Idaho National Labs biomass supply costing study

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Abstract

The Idaho National Laboratory (INL) has developed an economic model for the delivery of agricultural residues from the field to the biofuel processing plans. The model derives costs for in-field activities as well as loading and transport costs from field to biorefinery. The model calculates delivered feedstock costs based upon a single feedstock species, supply chain configuration, and user defined transport distance

In this study, we performed the INL model on a fine scale within a Geographic Information Systems (GIS) environment. This allows for small changes within a feedstock to be assessed. Using this method, we can compare to the more generalized INL model and test the accuracy of using a simplified modelling of the geographic resources.

As this level of information is not generally available to a planner, this model and also supply good representative input parameters to the INL model.

1 Objectives

2 Methods

2.1 Agricultural Biomass

- Some of the most promising biomass feedstocks are Ag. residues

- Residue feedstocks need to make economic sense
  - Now and in the future
  - About a third of the cost is from procurement and transportation of feedstocks
- INL has a sophisticated model for calculating costs of residue harvesting, storage, and transportation.
  - Basically can model individual farms
  - Corn and wheat test cases
  - Selected counties in IA and KS

2.2 Available Data

- Agricultural estimates of crop type and yields. *Ag. Statistics*
  - Basis for future estimates
- National Cropland Data Landcover *Ag. Statistics*
  - Satellite based
  - About 24 crops
  - Fairly accurate but confused by roads, etc
  - Includes Other Land Cover, non-cropland
- SSURGO Soils
  - Mapped out soil types
  - Components
    - Land capability
    - Some common crop information
    - Typical yields
    - Erosion factors

2.3 Requirements for INL

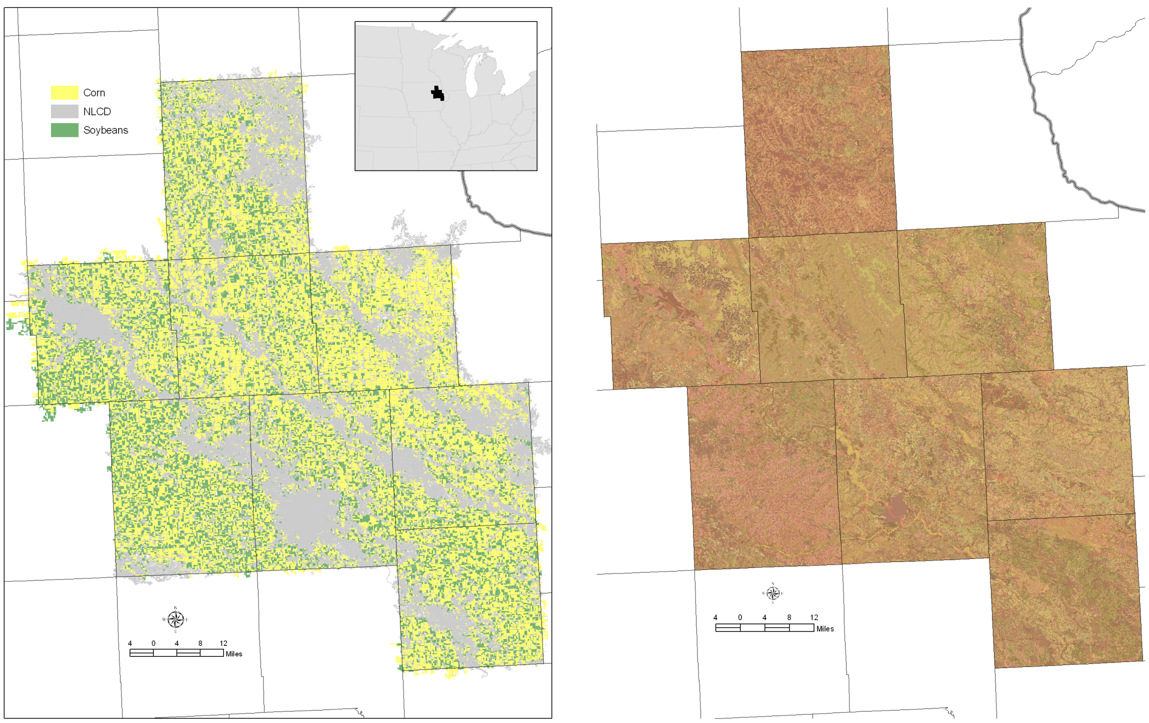
Need information on a per farm basis within a county. Not for any particular time, so these are not real farms but likely farms.

