Sustainability-Driven Integrated Landscape Management for Bioenergy Production through the Application of LEAF

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Landscape Environmental Assessment Framework (LEAF) is an environmental analysis platform that integrates environmental models, publicly available data, and financial performance tools for multiple spatial scales at fine resolution. It is designed to model environmental and economic impacts of cropping systems using precision agricultural data sources and environmental models. The agricultural data includes soil attributes, crop rotation, tillage practice, cover crops, nutrient (N) management, and operational expenses. Three environmental models, Wind Erosion Prediction System (WEPS), Revised Universal Soil Loss Equation Version 2 (RUSLE2), and Denitrification Decomposition (DNDC) are part of the LEAF framework.

WEPS is a process-based, mechanistic model that simulates loss of soil from the forces of wind. It uses a range of soil, agricultural management, and climate data to develop daily estimates of soil losses from wind erosion, suspension, and saltation/creep. RUSLE2 simulates rill and inter-rill erosion from surface flow and rainfall and is based on both empirical and mechanistic modeling components. Like WEPS, it uses soil, agricultural management, and climate data and is primarily used in the LEAF framework to estimate soil losses. DNDC is a process-based carbon and nitrogen bio-geochemistry model, and using the soil, agricultural management, and climate data it models the carbon and nitrogen cycles in agricultural fields to estimate changes in soil organic carbon, emissions of CO_2, NO, NH_3, and N_2O into the atmosphere, and leaching of NO_3 into the soils.

Primary data sources that were used to model the grain, biomass, and energy crop productions included the SSURGO Soils database, the DAYMET weather data, and crop productivity data from National Commodity Crop Production Index (NCCPI) and National Agricultural Statistics Service (NASS). Six counties from the US were selected based on the large corn fractions of total grains produced in them - Castro, TX, Cayuga, NY, Dyer, TN, Fillmore, MN, Hancock, OH, and Sheridan, KS. Data for the estimation of production costs and profits for each county were obtained from various crop budget sources within the individual states. Different approaches were used based on survey data, yield to rent relationships, etc., to estimate the subfield-level rental costs.

A baseline LEAF simulation was conducted for 2010 to 2014 for these six counties which resulted in estimates of annual profits and grain productions at subfield levels for all

combinations of grain rotations exercised. Two sets of sustainability criteria were then imposed to control the amount of soils and nutrients lost from the subfields. Simulations using LEAF were then conducted to assess the amount of biomass that could be removed to meet these two, minimal and rigorous, sustainability criteria. Four levels of biomass removal were permitted from a minimum of 0% to a maximum of 83%. This allowed 5-year average estimates of sustainable biomass production to be made for each subfield. Analysis of the grain and biomass results suggested that a significant amount of biomass could be produced on each grain-producing subfield.

Analysis of profitability distributions across the subfields in the counties indicated a substantial number of subfields were non-profitable. These subfields were marked for production of energy crops. Energy crop suitable for each state were identified and new LEAF simulations were conducted to estimate the amount of energy crops that could be produced in non-profitable subfields. These were added to the biomass produced on profitable subfields to develop county-wide estimates of total annual biomass (biomass + energy crops) production. It was determined that depending on the energy crop produced the total biomass increase from baseline varied from county to county. However, when these data were extrapolated to the six-state and national levels, there was a significant increase, from the baseline levels, in the total biomass that could be produced.

Finally, using previous studies on cost and yield relationships for biomass from corn and switchgrass production, estimates of total additional costs, consisting of preprocessing, handling, harvesting, and transportation costs, were made for the two sustainability criteria for each subfield. It was again found that production of energy crops along with biomass from row crops provide higher reduction in cost than with production of biomass on row crops alone.

In conclusion, biomass production can be enhanced by starting production on current row crop subfields and (by production of energy crops) on non-profitable subfields. The total biomass production from these efforts can meet BETO's 2022 goal of 265 million dry tons and the goal of $80/ dry metric ton[1] is more easily achievable through incorporation of energy crops on non-profitable row-crop subfields. These projections of biomass productions are also sustainable from grower's perspective and limits carbon and GHG footprints to the environment.

It is recommended that sustainability metrics to ensure minimal impacts on receiving water bodies should be incorporated into the LEAF-based assessment. Additional, currently unused, tracts of agricultural land should be included in the LEAF-based analysis as potential energy crop production subfields. More detailed, sub-field level biomass cost analysis that takes into account management practices as a function of biomass removal rates and the type of grain and energy crop produced should be conducted to get more realistic estimates of biomass costs.

[1] US DOE, EERE. 2015. Bioenergy Technologies Office Multi-Year Program Plan, March 2015.