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Hybrid Poplar based Biorefinery Siting Web Application (HP-BiSWA): An online decision support application for siting hybrid poplar based biorefineries

Justin Merz[a], Varaprasad Bandaru[b,*], Quinn Hart[a], Nathan Parker[c], Bryan M. Jenkins[d]

[a] Department of Land, Air, and Water Resources, University of California, Davis, CA, United States
[b] Department of Geographical Sciences, University of Maryland, MD, United States
[c] School of Sustainability, Arizona State University, United States
[d] Department of Biological and Agricultural Engineering, University of California, Davis, United States

ABSTRACT

Hybrid poplar has potential as feedstock for the production of bioenergy and bio-based products. Planning effective placement of hybrid poplar based biorefinery facilities takes tremendous time and financial resources. A hybrid poplar based biorefinery siting application (HP-BiSWA), a web-enabled refinery siting application, was developed so that potential stakeholders may quickly assess available resources at selected locations and provide information relating to the economic competitiveness and financial risks associated with construction and operation. At present, the tool supports evaluation of the potential for hybrid poplar based jet fuel and acetic acid production based on user-specified conditions. The application is generally expandable to other feedstock, technology, and product types. HP-BiSWA uses various modules (i.e. 3PG-crop growth model and farm budget application) and services (i.e. parcel service, transportation routing service, crop service, soil and weather services) to retrieve and estimate information to optimize and select potential parcels for poplar cultivation, and ultimately determine net revenue for biofuel production under selected decision options.

To demonstrate the utility of HP-BiSWA, a case study analysis was performed for Centralia, WA based on a 380 ML/yr (100 MGY) jet fuel biorefinery using two scenarios: (1) a 175 km feedstock supply radius with 50% pastureland use, and (2) a 225 km feedstock supply radius with 25% pastureland use. The case study captures the interactive effects on biorefinery performance with changes in feedstock supply area and available water, power, and other resources for operation of the biorefinery.

1. Introduction

Biofuels are considered an essential element of renewable energy that could help develop energy independence, support environmental stewardship and spur rural economies (Chum and Overend, 2001; Tilman et al., 2009; Jenkins et al., 2009). Researchers have extensively investigated hybrid poplar [*Populus* spp.] for the production of bioenergy for reasons including its fast growth, ease of cultivation, easy adaptation to new climates, and its ability to offer a wide range of other benefits (e.g. lower greenhouse gas emissions, improvement of soil and water quality and biodiversity) (Bradshaw et al., 2000; Yemshanov and McKenney, 2008; Hinchee et al. 2009; Wang et al., 2013; Camargo et al., 2013). Although hybrid poplar has already been recognized as a potential feedstock source for low-carbon biofuel production, commercial deployment is not yet realized. This is due in part to a lack of clarity around resource availability (e.g. land and water resources for popular cultivation) for construction and operation of biorefinery facilities, and that the investment pro forma does not project sufficient revenue to attract investors (Bandaru et al., 2015). Addressing these issues requires the development of precise and fine-scale spatial data on both potential locations for hybrid poplar production and biomass supply potential, as well as transportation and utilities infrastructure. Further, a comprehensive modeling and analysis framework is needed to evaluate economic competitiveness and financial risks of biomass-to-biofuel conversion technologies under various economies of scale for given sites.

Several biorefinery siting models have been developed (Panichelli and Gnansounou, 2008; Parker et al, 2010, Kim et al., 2011; Delzeit et al., 2012; Bandaru et al., 2015) to site the biorefinery locations in relation to the costs of all elements in the supply chain. These models are generally based on optimization algorithms and methods. For instance, Parker et al. (2010) developed the Geospatial Bioenergy System Model (GBSM) based on mixed integer linear programing that considers spatial information on feedstock resources, existing and potential refinery locations and transportation routes, and provides optimum locations and sizes of biorefineries based on a maximum profit objective

* Corresponding author.
E-mail address: vbandaru@umd.edu (V. Bandaru).