- Need to locate where crops are planted within a county
- Need to avoid public lands, cities, lakes, etc.
- Since yield is important, need to match amounts harvested
- Need reasonable blocks of area
- Need to know soil type for erosion control

2.4 Plan

- Create pseudo-farms (or fields)
- Assign crops to the farms (based on suitability)
- Assign each farm parameters for running their model
  · Land
  · Yields
  · Erosion factors
- Can change number of farms for different years, predictions

3 Study area



(a) Crop types (b) SSURGO Soils

Fig. 1. Study Area

3.1 GIS Model Development

The purpose of the GIS model for this program is to supply inputs to the Genetic Algorithm Modeling System (GAMS) optimization model. These inputs include; the total amounts of various feedstocks available; potential biorefinery locations; transportation costs from feedstock sources to biorefinery locations.

4 Feedstock modeling

Figure 2 shows a basic overview for determining the variation on harvest yield for an agricultural region. The process involves dividing the region in to representative pseudo farms, deciding on whether these farms are in production based on a land cover map, and then assigning variable yields based on the county estimates and underlying soil types.

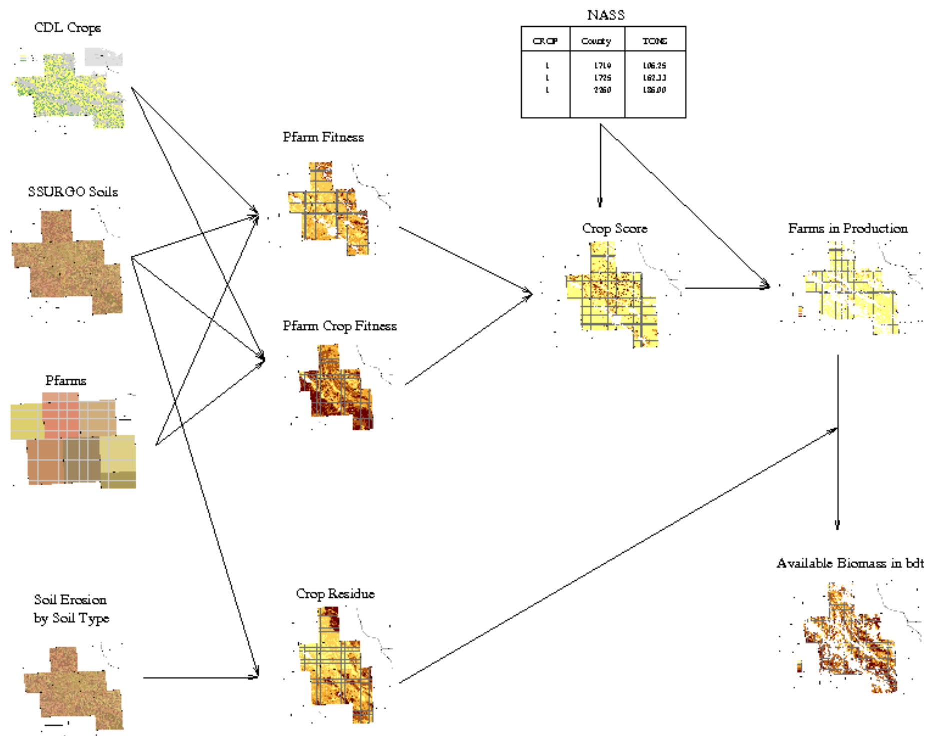


Fig. 2. Overview

4.1 Pseudo-farms

First, the region is divided into a series of *pseudo-farms* (Figure 3(a)). These are matched to a standard grid as opposed to trying to match any real farm delineations. A standard grid is chosen to provide some faster image processing for some national level datasets, like land cover for example. Pseudo-farms are needed to divide the area into workable sizes.

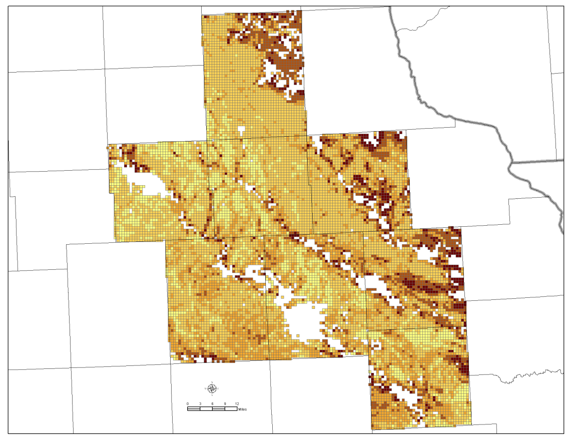
For each pseudo-farm, a number of fitness variables are assigned, to try and determine where crops will be grown, and their yields.

