New England Food Hub Site Suitability Analysis

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About the Organizations Involved

CLF Ventures, Inc.

CLF Ventures (CLFV) is the non-profit consulting affiliate of the Conservation Law Foundation, New England's leading regional environmental advocacy organization. CLF Ventures works with corporate, government, and non-profit clients to cultivate a thriving economy that is environmentally and socially sustainable. We navigate complex technological and environmental problems involving a diversity of stakeholders, where good process is critical and significant values are at stake. For more information, visit http://www.clfventures.org.

Wholesome Wave Charitable Ventures, Inc.

Wholesome Wave is a national 501(c)(3) organization that is helping to reshape the American Food system by putting entrepreneurial, innovative thinking to work. Our organization partners with farmers, farmers markets, community leaders, healthcare providers, like-minded nonprofits, and government entities to implement programs that increase affordability and access to healthy, locally grown fruits and vegetables for consumers in underserved communities. We operate by partnering with community-embedded organizations to implement our programs, including our Double Value Coupon Program, the Fruit and Vegetable Prescription Program™ and Healthy Food Commerce Investments. Wholesome Wave programming is now in 28 states and the District of Columbia with more than 60 partners implementing the DVCP, FVRx™, and HFCI at nearly 400 participating farm-to-retail venues. For more information, visit http://www.wholesomewave.org.

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Table of Contents

Figures and Maps

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EXECUTIVE SUMMARY

Food hubs are businesses that address infrastructure gaps in local and regional food systems. The Food Hub Site Suitability Analysis, a project of the New England Food Hub Cluster Initiative, was designed to

1) identify the most suitable locations for food hubs in New England based on supply, need, infrastructure, and demand criteria and
2) inform and enhance state- and regional-level discussions about food hub placement and food system development.

Using Geographic Information Systems (GIS) technology, we created site suitability models to determine the most suitable locations for four types of food hubs. The types were based on the products the hub would sell (fruits/vegetables or seafood) and the kinds of activities it would pursue:

- **First-mile hubs** aggregate products close to the site of production and process to preserve freshness, flavor, nutrients, etc.
- **Last-mile hubs** process products for convenience and/or to meet buyers' needs (e.g., packaging food into individualized portions for a school food service).

Our models followed the basic site suitability analysis structure depicted in **Figure 1** below. We compiled our data from a variety of sources and solicited feedback throughout the project from experts on food systems topics and spatial analysis methods.

Figure 1. Weighted-Overlay Site Suitability Analysis

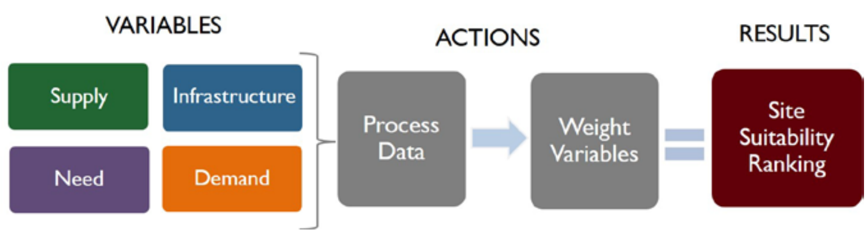
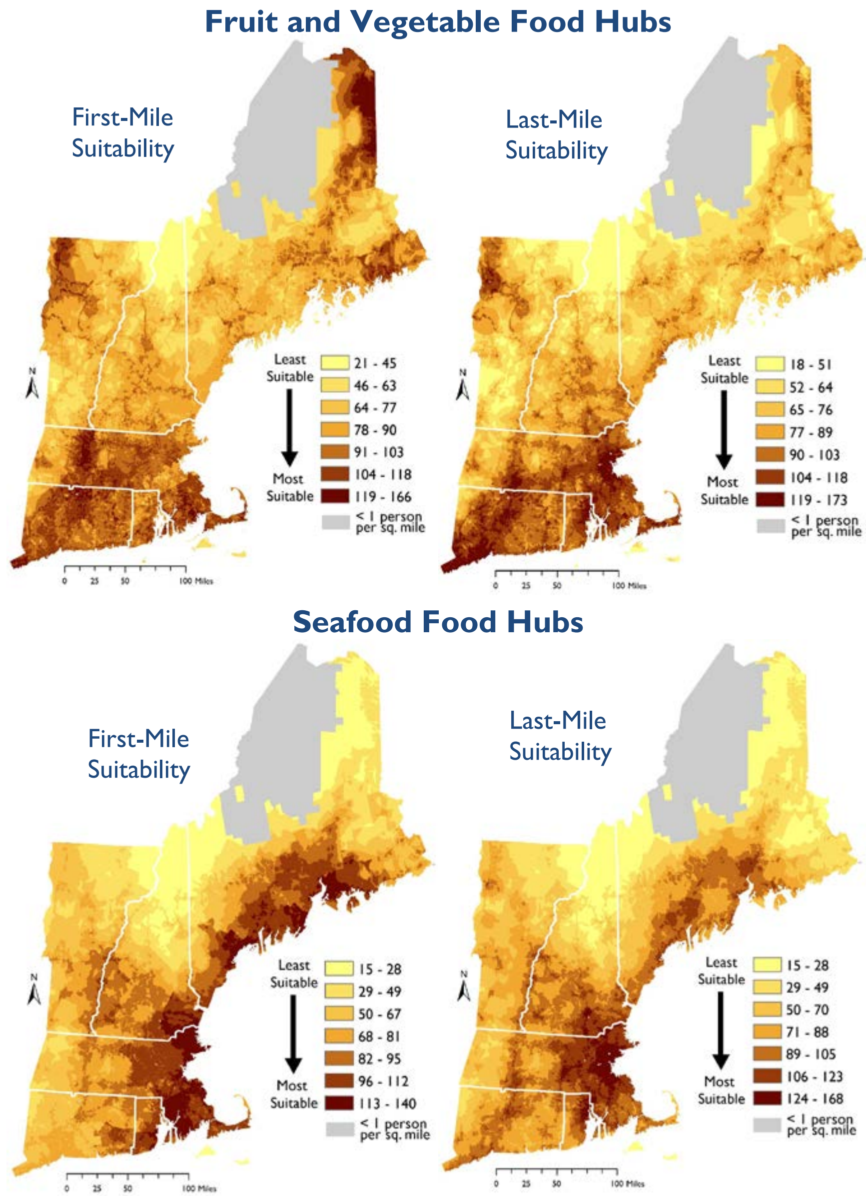


Figure 2. Site Suitability Model Results

*See the **Results** section (p 30-33) for more detail.*



The results of our models (pictured in **Figure 2** above and in detail on pages 30-33) indicate the most and least suitable locations for each type of food hub in New England. For example, the most suitable locations for **first-mile fruit and vegetable hubs** are located in northeastern Maine, southeast and central Massachusetts, central Connecticut, and northwest Vermont.

Conclusions

Food hub founders, policy makers, and investors can use the models and information provided in this report as critical input to frame their decision-making on food hub placement, design, and support. Because food markets are not bound by state borders, decisions on food hub placement and support should similarly transcend state boundaries and be made in the context of a region.

As discussed in the Data Limitations sections throughout this report, there are limits to the conclusions that can be drawn from this analysis due to gaps in the available data and the large geographic scale of this project. One takeaway of this research process is that there are significant gaps in our knowledge about existing food system infrastructure and the need for expansion and/or new business development. In addition to supporting the development of particular food hubs, investors and policymakers might consider supporting region-wide research efforts to address knowledge gaps, especially projects that bring together the same information for multiple states in compatible formats. This kind of support would allow stakeholders to develop a truly multi-state regional perspective on food hub development.

Future progress on this work, in New England and in other regions, should include:

- Input from producers and buyers about their need for food hub services;
- Input from existing food hubs about the geographic area they currently serve and their capacity and desire to expand; and
- More comprehensive datasets of existing infrastructure. This could include making phone calls to determine which of the food processor businesses in the state license databases would be willing and able to partner with (or lease space to) new or expanding food hubs; gathering on-the-ground information about on-farm aggregation and/or processing efforts; and/or surveying existing supply chain businesses about their current partnerships and distribution routes.

Finally, most decisions about where to locate a new food hub will be made at a much smaller scale (e.g., choosing between counties or among certain parcels of land or facilities). The results of our analysis can help a state or area identify a potential macro location. Further work should then be done to collect detailed information from existing value chain entities (producers, processors, aggregators, distributors, buyers) about their current capacity, need, and interest in collaboration, in order to make more precise location decisions.

Site Suitability Report Contents

I. **Introduction** offers background information on food hubs and the development of this project.

II. **Methodology** provides an overview of GIS technology and site suitability analyses, describes prior GIS research on food hub topics, and explains the scope, process, and criteria used in this project.

III. **Variables** includes maps and a discussion of our analysis methods and the data sources and limitations for each variable in our models.

IV. **Weighting** details the priorities of each hub and how we weighted the variables in relation to each other.

V. **Results** includes maps and a narrative description of the final suitability results for each type of food hub.

VI. **Discussion** addresses the conclusions that can be drawn from this project and opportunities for further research in this field.

VII. The **Appendix** includes links to data sources for each of the variables included in our analysis and provides more detailed information about the tools and techniques used in this project.

