Economics of Macroalgae Utilization

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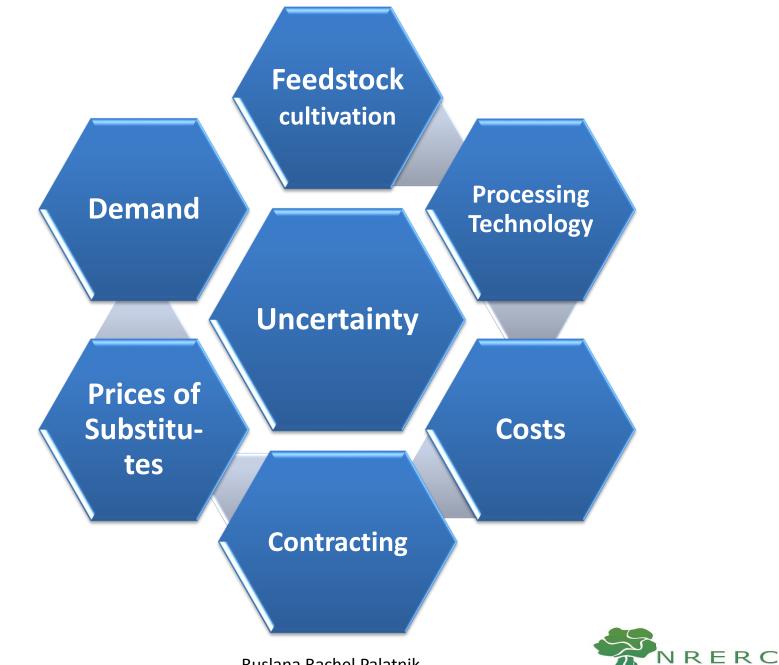


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		5. Singh- B. A. Simmons		L Introduction	approach aimed at cascading valorization of both protein non-protein seawood constituents is required to realise an	Review: 20 November 2015/Review and and an entrol 25 March 2016	ELSEVIER. journal homepage: www.elsevier.com/tocate/ifset
	698	Biological and Materials Science Center, Sandia Na Laboratories, Livermon, GA 9652, USA		Liseture commany. Algae que de cand biomantage Protectment and cantharing for	nomically feasible value chain. In this study, sus biorefinery approach is presented for the green seaw	Constant: 20 November 2005 (Konstant and adopted 20 March 2016) O The Author(c)/2016 This acticle is published with open access at Springerlink on	
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		-	 Corresponding autors to it as 1987 422 225. Corresponding autors to it as 21 strenzom. 	1. Introduction	protein -enriched (343 g kg ⁻¹ in DM) extracted fraction, extracted fraction was characterised for use in animal fau	nomically fourible value chain. In this study, such a U. in: biomfinery approach is presented for the green seawood memory	* Post or holes of this issue over all the days 7.4 Adv. https://www.inter.org
			Proval addresses gaugi Ministration (1. tao); shangar@falan.edu.cn (3. Zhang).			Uha larace centahing 225 g patein (N×4.6) kg ⁻¹ dry mas- ter (DM). The sugar in the biomass ware solublized by het high	⁶ An Marville University, Department of Physics, Marville, Procest ⁶ In a Mary J. Nature for National Networks Collision, Statistical to Adda and go Dadinadas, Contrany
			http://dudiciog.to.tom/journal.tom/come	Macroaigae, bechnical synonym for 'seawwed', is a collect lenning to a series of non-phylogenetic [117], multi-cellular scopic [@] and eukarystic organisms. The advantages of		water beatment followed by exsynatic hydrolysis and centri- fugation resulting in a suger-rich hydrolysis (N.S. g L ⁻¹ produ	ARTICLE INFO ARSTRACT
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מרכז לחקר משאבי טבע וסביבה Natural Resources & Enviromental Research Cente

Cultivation: Production per ha varies

No distinct patterns in the productivity of different farming systems

- neither in terms of production per unit of cultivation line
- nor in terms of production per unit of farming area

Reason

- farm locations
- Growing cycles
- Type of seaweed

Range of 6 -108 tonne/ha per year





Growth Rate Variation

- growth rate of *Kappaphycus*
- Same location, different farming systems
- Same farming system, different locations
- from 0.2 to 10.86 percent per day

- Hayashi et al. (2010)
- FAO et al. (2013)