Farm fitness (Figure 3(b)), is a score without a specific crop which gives the total amount of arable land and the average land capability. Farms need to be more then 10% arable to be included. Otherwise it is considered not farmed.

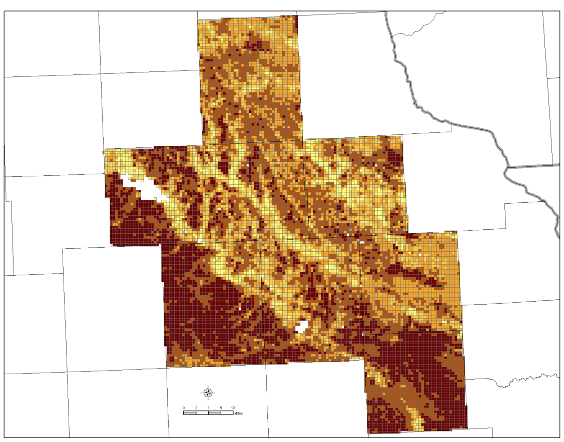
For a specific crop, *Pseudo-farm crop fitness* (Figure 3(c)), calculates the amount of area either identified as that crop, or identified as typical crop for the underlying soil types. Also calculates expected yield for crop.

The *Farm crop score* combines NASS cropland types and SSURGO fitness, for the crop and in general. Areas with both get scored highest.

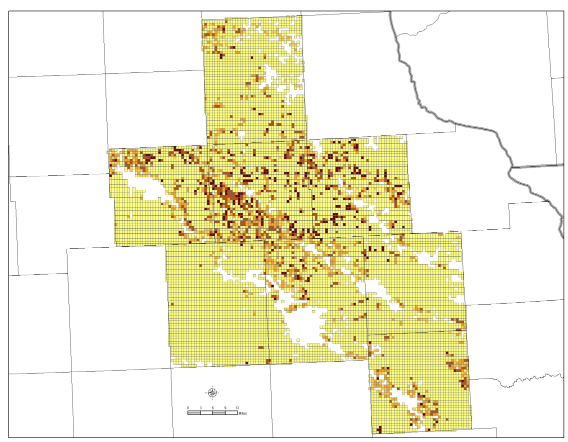
(a) Pseudo-farms



(b) Pseudo-farm fitness



(c) Pseudo-farm crop fitness



(d) Pseudo-farms Score

Fig. 3. Pseudo-farm scoring

Now for a particular crop type and expected acres harvested the most likely pseudo-farms to be planted are selected. Actual, per-county production amounts are used to get pseudo-farms in production for a specific year. Once the farms are selected, we adjust the yields within the farms to match the total county output. Use an average yield for soils without crop yields (Figure 4(a).

Once yields are calculated, the amount of biomass recovered needs to be determined. Each pseudo-farm has a soil type and slope that affects how much residue needs to be left on for tolerable soil loss (Figure 4.1).

Use the bushels of predicted corn to estimate the standing biomass, and remove the residue needed, to produce a map of standing biomass per pseudo-farm (Figure 4(c)).

5 Results

Eight counties were modeled in this study. From the total amount of biomass available from these counties, four refineries were located to process the biomass. The refineries were located using a k-means clustering on the total amount of feedstock, as a method of approximating equally sized refineries.

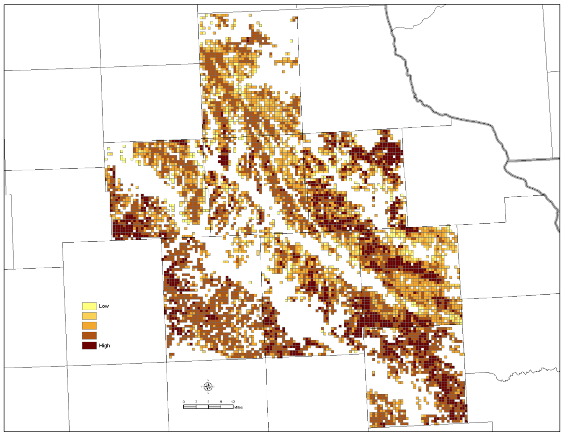
Figure 5(a) shows location of the refineries and the expected destination of the feedstock for each refinery. This model is the result of running a network model that includes all roads within the region, and assigning each pseudo-farm to the refinery closest to it. The map shows that despite this more accurate networking model, feedstocks generally are assigned to the most geometrically proximate feedstock location. Also, when refineries utilize all feedstock, then the feedstock "sheds" of the refineries are necessarily well modeled as circular patterns.