INTRODUCTION

In recent years, local and regional food system development has shifted from direct-to-consumer sales (through farmers' markets and CSAs) to intermediated sales between producers and institutional buyers. One major barrier to "scaling up" food system development is the lack of infrastructure designed for local and regional systems. Food hubs address those infrastructure gaps by aggregating, processing, distributing, and/or marketing source-identified products to individual and institutional buyers within a particular geographic area. Though the term itself is relatively new, some food hubs have existed for decades, and their numbers are rapidly increasing across the United States (Barham et al. 2012).

The **Food Hub Site Suitability Analysis**, a two-phase component of the **New England Food Hub Cluster Initiative**, was designed to 1) identify the most suitable locations for food hubs in New England based on supply, demand, and infrastructure criteria and 2) inform and enhance state- and regional-level discussions about food hub placement and food system development. The geographic information systems (GIS) models in this project are built on Wholesome Wave's framework of food hub types and include spatial data about variables related to supply, need, infrastructure access, and demand.

This report details our **methodology**, the **variables** included and the sources of our data, how we **weighted** the variables in relation to each other, the **results** of our analysis, and a **discussion** of our conclusions and questions for **further research**. Technical details related to the GIS methodology and links to our data sources are listed in the **Appendix.**

The **New England Food Hub Cluster Initiative** is a multi-faceted project that will provide technical assistance and links to capital to support the development and growth of food producers, processors, aggregators, and distributors throughout New England. The project will grow the New England regional cluster/network of healthy food hubs through business development, piloting of a regional trade network, identification of best practices, stakeholder convening, and facilitating access to financing. It will also address the demand for locally produced foods and support the creation of new private-sector jobs in food production, storage, processing, and transportation throughout the Northeast. In addition, rural farmers, fishermen, and value-added processors will benefit from access to additional markets and revenue.

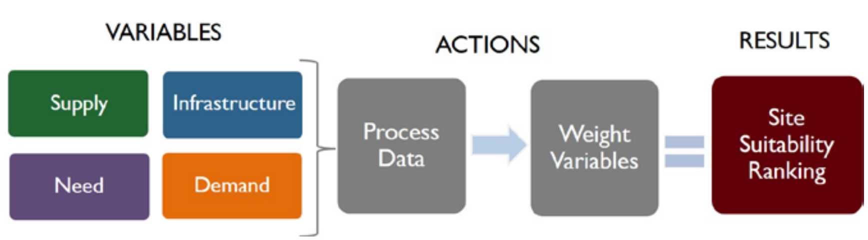
METHODOLOGY

Site Suitability Analysis

Geographic Information Systems (GIS) technology brings together databases and maps to analyze spatial data. There are many analytical uses for GIS; site suitability analysis (SSA) is one of the oldest (Andris 2008). Site suitability analyses combine multiple variables to determine the most appropriate locations for a particular goal or project. SSAs can be used to choose among a select set of locations or, as in this project, to rank all locations in a given area from least to most suitable. Weighted overlay is a commonly used form of site suitability analysis that allows researchers to prioritize variables in the model in relation to one another.

Creating a weighted-overlay SSA model involves four major steps: (1) identifying key criteria; (2) translating criteria into variables based on data availability, accuracy, and reliability; (3) dividing each variable's output into categories (e.g., 1-5 miles, 6-10 miles, etc.) and assigning values to those categories; and (4) weighting the variables in relation to each other. Each stage involves reviewing literature and consulting with stakeholders and experts in the field to validate assumptions and confirm the relevance and accuracy of the model's components. The basic process of a weighted-overlay SSA is depicted in **Figure 1.**

Figure 1. Weighted-Overlay Site Suitability Analysis



Food Hubs and GIS

There is a significant sector of food system research that focuses on spatial analysis, from determining the location and prevalence of food deserts to modeling the capacity of a region to produce its own food. The following food system projects have addressed spatial questions about food hubs:

In 2010, the **Regional Food Hub Advisory Council** (RFHAC) created a plan for a statewide network of food hubs in California (Cech 2010). RFHAC's analysis of suitable locations for new food hubs included indicators of demand (population density by county, locations of major cities); infrastructure (freeway proximity); and supply (distance from major highways, average farm size by county, number of farms by county). RFHAC weighted all variables equally, but conducted different analyses for "supply" and "demand" hubs.

In 2011, the **Urban Design Lab** (UDL) began creating a GIS optimization model for communities to compare various investment scenarios in their planning processes (UDL 2011). UDL piloted the model using private and proprietary data sources about beef and apple production in New York State. UDL's analysis includes data from each sector of the food system: production, processing, distribution, and consumption.

In an effort to identify the conditions necessary for food hub success, graduate students at **Tufts University** used GIS to analyze the landscape of existing food hubs. Working at the county level, they used multiple variables from the National, Agricultural, and Economic Censuses. Myles (2011) focused on indicators of food production, regional infrastructure (transportation, storage, and processing), value-added environmental services, demand for local/regional food, and potential markets for food hubs. Hamilton (2012) used indicators for county levels of food production, beginning farmer support, population density, and markets for local food. Both projects analyzed the data for all counties in the contiguous United States and ranked them according to their similarity to counties that contained food hubs at the time.

Site Suitability Scope and Process

This Food Hub Site Suitability Analysis (FHSSA) was designed to 1) identify the most suitable locations for food hubs in New England based on supply, need, infrastructure, and demand criteria and 2) inform and enhance state- and regional-level discussions about food hub placement and food system development. We limited our scope to food hubs that sell fruit and vegetable products or seafood products to institutional buyers such as grocery stores, schools, and hospitals. We further divided our analysis into two models based on the hub's main functions:

- **First-mile hubs** aggregate products close to the site of production and process to preserve freshness, flavor, nutrients, etc.
- **Last-mile hubs** process products for convenience and/or to meet buyers' needs (e.g., packaging food into individualized portions for a school food service).

In **Phase I** of the FHSSA we developed a weighted-overlay site suitability model for food hubs based on the projects described above (Cech 2010; UDL 2011) with some changes based on our geographic region and the data available for all six New England states. Our data collection in this phase was focused on business databases and government data such as the Agricultural Census. We completed the first round of analysis for the first- and last-mile fruit and vegetable hubs and presented our initial results to a group of food systems experts, GIS experts, and agricultural department officials in New England states. In **Phase II** we modified our analysis based on the feedback we received, augmented our datasets with on-the-ground expert knowledge, and ran our revised site suitability models for first- and last-mile fruit and vegetable hubs and first- and last-mile seafood hubs.

Food Hub Site Suitability Criteria

Food hubs are organizations that aggregate, process, distribute, and/or market differentiated products within a certain geographic area. The needs of a particular food hub will depend on its proposed function(s) and context but, in general, food hub site suitability criteria include proximity to supply, need for food hub services, access to existing infrastructure, and proximity to buyers and their demand.

- To evaluate **supply,** we calculated the density and diversity of fruit and vegetable cropland per square mile and ranked counties by the amount of seafood brought into their ports. For the fruit and vegetable models we also ranked counties by their number of mid-sized farms.
- To highlight areas in **need** of food hub services, we mapped the locations of existing food hubs and prioritized locations furthest away from those hubs.
- New food hubs could benefit from using existing **infrastructure** (aggregation or processing facilities) and/or working with existing supply chain businesses, so we prioritized locations closest to those businesses. We also prioritized locations with high access to major transportation routes in the region.
- To account for **demand** from grocery stores and other buyers, we used population density as a proxy for grocery store concentration and calculated the density of other institutional buyers, including hospitals, schools, colleges, nursing homes, and prisons.

The **weighting process** allows us to adjust the analysis based on the relative importance of each variable as well as on the hub's priorities. To keep the variables equal until the weighting process, the suitability values for each variable range from 0 to 7.

The **Variables** section below includes more information about our data sources and our analysis methods and maps for each of the variables.

VARIABLES

In the following section we provide maps of each variable, along with information about our data sources, how and why we used particular data, and the limitations of our data. **Figures 2** and **3** below detail the variables included in the First- and Last-Mile Models, respectively.

