An Innovative Approach to Identify Regional Bioenergy Infrastructure Sites

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Abstract

The Northwest Advanced Renewables Alliance (NARA) has been formed with initial funding from the USDA-NIFA (U.S. Department of Agriculture – National Institute of Food and Agriculture) program to produce aviation biofuels and co-products from woody biomass. Innovative products such as bio-jet fuel (biojet) combine numerous scientific and technical developments to address a significant social need. In order for these innovations to become truly transformational, however, a supply chain of sufficient size must be employed for building and sustaining regional, national, and eventual international impact. Developing major new supply chains for natural resource-based industries must engage communities that represent a convergence of natural resource availability, physical supply chain assets, and a social will and capacity for collective action directed toward sustainable economic development.

This paper describes the development of multiple empirical quantitative measures for core dimensions of community assets. These measures are used to assess community-level resilience and adaptability to change arising from social capital, civic engagement and creative vitality. Community-level social capital and creative capacity, combined with an analysis of physical asset constraints, are merged through GIS application to better understand key community supply chain issues with regard to regional bioenergy infrastructure projects. This knowledge can then be used to develop a more complete understanding of how community social capital and creative capacity might play an important role in building community support for or addressing community opposition to regional bioenergy infrastructure projects.

Keywords: Biofuels supply chain, bioenergy, creative capacity, social capital, GIS

Introduction

The Northwest Advanced Renewables Alliance (NARA) initiative is focused on developing socially acceptable and economically viable biofuel solutions for the United States Pacific Northwest (PNW) region. Under this project, we are exploring various metrics, methods and analyses to identify potential communities in the PNW states of Idaho, Montana, Oregon and Washington that are “physically” and “socially” able to accommodate and accept potential NARA infrastructure/supply chain nodes and biofuel markets. This paper specifically provides an introduction to some of the physical and social asset tools being developed and deployed to better understand, identify and delineate these NARA communities.

Determination of these pilot communities will be greatly facilitated through an in-depth study using Geographic Information Systems (GIS) to visually display and screen the physical assets and county-level social data, which will enable us to evaluate the creative health and social structure for each state. The advantage of using a GIS-based approach is that both spatial and non-spatial data can be assembled and compared simultaneously using a single quantitative analytical platform. Communities that rank high in both biogeophysical and social characteristics will be considered for final selection as a pilot program. Once the pilot communities are selected, a field study of local stakeholder perceptions will begin to assess the level of receptiveness of various stakeholder groups to the placement of biofuel supply chain nodes in their immediate environment and/or to the adoption of aviation biofuel. This assessment will allow us to “ground truth” our model.

Some of the key physical factors used to determine a site’s suitability are proximity to major road and rail, pipeline and petroleum terminals, location relative to major feedstock sources, and a sufficient workforce. Next, Index of Relative Rurality (IRR) scores were considered to determine if population centers of sufficient size and diversity of workforce elements (nearer to 0 on the IRR scale) are located in areas proximate to biomass and related biogeophysical assets. IRR scores indicate potential sites with a population base of sufficient size and scope (typically a “micropolitan” census designation) to permit an effective stakeholder engagement process to explore the potential for collective action around key biomass and biofuel infrastructure as a form of sustainable economic development for their community.

The social characteristics this paper uses to define a promising community include a strong creative arts economy (surrogate for creative thinking capacity), apparent potential for collective action (evidence of social capital attributes), the types and structure of social networks (organizations in which social trust and collective action skills are developed), and support for civic activity (e.g., volunteering). Creative Capacity was examined through the use of the Creative Vitality Index (CVI). CVI serves as a surrogate indicator for the health of the creative arts economy (performing, creative and literary) of a county based on the presence of arts-related businesses, members of the workforce, and non-profit organizations. The work of Richard Florida reported in *The Rise of the*

Creative Class (2002) highlights the strong connection between the presence of these arts-related aspects of local communities and their potential for economic development. The data for US counties were provided by WESTAF (Western States Arts Federation).