Figure 5(b) shows a breakdown of the actual travel costs associated with the individual pseudo-farms within a refinery region. These costs only include the on-road time costs, and do not include farmgate, loading, or unloading costs. As will be seen, this contributes most to the variation in the supply curves for feedstock availability.

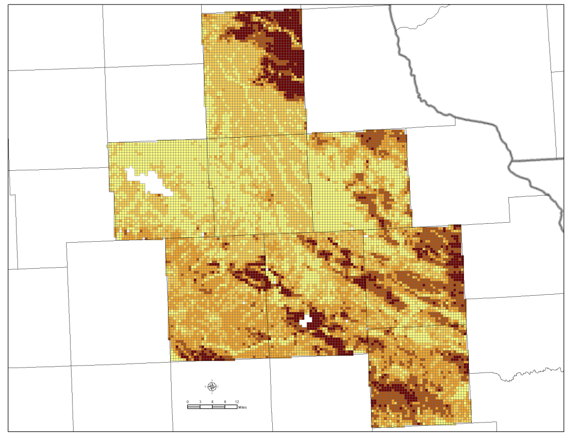
5.1 Supply curves

Figure 6 shows the individual supply curves for the 5 refineries in the study region. The figure shows that despite the differences in the harvest yields, and transportation infrastructure, the general shape of the curves are fairly consistent.

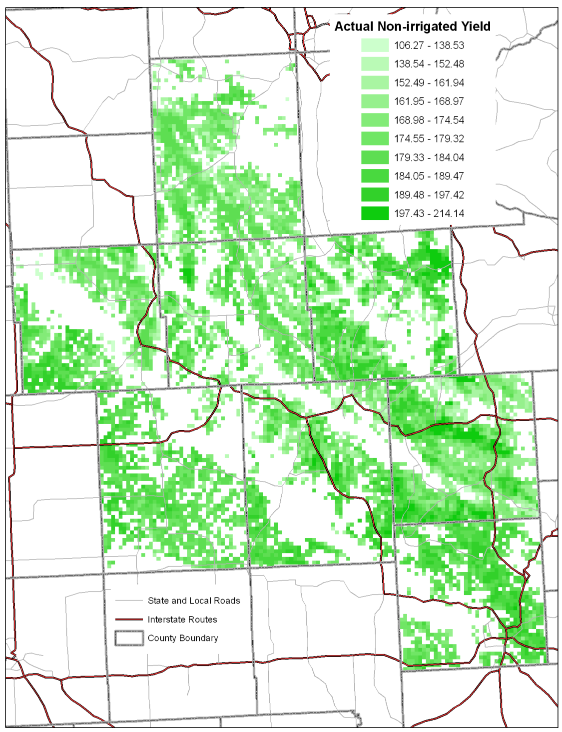
Figure 7 shows this same data as a histogram, which identifies the range of costs for feedstocks. Farmgate costs can be affected both by the amount of arable land in the region as well as by the harvest yields of the biomass. In general, however, these vary less than