Figure 2. First-Mile Food Hub Variables

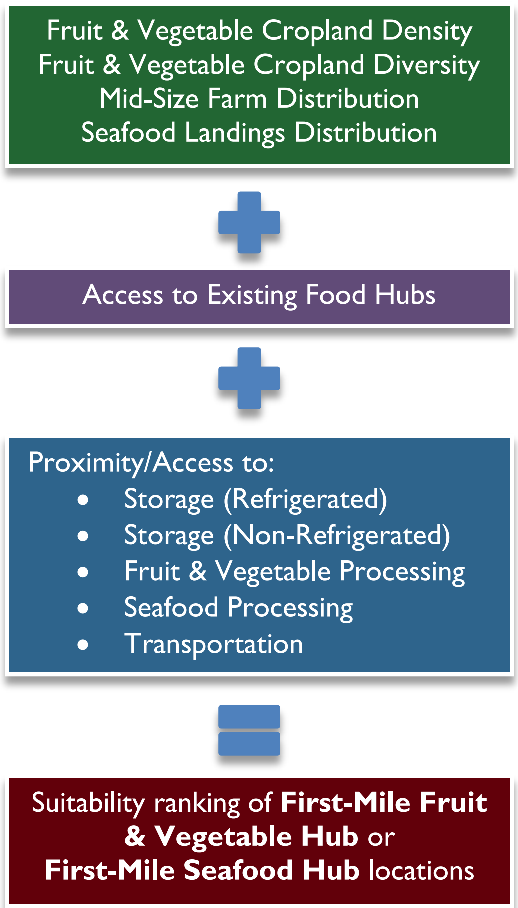
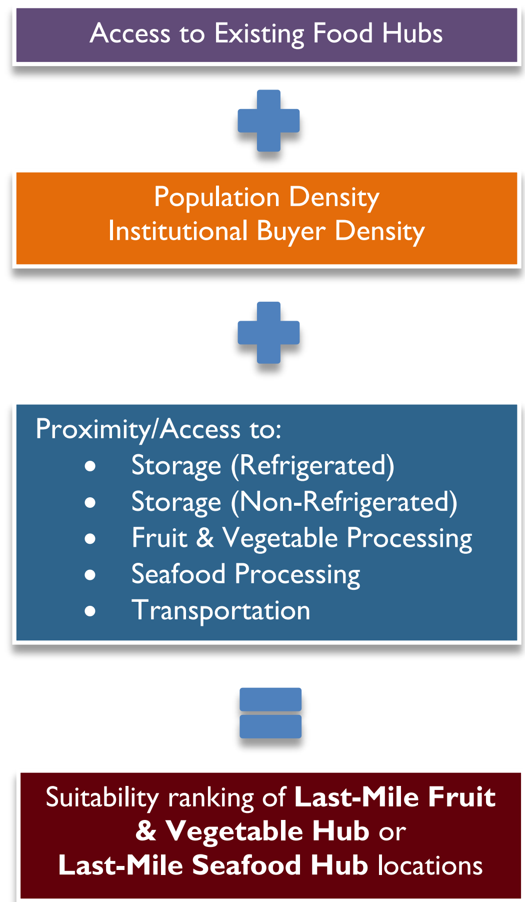


Figure 3. Last-Mile Food Hub Variables



1. Supply

A. Fruit and Vegetable Cropland Density
B. Fruit and Vegetable Cropland Diversity

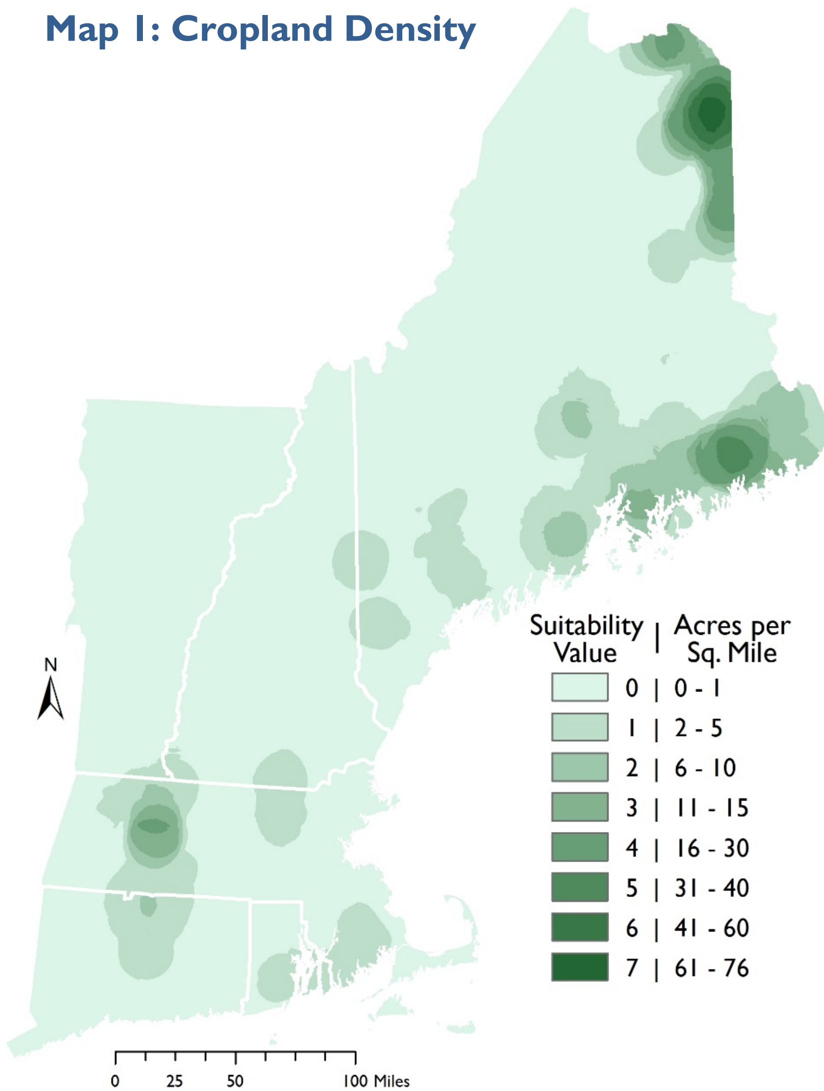
Why We Used this Variable
First-mile hubs aggregate and process products in the interest of preserving freshness, nutrition, and flavor. This means they need to be located near concentrated areas of production. First-mile hubs also need to have access to a diverse supply of crops and products to establish a resilient business model and meet buyer needs (James Barham (USDA) and Kathy Nyquist (New Ventures Advisers), personal communication, 2013).

Data Source
2012 Cropland Data Layer, National Agricultural Statistics Service (NASS), USDA

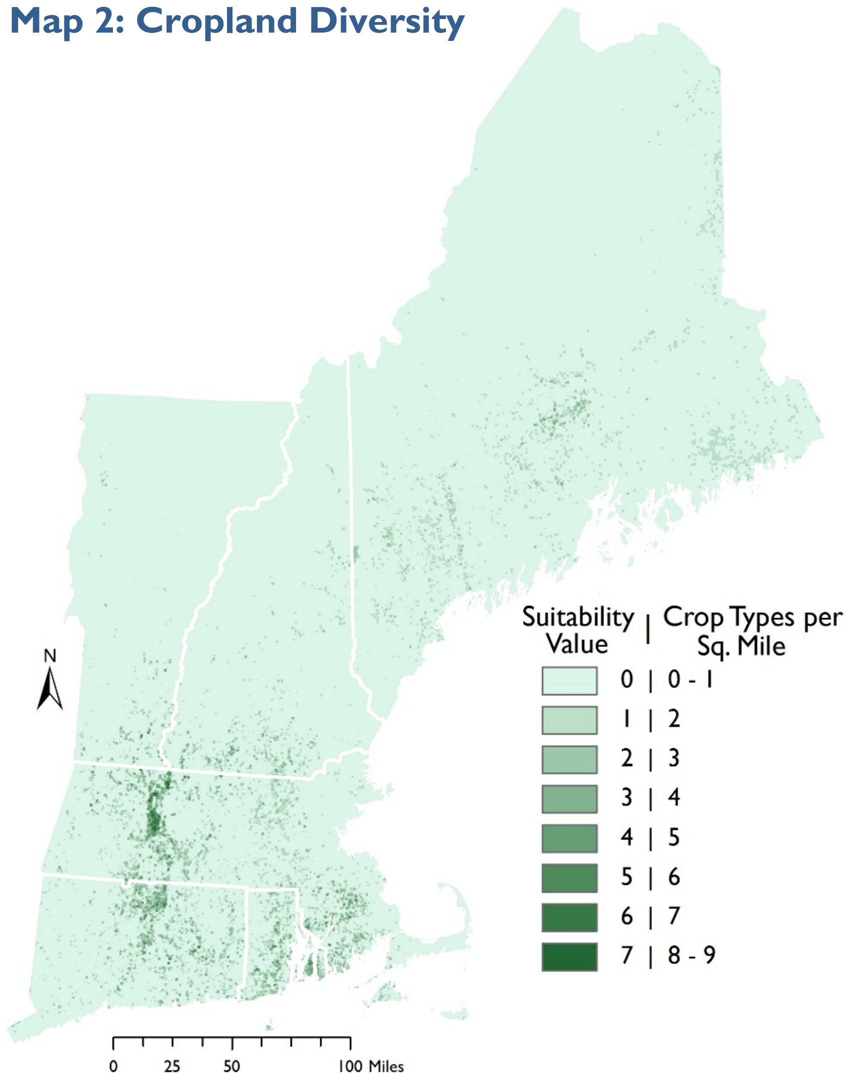
The NASS Cropland Data Layer (CDL) is created annually by analyzing satellite imagery and performing on-the-ground validation. Each CDL pixel represents 30 x 30 meters, or approximately ¼ acre. At this resolution, the CDL is the most precise publicly available dataset of specific crop production locations in the United States (Johnson and Mueller 2010; Johnson 2013).

How We Used this Data
We selected only fruit and vegetable crop categories from the CDL, removing categories such as urban/developed land, woodlands, pasture/grassland, and commodity crops such as wheat, corn, and soy. We used spatial analysis tools in ArcGIS to calculate the density of cropland in acres per square mile (**Map 1**) and the diversity of cropland in the number of crop types per square mile (**Map 2**).