Social Capacity was examined with measures of social capital derived from the work of Rupasingha and his colleagues (2000; 2006). The particular two measures used in this project entailed per capita scores for the presence of non-rent seeking organizations[1] and overall social capital scores reflecting: a principal component factor analysis combining non-profit density, census survey participation rate, voter participation level and associated network density. Social Capital, a crucial component of the social assets of a geographical area, is based on an identifiable set of the behaviors, attitudes and values of citizens (Coleman 1990; Putnam 2000; Halpern, 2005) and is the resource that emerges from "the norms and social relations embedded in the social structure of societies that enable people to coordinate action to achieve desired goals" (Borgada et al., 2002). This coordinated collective action is based heavily on "trust", which facilitates the formation of networks and is produced within networks. In turn, these networks are capable of producing purposeful civic activity to achieve shared goals (Coleman, 1988, 1990; Halpern, 2005; Putnam, 2000).

Combined, the paper's biogeophysical and social assets describe both the structural and socio-political components of each community and, in combination with their spatial coincidence, will contribute importantly to the final selection of pilot NARA communities in the four U.S. Pacific Northwest states. This paper's analysis is limited to the evaluation of Montana counties as an illustration of the process.

Methodology

Physical Assets: In order to identify the candidate communities, a GIS analysis was performed on both the physical and social assets in Montana. The physical attributes considered for the analysis include: cities (location and population), major road network, railroad network, 2004 forest residue data (county-level), refined products pipelines, pipeline terminals, and refineries (Figure 1). Assumptions made in this project are based upon the work of Zhang et al. (2011): only cities with a population greater than 1,000 will be considered for potential biofuel facility locations to ensure the availability of a work force; and, potential cities should be located within one mile of state/federal road and railroad networks to ensure that feedstock and co-products can easily be transported. In order to minimize transportation costs, it is important that the conversion facility be located near a pipeline terminal. The terminal will serve as an input point for the finished product, isobutanol. From the terminal, the fuel can then flow to a refinery to be converted into the final product, bio-jet fuel. Using a pipeline will greatly reduce transportation costs, which translates into cheaper overall prices for the aviation biofuel.

A spreadsheet of forest residue volume by county (2004 data) was added into GIS and joined to the county shapefile. The symbology of the County shapefile was changed to graduated colors, and the forest volumes were divided into 6 manually-determined ranges. No data was given on the volume of forest products removed in certain counties

[1]Non rent-seeking organizations: Government restrictions on economic activity produce economic and social benefits called "rents", through licenses, lobbying, restrictions etc. for certain sections of the economic society, at the expense of other sections. Organizations that seek to increase the overall economic wealth instead of capturing "rents" are known as "non rent-seeking organizations" (Krueger, 1974).

in north-eastern Montana and those counties with under 500,000 cu. ft. of forest residues were not color-shaded on the map, resulting in 18 Montana counties with suitable forest residue volume for subsequent consideration and analysis (Figure 1).

ESRI's ArcGIS v.10 ModelBuilder program was used to assess the region's physical assets because of the relative ease with which models can be created to run a series of commands simultaneously in order to solve complex problems. Within the ModelBuilder tool, a weighted analysis can be performed to assign weights to the layers and scaled values to data within a layer, thus enabling the user with a way to compare and prioritize vastly different datasets using the same numerical scale. The ModelBuilder tool was used in this project to identify well-suited communities based on their physical attributes.