(a) Pseudo-farms in Actual Production



(b) Crop residues

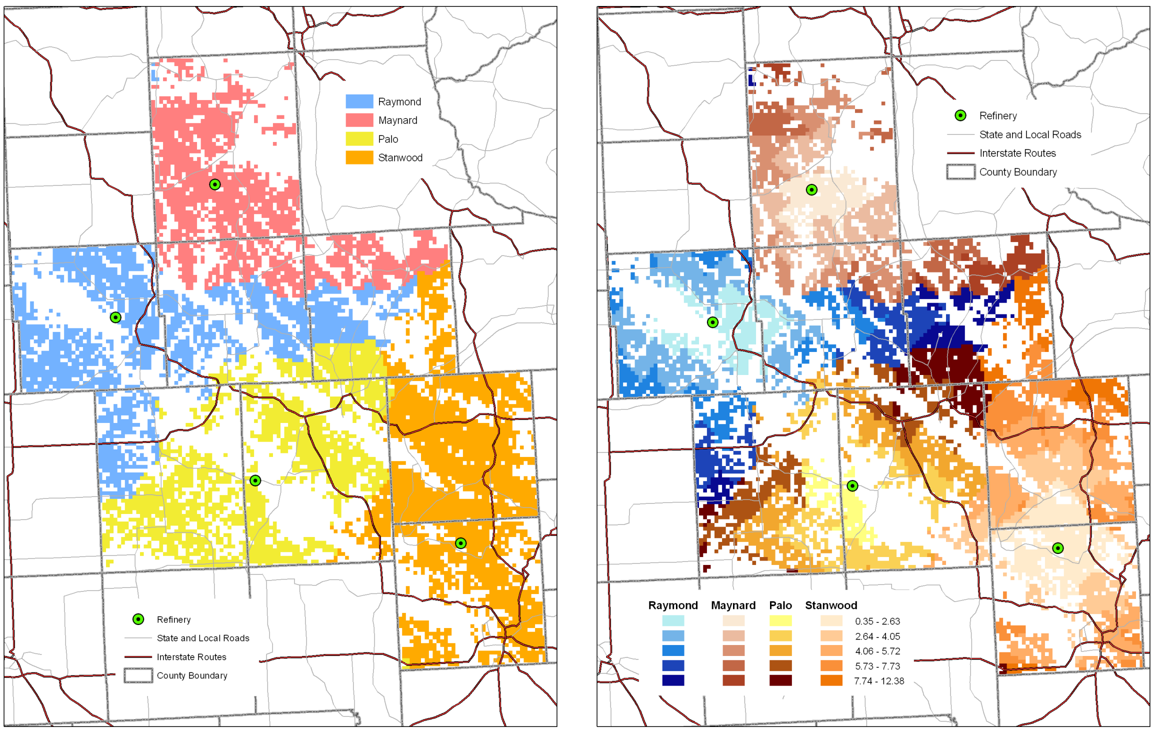


(c) Pseudo-farm yields

Fig. 4. Pseudo-farm biomass

the transportation costs. Transportation costs are affected by how far the biomass needs to travel, and in some extent to the speed of the roads being used. Figures 8 and 9 show the various contributions from the farmgate costs and the transportation costs of the feedstocks

That transportation is the most variable cost can also be seen in the utilized feedstock at any given price. Figure 6 shows that about %50 of the feedstock is available at $35. Figure 10 shows the farms that are utilized at this price.