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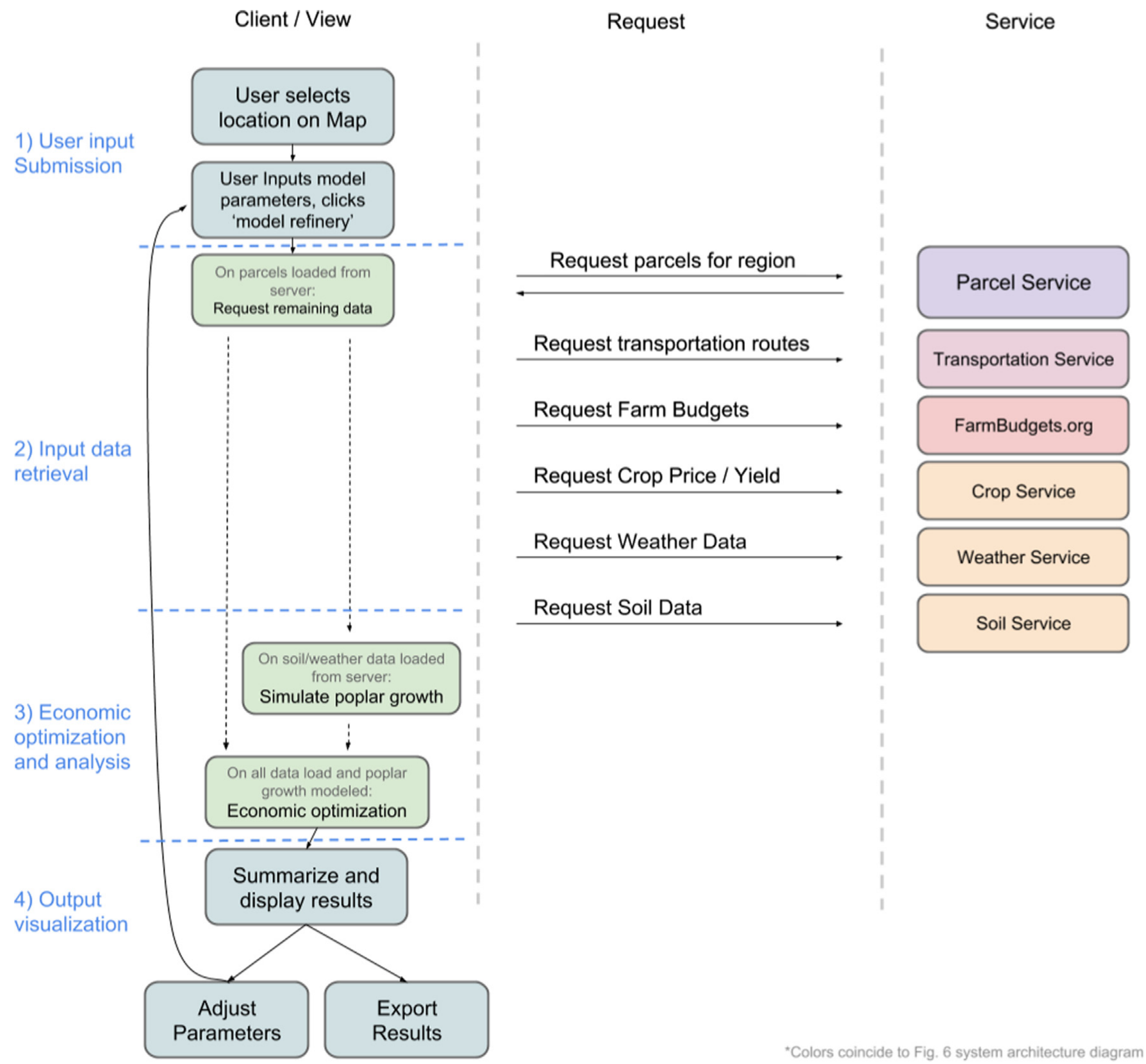

Fig. 1. HP-BiSWA decision support workflow. Blue and green colored boxes represent front-end side elements and client side processes, respectively. Server side services are represented in different colors. Services with orange color boxes associated with 3PG-CG model.

function. Recently, GBSM has been customized to site hybrid poplar based biorefineries (Bandaru et al., 2015). However, these models are designed based on sequential computing for personal computers and single use access, not for online sharing.

A web-enabled siting application allows planners, investors and other stakeholders to quickly access and evaluate locations of interest as well as understand feasibility of and barriers to biorefinery establishment (Lin et al., 2015). When developing a biorefinery, planners consider numerous decision factors, including facility capacity and economies of scale, conversion technology, public policy, facility location, and biomass availability. Interactions among these and other decision factors strongly influence investment, return, and long-term success. A web-enabled application allows users to more easily assess locations of interest and understand the economic tradeoffs. Investors can evaluate existing infrastructure and resource information, and predict project development costs and competitiveness of energy systems.

Currently, there are limited web-enabled biorefinery siting applications. One such application is BIOFLAME (Biofuels Facility Location Analysis Modeling Endeavor), which was developed using Visual Basic.NET and ArcGIS Engine 9.3 to site switchgrass (*Panicum virgatum* L.) biomass based ethanol facilities (Scott, 2009). Another is BioScope, which is based on the CPLEX solver and ArcGIS, to optimize biomass based ethanol production systems (Lin et al., 2015). Both BIOFLAME and BioScope require commercial software programs that may lead to problems with application continuity and management. The use of open source software, however, minimizes the application management costs and ensures continuity with a minimum amount of financial support.

Unlike its commercial counterparts, the Hybrid Poplar based Biorefinery Siting Web Application (HP-BiSWA) leverages open source software programming packages and in-house modules and services to assess individual sites across the U.S. Pacific Northwest (PNW) region for further insight into the economic competitiveness and financial risks of hybrid poplar based jet-fuel and acetic acid production facilities. The approach may be extended to other feedstocks, products and regions as well. Further, this application can be used by different stakeholders (e.g. planners and investors) to quickly access and evaluate locations of interest. The objective of this paper is to describe architectural design of the HP-BiSWA and its development along with examples of its implementation and use.

2. Software overview

The HP-BiSWA integrates various models and tools that represent the elements of poplar-based biofuel supply chain, including: feedstock production, transportation network costs, facility-specific technical and economic (technoeconomic) performance and optimization of the supply chain. The underlying models and tools on the feedstock supply