Map 1: Cropland Density



Map 2: Cropland Diversity



Data Limitations

CDL accuracy varies by crop and geography. Overall CDL accuracy for New England was 76.6%. The region's vegetable and berry data were more accurate than average (78.8% and 82.2%), but orchard crop accuracy was only 15.6%. This could contribute to the low density of fruit and vegetable production across Vermont, New Hampshire, and Maine in this analysis.

C. Mid-Size Farms

Why We Included this Variable

Food hubs attempt to address the food system infrastructure gaps that are particularly problematic for mid-size farms. The CDL does include information about farm size, so we added a separate variable to target those farms.

Data Source

2007 Census of Agriculture, USDA

The Agricultural Census contains information on the number of farms per sales class in each county.

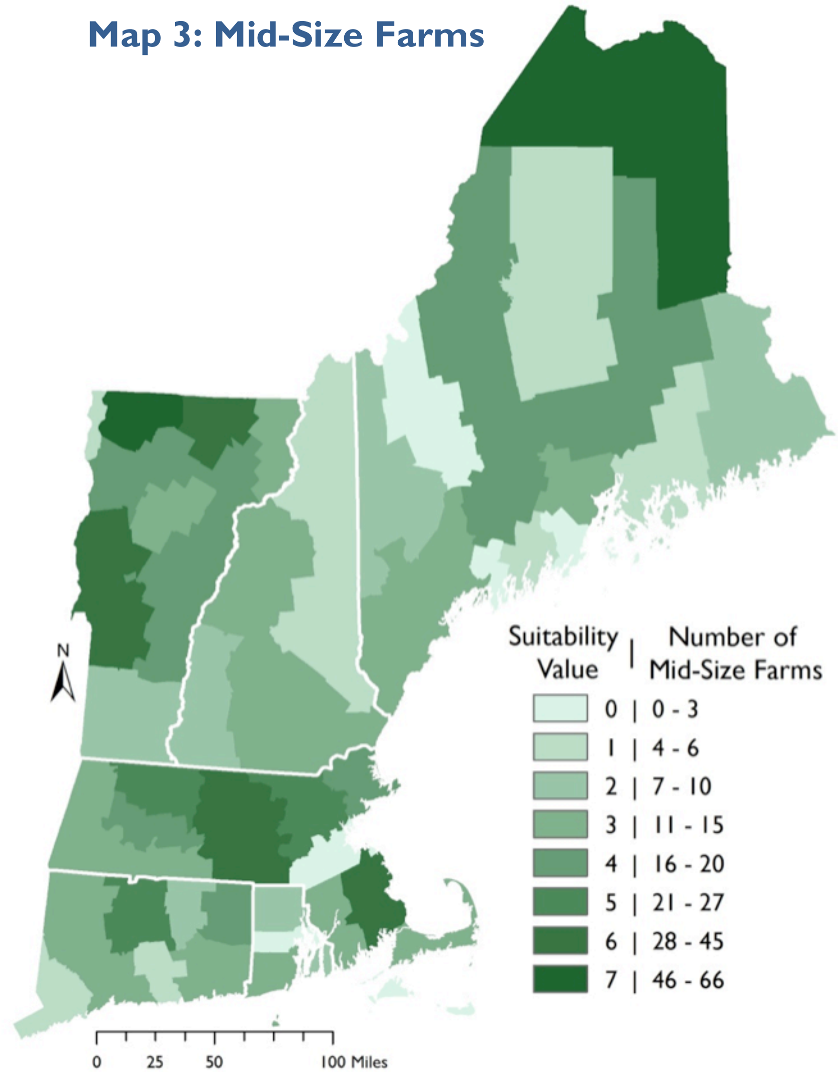
How We Used this Data

We ranked each county by the number of its farms that fall into the middle sales categories, \$250,000 to \$500,000 in annual sales.[1]

Data Limitations

- The data for farms by sales class is only available at the county level for all of New England. This is a much lower resolution than the Cropland Data Layer.
- This dataset includes all types of farms, not just fruit and vegetable operations. The USDA's data on farms by sales class and crops/products is not available below the state level.

Map 3: Mid-Size Farms



[1] The USDA recently updated its farm size classification system such that the category for mid-size farms is \$350,000 to \$999,999 in gross cash farm income (Hoppe and MacDonald 2013). That data is not currently available at the county level, so our analysis uses the nearest equivalent: farms with \$250,000 to \$500,000 in annual sales.

D. Seafood Production

Why We Included this Variable
First-mile hubs aggregate and process products in the interest of preserving freshness, nutrition, and flavor. This means they need to be located near concentrated areas of production.

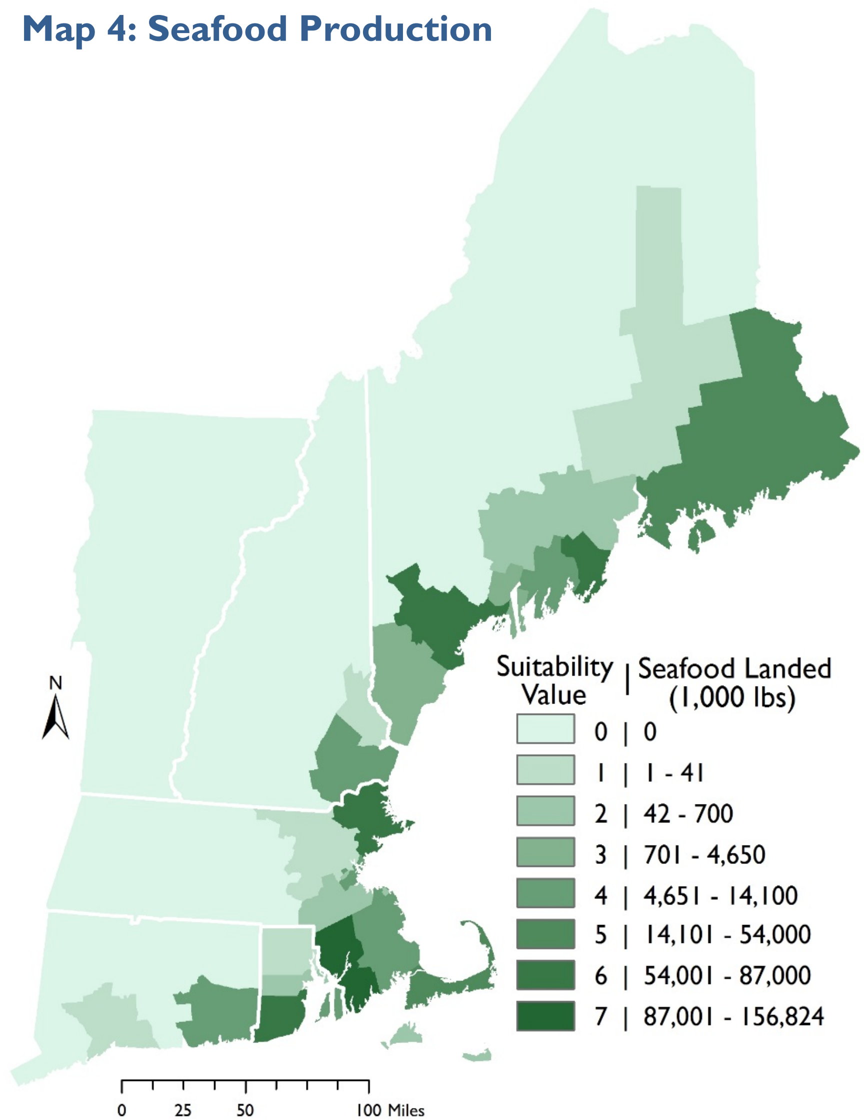
Data Source
2012 Landings (Pounds), Custom Data Request, Atlantic Coastal Cooperative Statistics Program (ACCSP)

ACCSP is a cooperative state-federal program that manages a data warehouse of public and confidential data on commercial seafood catch and effort for all states on the Atlantic Coast.

How We Used this Data
We submitted a custom data request to ACCSP for 2012 port-level landings data in New England. Because of its confidentiality policies, ACCSP was only able to provide county-level landings totals for all species combined. We used this information to rank each county by the number of pounds of seafood landed in 2012.

Data Limitations
- For confidentiality reasons, ACCSP could not release data at the port level or broken down by type of species.
- Also for confidentiality reasons, landings data is not linked to particular seafood entities, so our analysis cannot take into account the size of those firms.

Map 4: Seafood Production



2. Need

A. Existing Food Hubs: Fruits/Vegetables and Seafood

Why We Included this Variable
New England is already home to many food hubs. Our analysis needed to take into account the fact that these hubs are likely working with the producers closest to them.