(a) Representative Refinery locations and their associated feedstock sheds

(b) Travel costs $/bdt for individual farms

Fig. 5. Refinery locations and travel costs

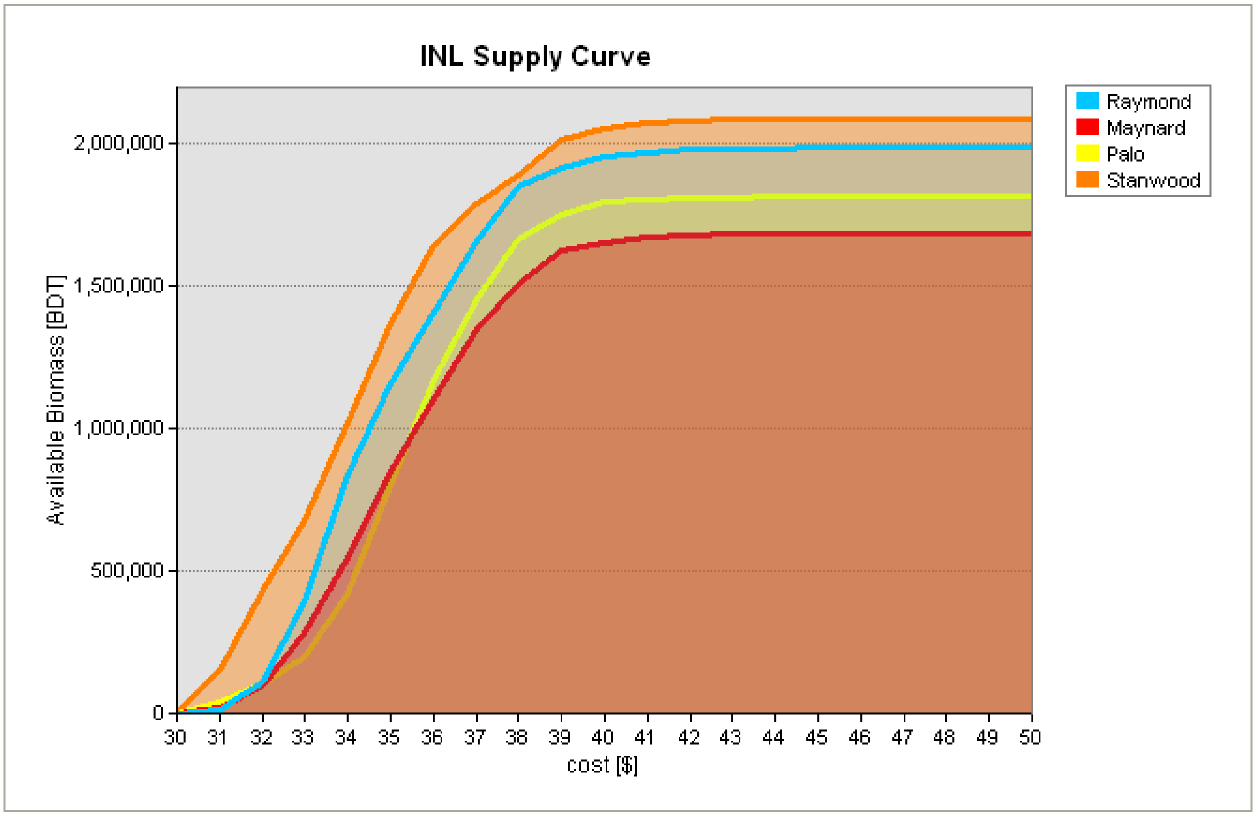


Fig. 6. Example refinery supply curves for Iowa.