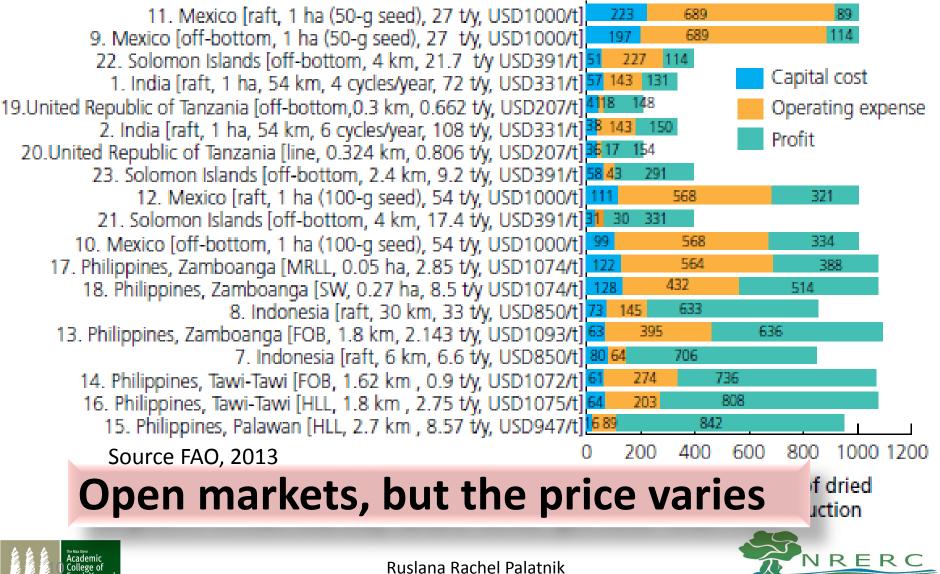
Conversion factor (yield) varies (Ulva)

Biomass DW derived	Conversion Factor	Reference		
product				
Ethanol [g m ⁻²]	0.03-0.23	Nikolaisen, et al. 2008, van der Wal, et al ., 2013		
Buthanol	0.03-0.06	van der Wal, et al 2013		
Acetone	0.01-0.02	Potts, T. et al. 2012; van der Wal, et al., 2013		
Methane [m3/ tonDw]	10-96	Bruhn, et al., 2011		
Protein [g m ⁻²]	0.18	Abudabos et al. 2013, van der Wal, et al 2013		
Energy [KJ m ⁻²]	19	Yantovski, 2008		
Kg CO ₂ per KWh of	0.54	EPA		
natural gas	(Source: Lehahn et al. 2016)			

	ENAlgae2015 FAO 2013		Konda et al 2015	Korzen et al 2015	Seghetta et al 2016	
(seaweed)				Green Ulva Rigid Cult	Brown: Laminaria Digitata	Brown: Saccharinn Latissiine
-		Philippines, Indonesia, Tanzania, India, Mexico, Solomor Islands	refine ry	Israel	Denmark Cefinery	y
Output		Gracilaria (primary	co- production ethanol and alginate	DDGs fish feed and ethanol	co-production: ethanol, liquid fertilizer, fish feed	
	10 kg WW/m Iongline	8-57 WW ton/year/ha		15% daily average growth rate WW		average productivity of 1.5 Mg WW/ha
	twice a year, winter	4 to 8 cycles a year	NA	April-October	Summer	
DW/WW ratio				<mark>1/9</mark>	<mark>1/3</mark>	<mark>1/6</mark>
Yield		Average 0.25	0.15 ethanol	0.12 ethanol 0.6 DDGs	0.005	0.13
costs: ₈	simulated		NREL - simulated	NREL - simulated	NREL - simulated	

	ENAlgae2015		Konda et al 2015	Korzen et al 2015	Seghetta et al 2016	
Conversion technology	not assessed		fermentation	no pre- treatment, single step for the release of glucose, simultaneous fermentation to ethanol		
price to farmer \$/ton DW	9944	500-1000	100 (21-120)	630		
r	r - 5.5%, insurance 0.5%		irr 10%	5%		
reported profitability indicator	Cost per kg WW to selling price		MESP \$6.5– 10.5/gal ethanol; MSP \$ 3.1 alginate (?)	-	LCA ,externalities, no profitability reported; potential for carbon sink, but also for increase in human toxicity (cancer)	
price of output 9	~\$10,000/ton DW	average	MESP \$8.5/gal ethanol, \$3.1/kg	500-5000\$ DDGS, \$79/ton		

Profitability of carrageenan seaweed farming



Analytical needs



Scientific challenge



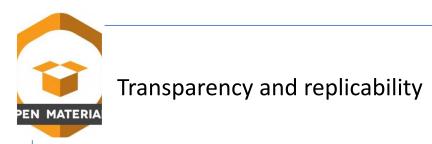
Multidisciplinary effort: how can we reduce the costs and increase yield?