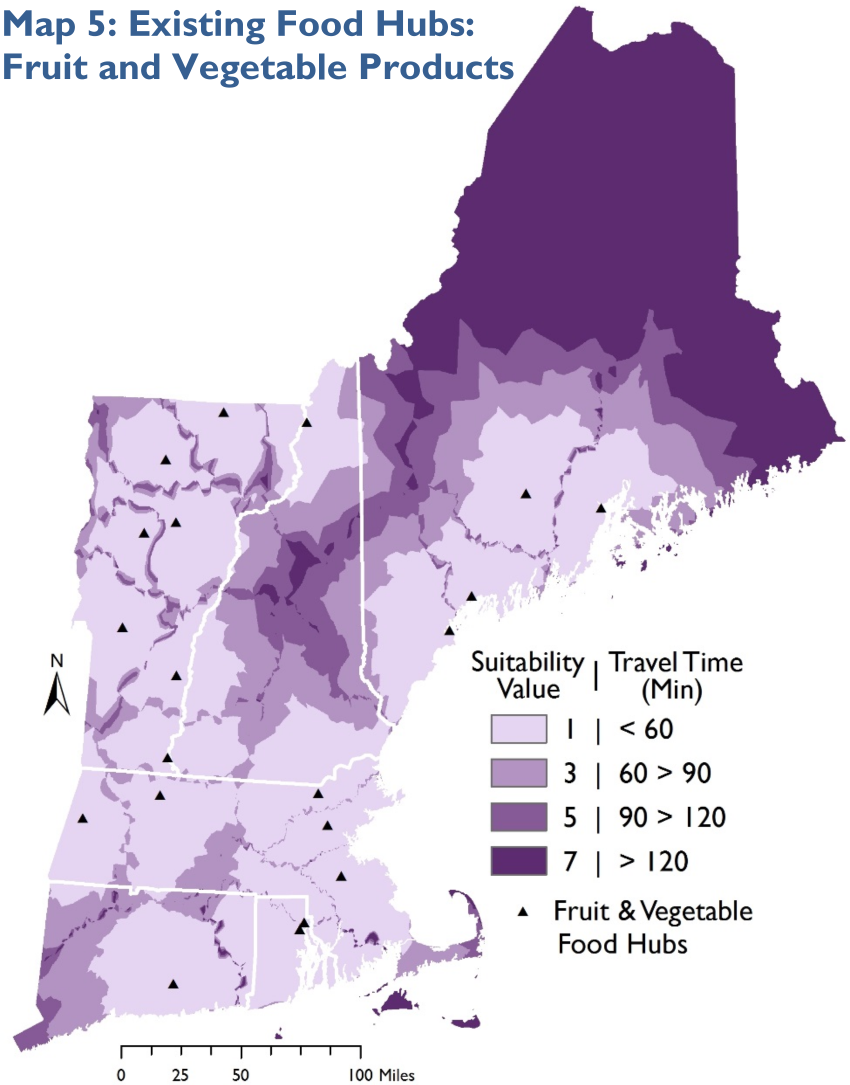
Data Source
2012 Food Hubs Database, Agricultural Marketing Service (AMS), USDA

The AMS maintains a database of food hubs in the U.S. that includes information on the hubs' location, type of product(s), and type of buyer(s).

How We Used this Data
We narrowed the AMS database of food hubs to those in New England that sell fruit and vegetable products (**Map 5**) and seafood products (**Map 6**) to institutional buyers. We then calculated the areas within 60, 90, and 120 minutes of those hubs and prioritized the areas furthest away from existing food hubs.

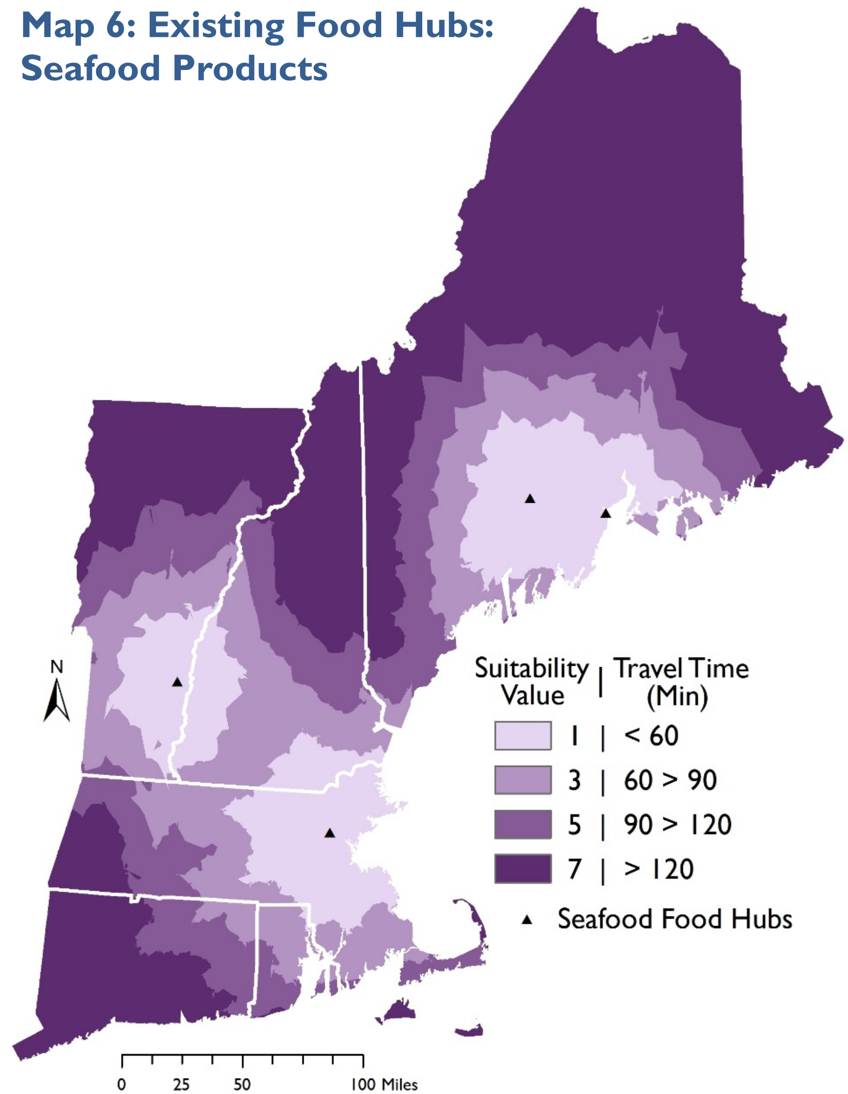
The most recent national survey of food hubs found that definitions of local were often measured in miles and ranged from radii of "30 to 250 miles, with an average of 130 miles and a median of 110 miles" (Fischer et al. 2013, 33). Over 80% of the hubs surveyed sourced all of their products from within 400 miles. We chose to use time units rather than mileage to take advantage of GIS technology's ability to account for actual driving time and road access information. Our travel time categories for the food hub and processing and aggregation infrastructure variables are smaller than the mileage equivalent because of the small size and density of the New England region relative to the rest of the United States (James Barham (USDA) and Kathy Nyquist (New Ventures Advisers), personal communication, 2013).

Map 5: Existing Food Hubs: Fruit and Vegetable Products



Data limitations
The USDA's food hub dataset may not include all of the new and emerging hubs in New England. We addressed this potential gap in our data by sharing our list of food hubs with officials in New England state departments of agriculture and including any additional hubs they knew of in our analysis.

Map 6: Existing Food Hubs: Seafood Products



3. Infrastructure

A. Transportation

Why We Included this Variable
Food hubs require access to distribution routes to move their products throughout the region, whether they are doing their own distribution or working with an existing company. We wanted to identify locations with high, medium, and low levels of access to distribution infrastructure in the region (**Map 7**).

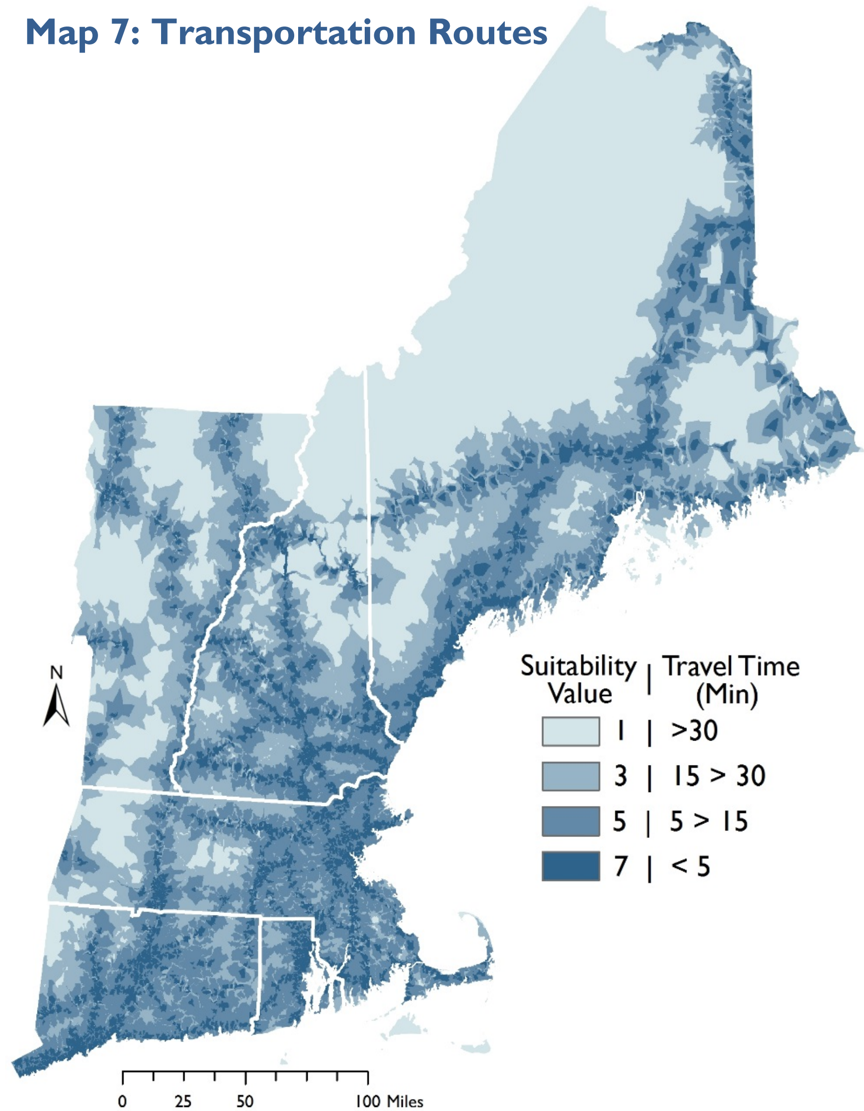
Data Sources
StreetMap Premium, ESRI (Tufts University Subscription); Roads, Maine Office of GIS; NH Public Roads, NH GRANIT