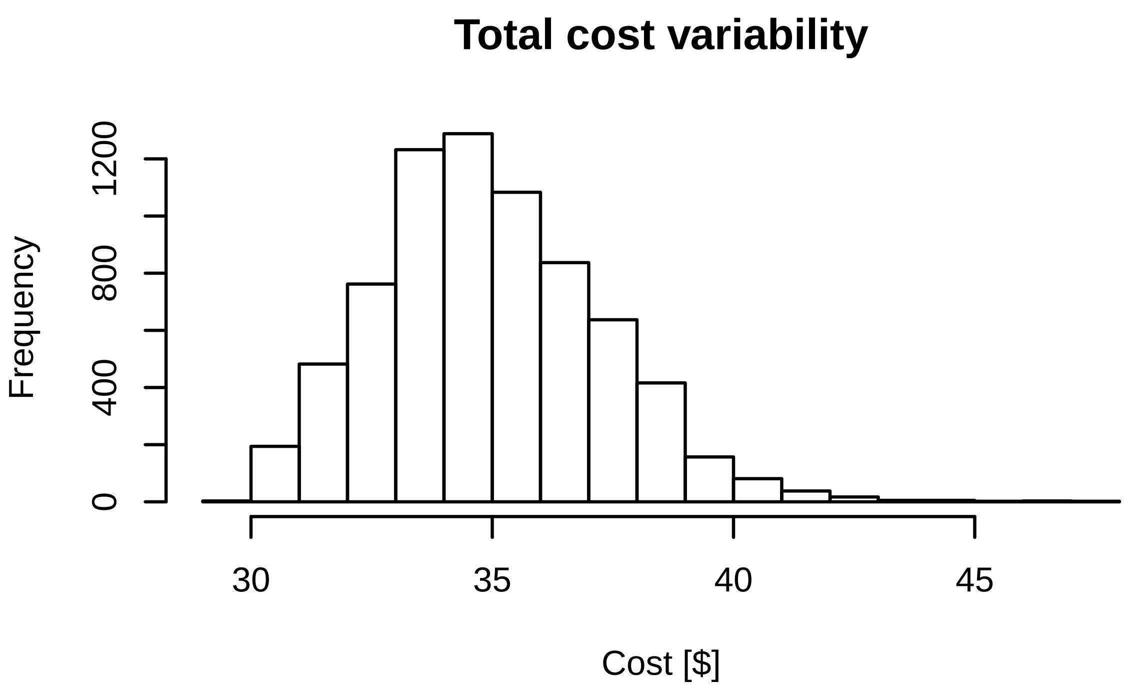


Fig. 7. Total costs $/bdt of biomass

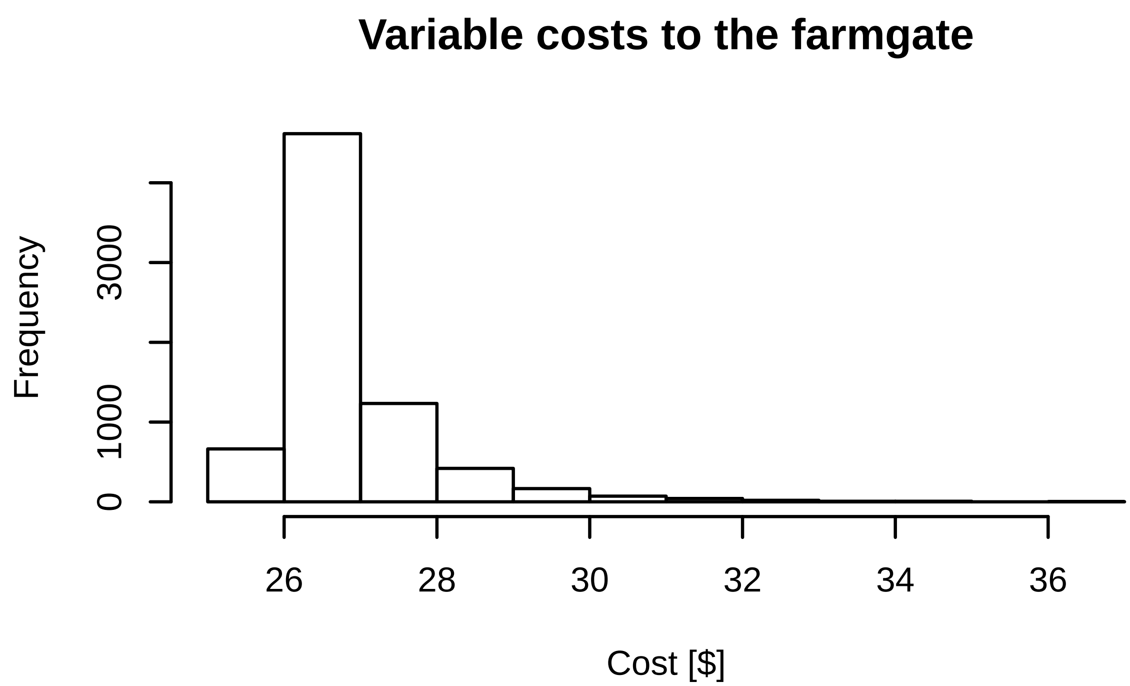


Fig. 8. Farmgate costs $/bdt