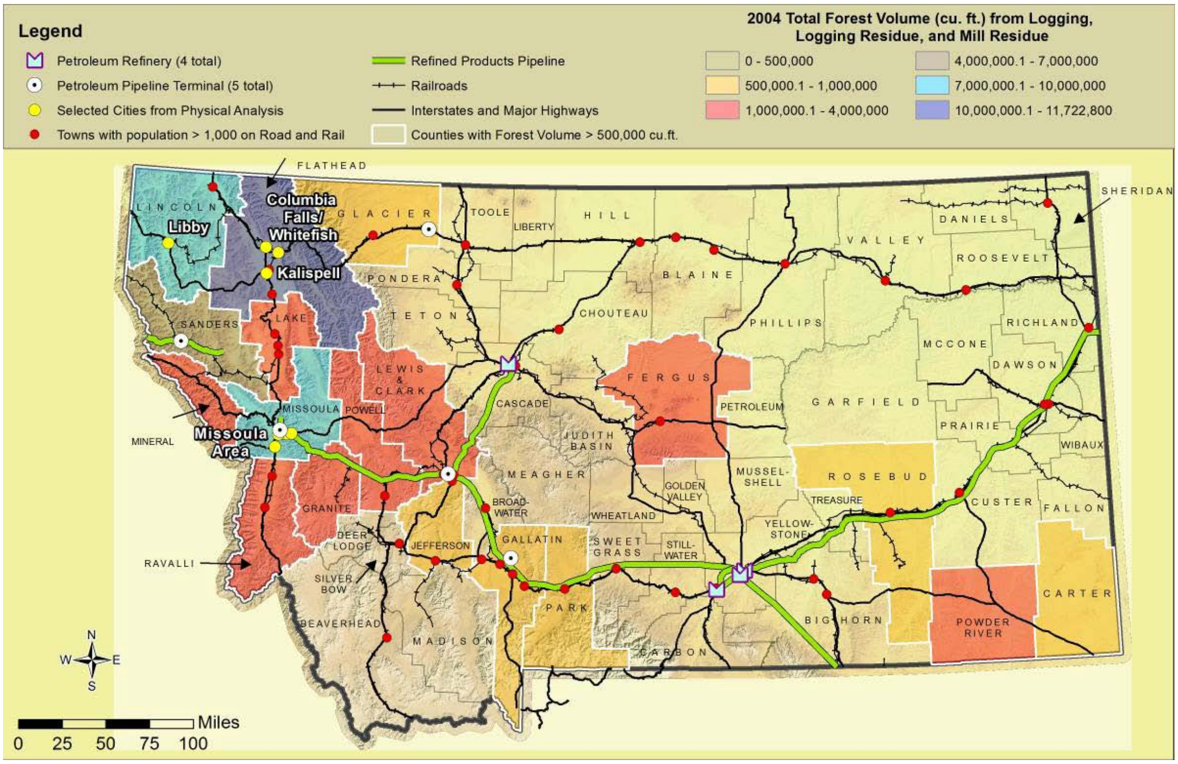

Figure 1. Base Map of Montana with Physical Assets and the 18 Counties with more than 500,000 cu. ft. of Forest Residue

Index of Relative Rurality: We also assessed the degree of "rurality" of a geographical area. To this end we have made use of the IRR, which estimates the degree of rurality of each county, with scores closer to 0 indicating a high level of urbanization and scores closer to 1 representative of high rurality. The IRR is based on four dimensions: population size, density, percentage of urban residents, and distance to the closest metropolitan area (Waldorf, 2006). The counties with scores nearer to 0 on this index that also feature high social asset scores AND spatial proximity to biomass sources and related structural assets will clearly be good candidates for consideration as potential NARA biofuel pilot communities.

Social Assets:

i) Creativity Vitality Index: Creative Capacity assessment was conducted by comparing the creative vitality of the counties within Montana to that of all US counties through the use of the Creativity Vitality Index (CVI). The CVI is an evaluative measure of the health of the creative economy of a given geographical area compared to the national index, and creates a benchmark for future measurement (Western States Arts Federation, 2010). The CVI is a composite score based on two components in a 3:2 ratio that weighs community participation in the arts and concentrations of arts-related employment. Each geographical area is evaluated on these components for the measurement of its CVI score. The national CVI is set at 1.00. This analysis is based on CVI scores of counties and states relative to the national CVI score in 2008.

ii) Social Capital: The level of supportive collective action expected from a particular county is measured through the following two measures:

a. **Putnam Groups (PG) Score:** The sum of per capita presence of non-rent-seeking groups multiplied by a constant for all US counties and has been estimated from various public sources (principally US Census-based statistics and derivative governmental and research centers) by Rupasingha, Goetz and Freshwater (2000). This data has been used in prior studies to predict community-level adaptation to economic change (Rupasingha et al., 2006).
b. **Overall Social Capital (OSC) Score**: This score represents the results of a factor analysis combining, in a single measure, per capita information on all organizations, turnout levels in presidential elections, rate of participation in the US census survey, and the number of tax exempt (non-profit) organizations in each US county.

High Social Capital and CVI scores reflect communities rich in social and creative capital and aids in predicting communities that may act collectively upon the opportunities that engagement with advanced renewable biofuel production presents for the NARA region. Less rural counties with high biomass availability and rich in social attributes may be considered as most suitable locations for pilot programs. Also, more rural areas that are proximate to relatively larger towns with greater biomass availability may also be considered for the pilot program as potential supply chain “procurement” nodes. The literature on “assets-based community development” is replete with examples of communities that have been able to mobilize their social capital and creative problem solving assets for the promotion of community-based economic development and local institutional sustainability.