The road datasets we used include information about road types, interstate ramp locations, intersection locations, and speed limits.

How We Used this Data
We calculated the areas within 5, 15, and 30 minutes of interstate entrance and exit ramps and major state highway intersections to prioritize locations with access to distribution routes and infrastructure.

Data Limitations
Our transportation analysis only includes access to major interstates and highways, so we did not account for all routes or rail/ferry transport options.

Map 7: Transportation Routes



B. Processing and Aggregation Facilities

Why We Included These Variables

New food hubs could benefit from using existing aggregation or processing facilities and/or working with existing supply chain businesses.

Data Source

U.S. Businesses, ReferenceUSA (Tufts University Library Subscription)

ReferenceUSA is a major business database that collects location and industry information on businesses across the country and allows users to search for and download datasets based on industry type.

How We Used this Data

We used **ReferenceUSA** to create datasets of four types of food system infrastructure businesses using the North American Industry Classification System (NAICS) [2] codes related to:

- Refrigerated Storage (**Map 8**)
- Non-Refrigerated Food Storage (**Map 9**)
- Fruit & Vegetable Processing (**Map 10**)
- Seafood Processing **(Map 11)**

We filtered the dataset by removing entries that were clearly not related to food storage. We then calculated the areas within 60, 90, and 120 minutes of the remaining facilities and prioritized locations closest to the existing facilities.

Data Limitations

For All Processing and Aggregation Datasets:

- ReferenceUSA is one of the largest available business databases with the option to search for and download business data by industry type. However, there are some gaps in the ReferenceUSA data, especially related to smaller and/or unincorporated businesses.
- NAICS codes are assigned to businesses during their interactions with the Census Bureau, Department of Labor, and other federal agencies. In general, a primary NAICS code is assigned to each business based on its primary function. However, most businesses perform more than one major function, and individual agencies have their own particular protocols for assigning and using NAICS codes. This means that our NAICS-based datasets likely include some businesses that do not actually focus on the activity identified in their primary NAICS code. We removed as many misclassified entries as possible but did not have the capacity to research and confirm each business in our datasets.
- Food processor businesses are licensed at the state level and datasets of those licensees are available from state licensing agencies, which are usually housed within Departments of Public Health or Health and Human Services. While these datasets are more robust than those available through business databases, unfortunately the licenses in New England states are much broader than the scope of our analysis in this project. (The datasets did not differentiate by the type of product nor the size or geographic scope of each business.) More information on how these datasets could be used in future research is included in the **Discussion** section below.

[2] Some business databases use the more detailed precursor to NAICS, the Standard Industrial Classification (SIC) code system. (SIC has an eight-digit category whereas NAICS stops at six digits.) However, our searches in ReferenceUSA using SIC codes were not significantly different from the NAICS code results.

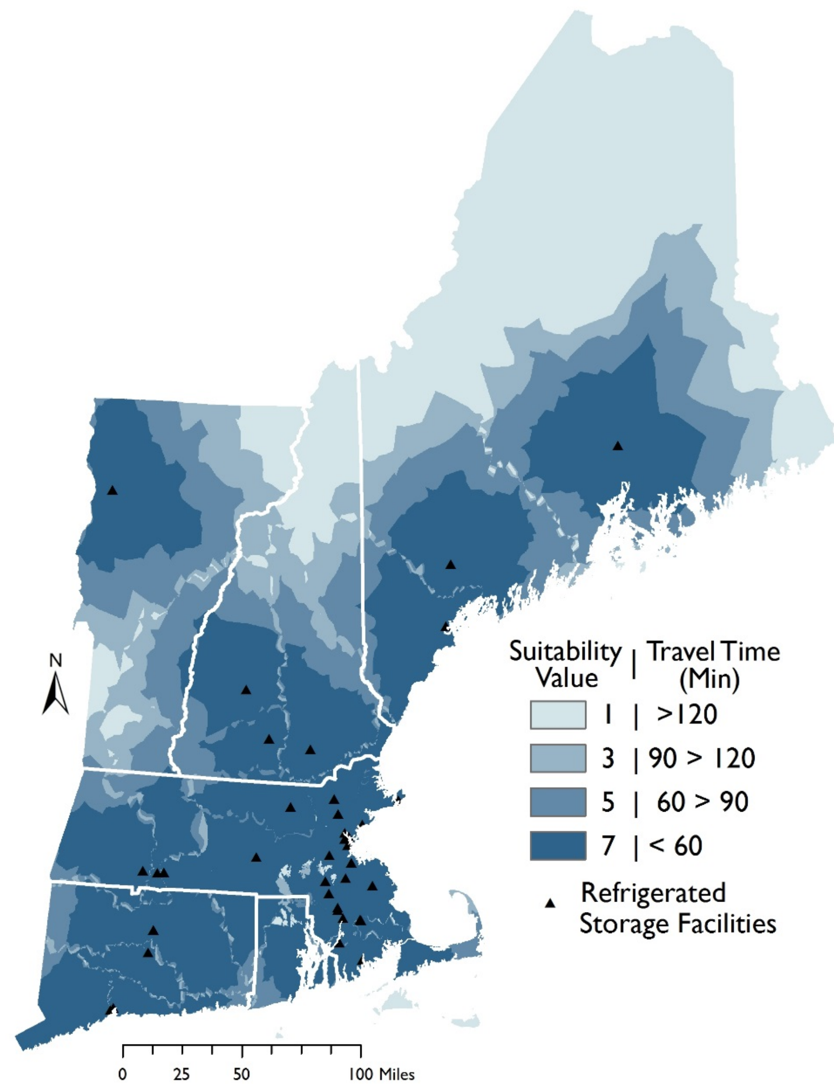
For Refrigerated Storage:

- This NAICS code is not specific to food-related businesses, so some of these facilities may not actually be engaged in food storage.

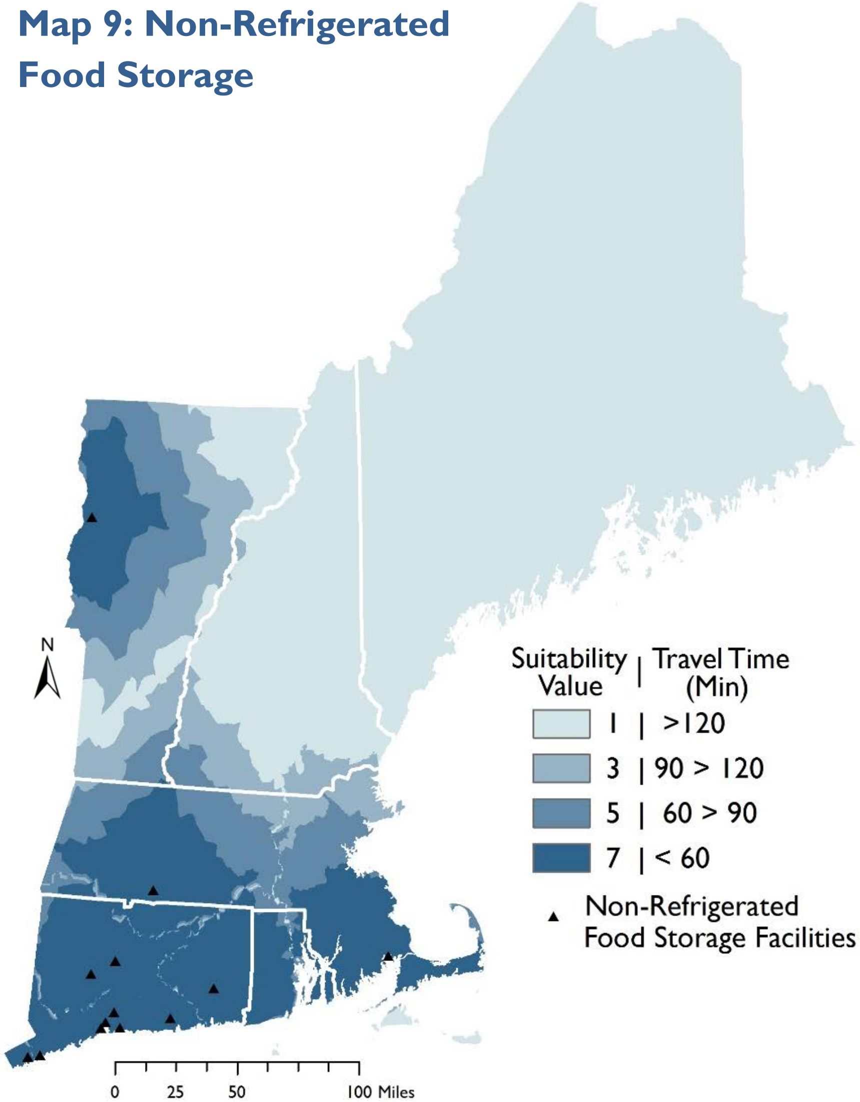
For Fruit and Vegetable Processing and Seafood Processing

- We did not have the data to connect specific types of processing facilities with the locations of related crop or seafood product production, so it is possible that some producers located very close to existing facilities would need other equipment or functionality to process their products.