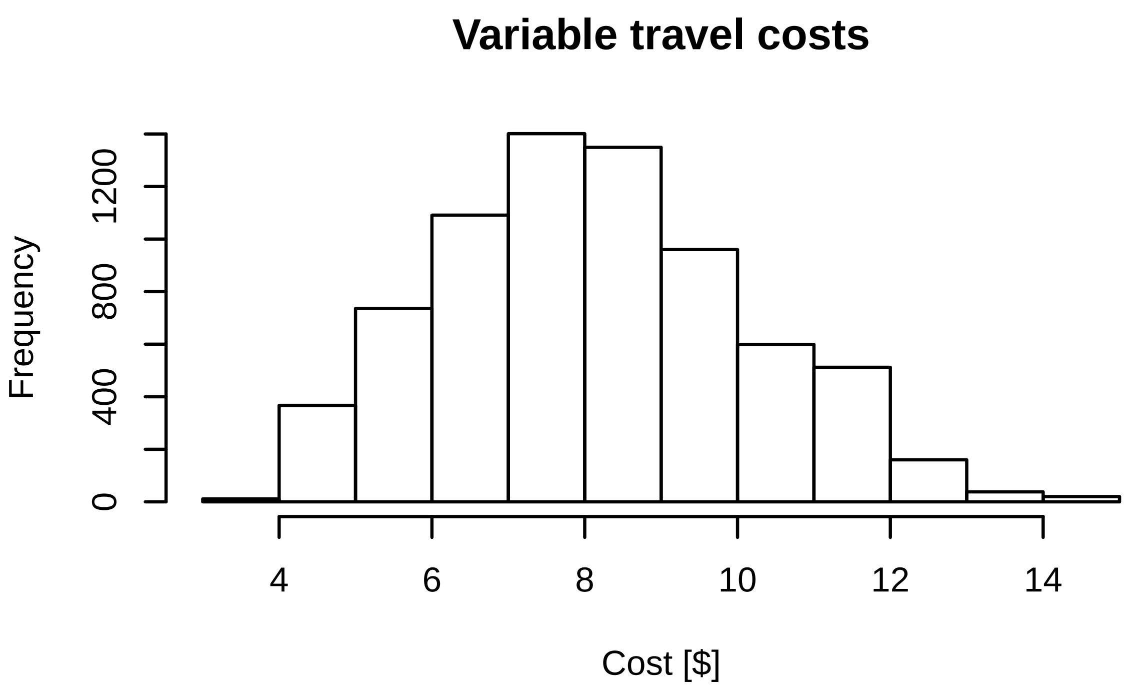


Fig. 9. Transportation costs $^{\$}/_{\mathrm{bdt}}$

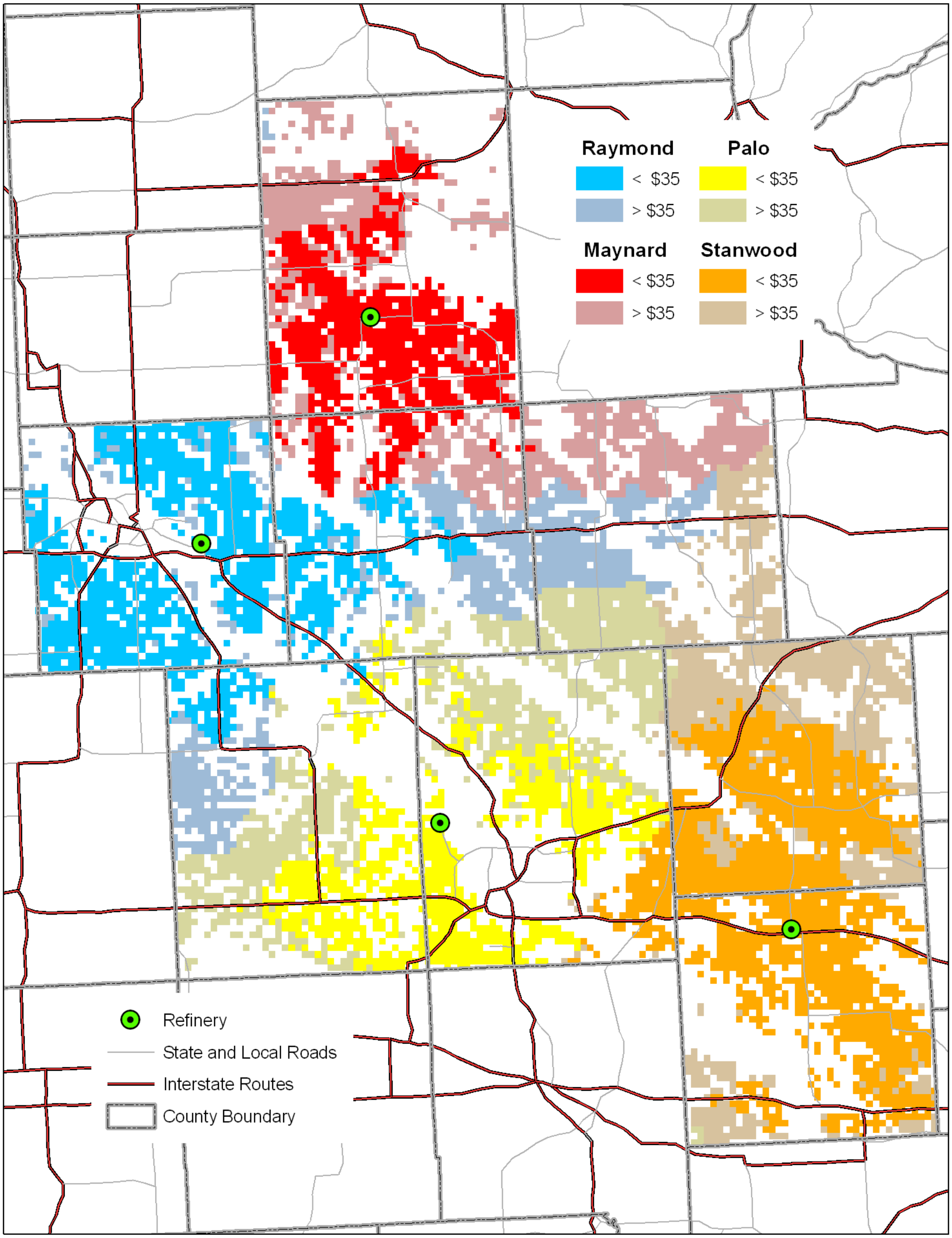


Fig. 10. Utilized biomass at 35 $/bdt.