The social asset analysis using GIS initially involved comparing the IRR values for each county against the highest forest residue-producing counties in the state. Since potential NARA pilot communities must be located in a region with high volumes of biomass, ***the goal is to identify those counties that have high forest residue yields yet also possess suitable human resources to capitalize on the economic development opportunities that may emerge.*** From these communities, we examined the social and creative capital potential. This process leads to geographically-based communities of sufficient size to permit NARA to engage a sufficient number of stakeholder representatives to facilitate a collaborative process directed toward collective action related to sustainable biofuel production.

Analysis

Physical Assets: In ArcGIS v10, the assumptions were implemented by selecting only those towns in Montana with a population of greater than 1,000 and by creating a 1-mile buffer around all major roadways and railroads. A Euclidean Distance raster of the pipeline terminals within Montana was created to determine the distance from any point in the state to the closest terminal. The resulting raster was then reclassified using the Reclass tool in Model Builder. The distances were divided into 10 equivalent ranges of 40 miles and were assigned a corresponding numerical score from 1-10, with a 10 being the closest to a terminal (0 – 40 miles from a terminal), a 9 being 40 – 80 miles from a terminal, etc. (Figure 1).

The Weighted Overlay tool was then used in Model Builder to combine the buffered road and rail, forest residue volume, and petroleum terminal distance rasters into one weighted raster. All four inputs were given equal weight (25%). Scaled values were assigned to the data within each layer as follows: for the buffered road and rail, any area inside the buffer was given a score of 10 and any area outside the buffer was given a score of 1; the terminal distances were ranked as indicated above; and the forest volumes were ranked with the highest volume range given a score of 10, the lowest volume range a score of 5, and any county with no forest volume data a score of 1. The weighted output raster consists of values ranging from 1 to 10, with a score of 10 indicating those stretches of buffered road and rail that are close to a terminal and in a high-producing forest residue county, and a score of 1 indicating those areas that are outside of the road and rail buffer, have no forest residue volume data, and are located far from a terminal. Nine towns were located in a region with a rank of 10, and include the Missoula area in Missoula County, the Kalispell/Columbia Falls/Whitefish area in Flathead County, and Libby in Lincoln County (all in the northwest region of Montana). These towns may be suited to host a conversion facility based on their county's forest residue volume and their proximity to road, rail, and a pipeline terminal (Figure 1)

Index of Relative Rurality (IRR): Table 1 shows the 18 Montana counties with a forest residue volume of over 500,000 cu. ft. and their corresponding IRR. Those counties with IRR values closer to 0 exhibit relatively lower rurality (higher urbanization) and hence are hypothesized to be better equipped to support NARA infrastructure/supply chain nodes. Accordingly, Table 1 provides IRR detail along with forest residue volume, and social asset scores. Flathead, Missoula, Powell, and Lewis & Clark exhibit both high forest residues and low IRR scores. These counties may be likely candidates for NARA community consideration (Table 1).

Social Assets: Table 1 provides social asset scores for the 18 counties exhibiting forest residue volumes greater than 500,000 cu. ft. Of the three western Montana counties with the greatest forest residue volume, Flathead and Missoula have CVI scores higher than the national average score of 1.00, indicating higher per capita presence of arts and culture related industries, organizations and occupations as compared to the nation. Missoula is in the top group in regard to overall social capital and Lincoln and Flathead are in the top group for the non-rent-seeking networks (Putnam Group scores) (Table 1). Lincoln's relatively high IRR and Putnam Group score and low CVI score, combined with a large biomass volume and close proximity to Flathead, suggest its value as an important source of biomass material.