More research on big scale cultivation (take into account market prices for seaweed)



Economic research on generic supply chain of cultivation AND refinery







Outline of the Study in Progress

- Develop an Analytical model
- Run Simulations for Parameters
- Apply real data (collected these days)







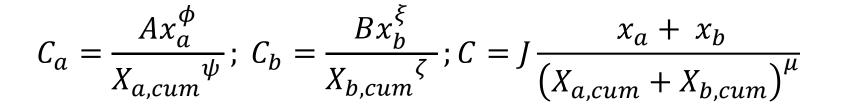
Conceptual Framework

- 2 stages of production:
- 1st stage: Marine farming of seaweed
- 2nd stage: biorefinery utilizes seaweed input to produce outputs (sugars, proteins...)
- Cost functions with learning by doing at each stage
- The producer goal is to maximize profit by determining the volume of seaweed and shares of final outputs subject to volatile prices





Learning by doing cost functions



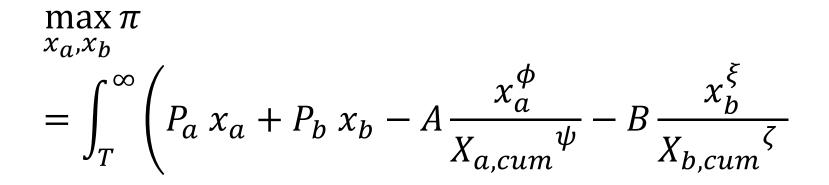
for some $\phi > 1$, $\xi > 1$ and $\mu < 1$.

- $X_{a,cum}$ is the cumulative production of proteins,
- x_a is the production of proteins at this particular moment. Similarly for b
- ψ , ζ , μ are the elasticities of learning by-doing that define the effectiveness with which the learning process takes place
- A, B and J are costs of the first unit produced





Dynamic Profit maximization



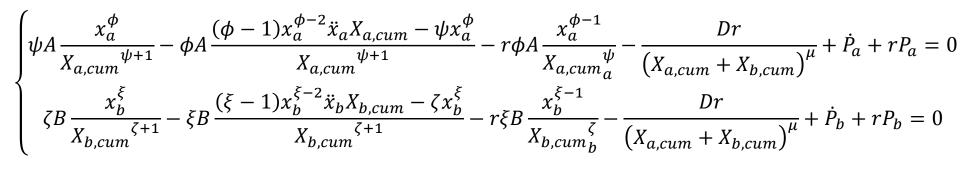
- P_a(t) and P_b(t) the prices of outputs a and b respectively.
- *r* discount factor







First order conditions



 \ddot{x}_a – growth ratio of production – first derivative of x_a





Simulation parameters

- learning rates of 4% on average for mature technologies such as coal, oil and lignite
- new renewable energy technologies such as solar photovoltaic energy exhibit high rates, around 20% on average. (Kahouli-Brahmi, 2008)

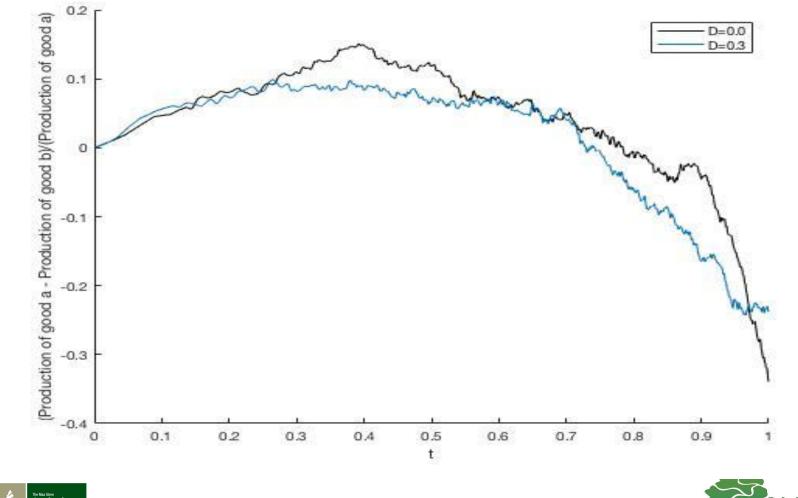
•
$$\xi = 1.2, \psi = \zeta = 0.5, \mu = 0.4.$$

- For simplicity A = B = 1.
- the change in prices is uniform, random with zero expected value.





Simulation Results Preview





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What is Next?

- apply this concept model to assess the profitability of producing biofuels and proteins from macroalgae under various conditions.
- Identify what should be:
 - the learning rate, yield, relative prices, shares of co-products
- for profitable production in the near future



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Natural

sciences

When nothing is going right,

go left

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