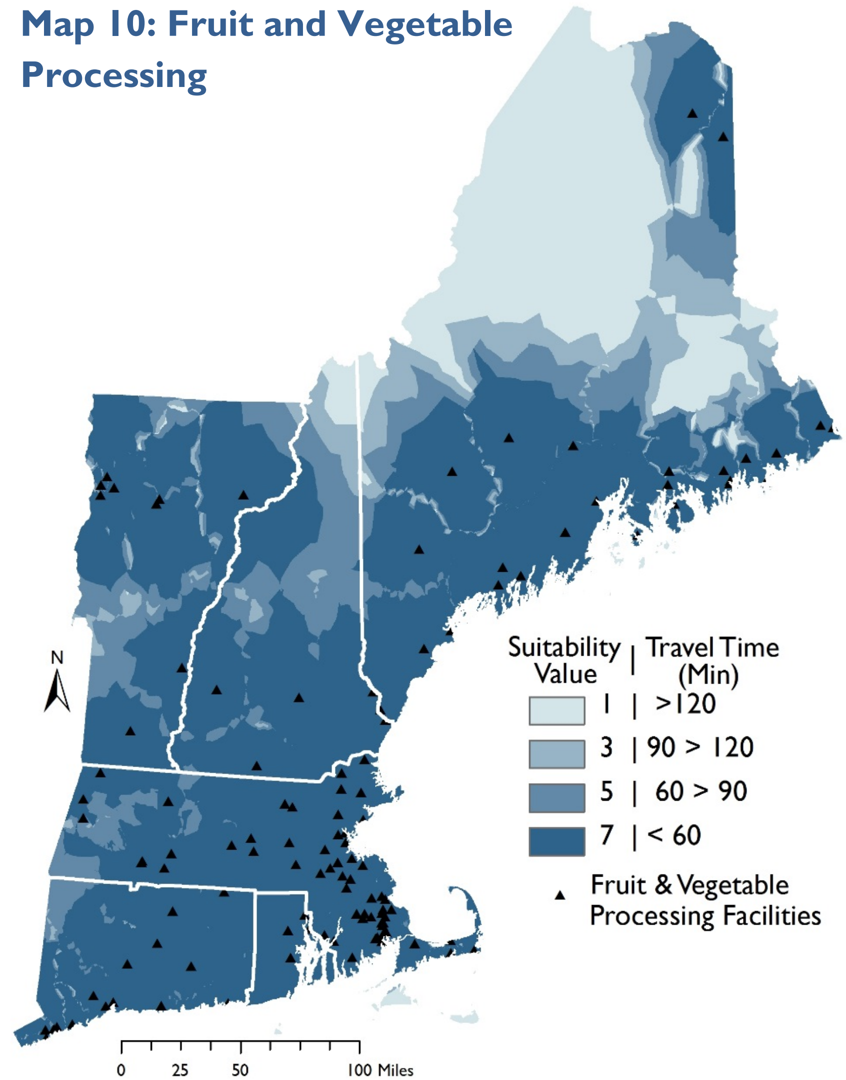
Map 8: Refrigerated Storage



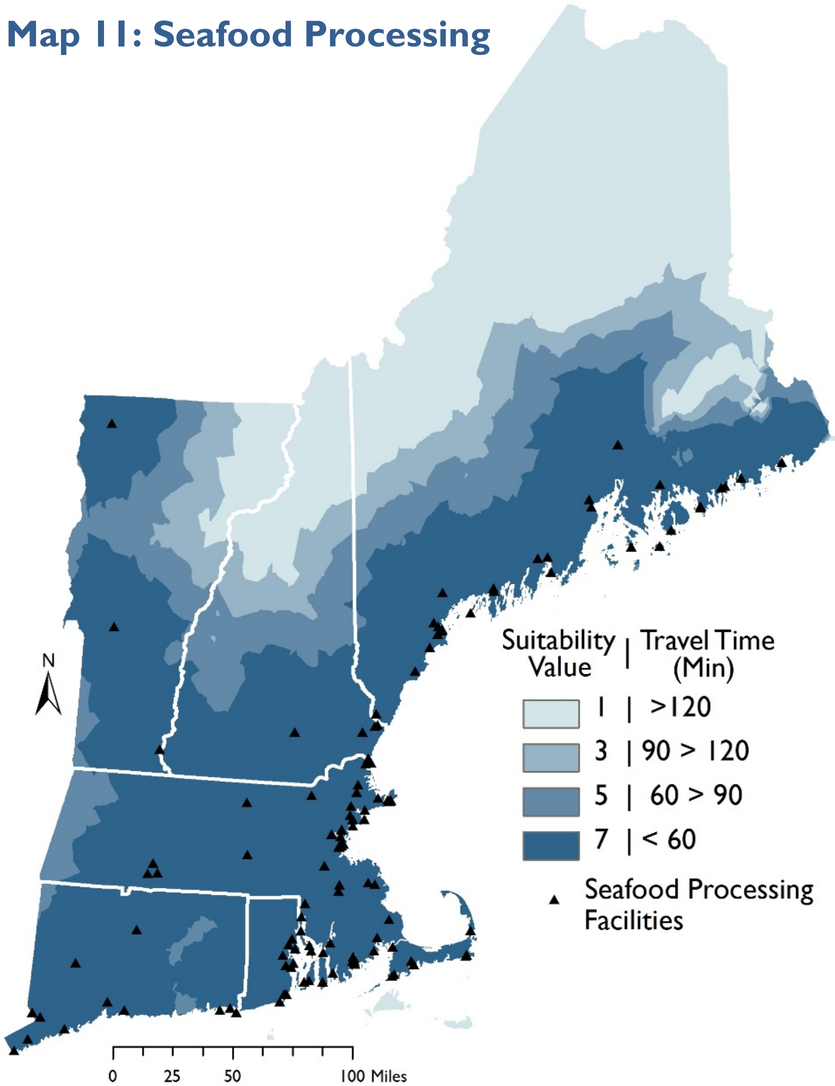
Map 9: Non-Refrigerated Food Storage



Map 10: Fruit and Vegetable Processing



Map 11: Seafood Processing



4. Demand

A. Population Density

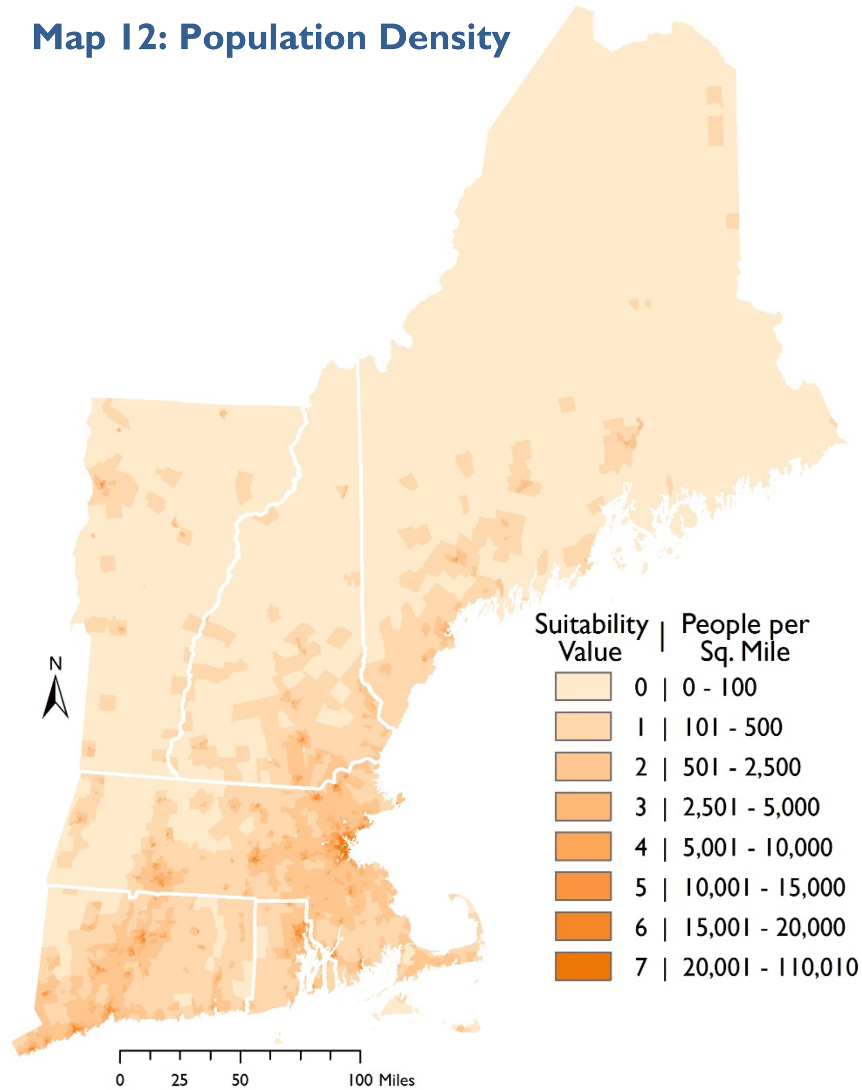
Why We Included this Variable
In general, grocery retailers are sited to take advantage of the high demand that exists in densely populated areas. We used population density (by census tract) as a proxy for the concentration of retail buyers.