Table 1. Top 18 Counties Based on Forest Residues (cu. ft.) (2004) and Corresponding IRR Scores (2000), CVI Scores (2008), PG (2000) and OSC (2009)

County	**Forest Residue (cu.ft.) 2004**	**IRR 2000**	**CVI 2008**	**Putnam Groups 2000**	**Overall Social Capital 2009**
Flathead	***11,722,800***	***0.531***	***1.203***	***13.388***	***0.693***
Lincoln	***8,310,650***	***0.654***	***0.539***	***13.850***	***0.713***
Missoula	***8,280,130***	***0.316***	***1.620***	***9.345***	***1.533***
Sanders	5,547,260	0.72	0.313	10.728	1.018
Powell	3,629,180	0.500	0.644	5.656	-0.084
Mineral	2,767,250	0.73	0.362	13.423	1.463
Lake	2,465,490	0.589	0.492	10.260	0.356
Granite	1,713,000	0.75	0.669	3.799	1.599
Powder River	1,681,880	0.88	0.571	20.953	4.511
Lewis and Clark	1,475,520	0.418	0.925	11.643	2.144
Fergus	1,428,070	0.598	0.496	17.603	1.665
Ravalli	1,158,790	0.614	0.743	9.261	0.654
Jefferson	964,112	0.74	0.622	2.025	0.565
Glacier	714,777	0.611	0.378	10.247	-0.472
Carter	693,280	0.91	0.251	13.307	2.541
Park	651,528	0.594	1.035	13.828	1.844
Gallatin	613,440	0.540	1.698	11.127	0.663
Rosebud	604,019	0.75	0.333	9.795	1.038
National Ave.	**--**	**--**	**1.00**	**11.78**	**0.00**

This preliminary analysis focused on Montana and its counties. Going forward, we will analyze all four states in the PNW region to shortlist counties hypothesized to be suitable for NARA activities. Table 2 compares the social attributes of the four NARA-region states to corresponding national scores. The CVI scores for Washington and Oregon are higher than the national mean score of 1.00, indicating a higher per capita presence of arts and culture related industries, organizations and occupations in these areas as compared to the nation. Montana scores are close to the national CVI mean score whereas Idaho lags the region and nation. In terms of PG and OSC state scores, Table 2 shows that, compared to the other states, Montana has a high non-rent-seeking score as well as a high overall social capital score. In the cases of Idaho, Washington and Oregon, the same benefit of simultaneous consideration of biogeophysical and social assets should be apparent. Each of these states features substantial socio-economic diversity, and the best fit to the needs of the potential sustainable biojet supply chain for the Pacific Northwest will require careful and considerate site selection and stakeholder engagement in the most propitious communities.

Table 2. CVI, PGS and OSC Scores for the PNW Region

Region	Country	CVI (2008)	Putnam Groups (2000)	Overall Social Capital (2009)
Idaho	United States	0.662	6.89	-0.358
Montana	United States	0.921	12.03	1.622
Oregon	United States	1.018	9.61	0.366
Washington	United States	1.014	10.85	-0.518
National	United States	1	11.78	0

Conclusions

The results from the physical attribute analysis suggest the communities of Libby (in Lincoln County), Kallispell/Whitefish/Columbia Falls (in Flathead County) and Missoula (in Missoula County) may be likely candidates for a NARA community based on their proximity to major road and rail, pipeline terminals and high biomass volumes. The results from the social asset analysis indicate that Missoula, Lewis and Clark, and Yellowstone Counties all are less rural, highly urbanized, and have a high potential for creativity and forming networks. Thus, the final selection for our initial target NARA community will be the Missoula greater area in Missoula County, since it contains the desired traits of having both high physical and social assets.

Limitations

First, this paper is limited to Montana and its counties. An in-depth study of all four PNW states and counties is the next step in the ranking and identification of potential NARA communities. Second, this paper provides an initial analysis of biogeophysical and social asset measures and is intended as a primer on the potential metrics, methods and analysis that may be deployed to efficiently determine potentially favorable sites for sustainable economic development activities. Use of CVI scores may be seen as an indicator of a community's willingness and capacity to take on and/or identify innovative solutions to addressing NARA community challenges. The Putnam Groups and Overall Social Capital scores address two dimensions of social capital as networks and may be viewed as the presence of collective capacity to mobilize the political and policy resources necessary to make those solutions happen.

Future work will refine scales and develop additional metrics and indices to further delineate potential sites in Montana and the other three NARA states of Idaho, Oregon and Washington. Finally, these protocols provide an efficient way to quantify conditions conducive to biofuels siting acceptance and, as such, represent powerful tools for developing hypothesis for further testing with the development of on-the-ground validation work protocols.

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