left[\theta_{i,j}\right]$ contains all vectors perpendicular to the column spaces containing all the predictor variables. There will be one eigen space $\left[\theta_{i,j}\right]$ for each distinct eigenvalue $\left[\lambda_{i,j}\right]$ for $i = 1,2,\ldots,n$ and $j = 1,2,\ldots,k$ when $n>k$ and so there will be k eigen spaces for . Trace of the eigen value matrix also defines the total variance of the predictor variables [4].

$$[\phi] = \begin{bmatrix} (\theta_1^1)^2 / ((\theta_1^1)^2 + \cdots \ldots\ldots + (\theta_k^1)^2) & \ldots\ldots & (\theta_1^k)^2 / ((\theta_1^1)^2 + \cdots \ldots\ldots + (\theta_k^1)^2) \\ \vdots & \ddots & \vdots \\ (\theta_k^1)^2 / ((\theta_1^1)^2 + \cdots \ldots\ldots + (\theta_k^k)^2) & \ldots\ldots & (\theta_k^k)^2 / ((\theta_1^1)^2 + \cdots \ldots\ldots + (\theta_k^k)^2 \end{bmatrix}^{1/2}$$

$\left[\overline{T}\right]$ is an orthogonal square matrix of size, $k \times k$, with normalized eigen vectors $\left[\theta_{i,j}\right]$ for the three participating predictor variables. The normalized eigen vectors can be represented as [4]

Then $\overline{[T]} = [\phi]^t$, which constitutes the transformation matrix $\overline{[T]}$. The correlated predictor matrix column elements $X_i = \overline{X_{i,j}}$ for $i = 1,2,\ldots,k$ with correlation coefficient are linearly transformed into mathematically uncorrelated variables $V_i = \overline{V_{i,j}}$ and scaled as [4]

$$\frac{\left(\left[\overline{X}_{i,j} - \mu_{\overline{X_{i,j}}}\right]\right)}{\sigma_{\overline{X_{i,j}}}} = \left[\overline{T}\right]\left[\frac{\left[v_{i,j}\right]}{\sqrt{\lambda_{i,j}}}\right] \qquad \text{(A3)}$$

The Multivariate Framework (Source: Plappally et al 2011, JEMT, ASME.