Theoretical vs Actual: A Comparison of Cultivation Production Functions
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There is currently a lack of publically available, large scale algal production data. Without production data it is difficult to estimate the economic feasibility of a large scale production facility. Because of this, lack of data, time and again, researchers have extrapolated production from bench-scale studies or theoretical models. Specifically, production models were developed under the Aquatic Species Program (ASP) in the 1990’s and more currently at the Pacific Northwest National Laboratory (PNNL) with their Biomass Assessment Tool (BAT) [1].

Under the National Alliance for Advanced Biofuels and Bioproducts (NAABB) consortium field testing of several algal species occurred. From this, an algal production data set was built. Researchers at New Mexico State University (NMSU) were able to use this data set to estimate an economic algal production function (EAPF) [2]. EAPF takes into account location, species, and seasonal differences, as well as other factors.

The EAPF provides the opportunity to incorporate a production function for large scale farming into an economic feasibility analysis for an algae farm. The Farm Level Algae Risk Model (FARM), developed as a part of NAABB research, is used to conduct an economic feasibility analysis of a 4,850 hectare farm with both the BAT and EAPF algal production information. The technologies developed in and reported by NAABB are used as the foundation for the stochastic simulation [3]. Comparing the theoretical production function with one estimated from actual field data will allow researchers to better understand gaps that occur between the lab and the field, as well as improve economic feasibility analyses.

**Economic Modeling**

The Farm-level Algae Risk Model (FARM) is a Monte Carlo firm level economic/financial simulation model developed by NAABB scientists for analyzing the financial feasibility of algae farms. The model is designed to facilitate analysis of the probability of economic returns and costs of crude oil production for an algae farm under alternative management/technology systems. The model is an integrated systems compilation of several techno-economic models for different phases of a commercial algae farm, but it does not stop there as it includes the financial, marketing, and income tax aspects of a business. The simulation results provide estimates of the probability of economic success for different pathways, as well as the costs of production for algae crude oil and the sensitivity of the costs of production to changes in capital expenses (CAPEX) and operating expenses (OPEX).

**Biomass Production for the Farm was simulated in FARM using the monthly biomass probability distributions from BAT for an algal farm in the Pecos, Texas, area. The BAT model produced monthly biomass yields for 30 years based on simulated monthly weather data for the farm site.**

The 30 years of monthly biomass data were used to estimate parameters for a multivariate probability distribution of monthly biomass production. The multivariate probability distribution of monthly biomass production was used in FARM to simulate monthly stochastic biomass production for the 10 year planning horizon. The production probability distribution is sampled annually for 500 iterations to simulate most all possible production levels represented by the 30 years of Pecos, Texas, weather data used by BAT [4].

**EAPF Scenario**

The EAPF dataset includes 10,316 days of algae growth, from which 495 growth period observations were generated. Regression equation variables include ash free dry weight (ADFW), photosynthetically active radiation (PAR), initial ash free dry weight density, days in the growth period, ambient air temperature, precipitation, algal species and location dummy variables. Locations included two in Texas (Pecos and Flour Bluff) and three in New Mexico (two in Las Cruces and one in Atoka).

The FARM can use EAPF to simulate stochastic algal production for various regions in the South West. The user specifies the location parameters and the associated weather data. For this analysis, the Pecos location was used. During simulation of a 10 year planning horizon the FARM simulates random weather values consistent with the month/year being simulated. In addition, the model simulates stochastic shocks to the projected mean values generated by the EAPF function using the assumed location parameters and realized weather values. The stochastic shocks are simulated from a normal distribution with the mean zero and standard deviation equal to the estimated standard deviation for the residuals from the EAPF econometric model.

**Results**

The PNNL farm produced roughly 76,000 tons (41%) more algae per year on average than the EAPF farm. In the winter months (October through March), the EAPF farm had greater production than the PNNL farm, but this was reversed during the summer months (April through September). Overall, the EAPF production had a much flatter distribution over the course of the year than the PNNL production, which was more seasonally peaked (Figures 1 & 2).

**An economic probability of success was also generated for each combination of CAPEX and OPEX reduction. Combinations having a zero percent chance of economic success were classified as red, while those with a 50% or less chance were classified as yellow. Combinations with a greater than 50% chance were labeled as green. Table 2 displays the number of combinations each scenario had in the red, yellow, and green classifications. The BAT scenario had one more combination classified as green than the EAPF scenario. All in all, both scenarios had 95 or more combinations that resulted in a 0% probability of economic success, even when utilizing the best technologies available.**

**References**