Data Source
2010 Census, U.S. Census Bureau

How We Used this Data
We calculated population density per square mile for each census tract and prioritized locations closest to densely populated areas (**Map 12)**.

Data Limitations
- Grocery store siting is a multi-faceted process; as such it does not follow population density trends exactly.
- Not all grocery store chains and food retailers have the desire or capacity to source locally or regionally grown products.

Map 12: Population Density



B. Institutional Buyer Density

Why We Included this Variable

In addition to grocery buyers, food hubs also sell their products to institutions such as hospitals, colleges and universities, K-12 schools, nursing homes, and correctional facilities. These institutions do not correlate to population centers as closely as grocery retailers do, so we calculated their concentration separately.

Data Sources

Information about most of these institutions was available in a spatial format from state-level GIS clearinghouses (UConn MAGIC, Maine Geolibrary, MassGIS, NH Granit, RI GIS, and Vermont Center for Geographic Information). We combined those datasets with information we collected and mapped from other sources, including Connecticut Department of Corrections; Local-Nursing-Homes.com; Medicare.gov; MyPlaceCT.org; New Hampshire Department of Education; New Hampshire Resources for Residents; Vermont Department of Disabilities, Aging, and Independent Living; Vermont Department of Corrections; and Vermont Health Care Association. (Links to these data sources and the others used in this project are available in the **Appendix**.)

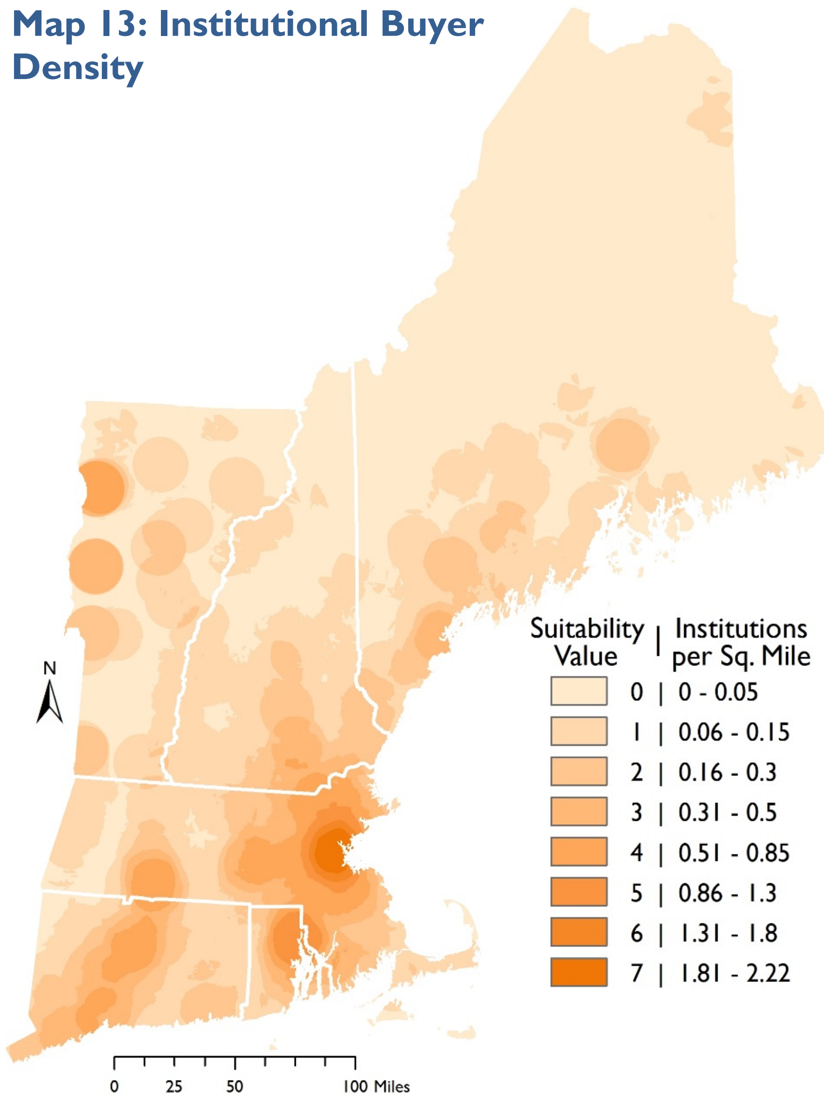
How We Used this Data

We combined our datasets of different types of institutions, and calculated the density of institutions per square mile. We prioritized locations close to the highest concentration of institutions (**Map 13**).

Data Limitations

- Not all institutions have the desire or ability to purchase significant quantities of locally or regionally grown foods.
- We do not have access to data on the number of people each institution feeds on a daily basis or institutional funding for food purchases. Though some institutions have much more market power and capacity than others, each institution was treated equally in our analysis.

Map 13: Institutional Buyer Density



WEIGHTING

In a site suitability analysis, weighting is the mechanism for taking into account the importance of each variable relative to the others. The results are essentially a scoring system for locations in a given region. The region is divided into cells; in this analysis each cell is 30 meters by 30 meters, or approximately ¼ acre. Each cell receives a score (the "suitability value" indicated on the maps above) for each variable. To keep all variables equal prior to weighting, each variable's values are on the same scale, 0 to 7. Before adding together the values for each location, our Site Suitability Analysis models multiply the base values for each variable by the weights we set based on the food hub type. In the following section, we provide the details of, and reasoning behind, our weighting choices for each model in this analysis.

Two of our weighting decisions applied to all models: first- and last-mile hub, seafood and fruit/vegetable products.

- To prioritize areas in need of food hubs, we weighted **access to existing food hubs** as one of the highest criteria.
- Within the infrastructure category, we weighted **highway access** above **proximity to existing processing and aggregation infrastructure**. Our reasoning was that it is unlikely that highway access point locations will change in the near future or that food hub proponents could influence the development of new ones. In contrast, though it might be more expensive than working with existing infrastructure, food hub entrepreneurs *could* build new aggregation and/or processing facilities.

The specific choices we made for each type of model are explained in this section, followed by charts with the details of each variable and its weight.

A. First Mile

The weighting scheme for first-mile hubs was based on our theory of their priorities:

1. *proximity to concentrated areas of production*
2. *proximity to diversified crop production*
3. *proximity to mid-size farms*
4. *proximity and access to existing infrastructure*

In theory, proximity to high numbers of mid-size farms is key for first-mile fruit and vegetable hubs. However, the resolution of that dataset (county totals) was too low to provide us with precise locations. In addition, the farm size dataset is not specific to fruit and vegetable crops. To account for these limitations, we gave **mid-size farms** a mid-level weighting, below **cropland density and diversity, food hub access**, and **transportation access**.

Weighting for First-Mile Fruit and Vegetable Hubs

The un-weighted value range for first-mile fruit and vegetable hubs is 0 to 56; the maximum potential weighted value is 217.

Variable	Unit	Weight	Weighted Max.
Supply			
F&V Cropland Density	Acres / sq. mi.	5	35
F&V Cropland Diversity	# of crop types / sq. mi.	5	35
Agriculture of the Middle	# of mid-size farms / county	3	21
Need			
Food Hub Access	Travel time to existing food hubs (120, 90, 60 min.)	5	35
Infrastructure			
Refrigerated Storage	Travel time to facilities (60, 90, 120 min.)	3	21
Non-Refrigerated Storage		3	21
F&V Processing Facilities		3	21
Transportation Access	Travel time to access points (5, 15, 30 min.)	4	28
Weighted Maximum Total Value			**217**

Weighting for First-Mile Seafood Hubs

The un-weighted value range for first-mile seafood hubs is 0 to 35; the maximum potential weighted value is 140.

Variable	Unit	Weight	Weighted Max.
Supply			
Seafood Production	Lbs. landed / county	5	35
Need			
Food Hub Access	Travel time to existing food hubs (120, 90, 60 min)	5	35
Infrastructure			
Refrigerated Storage	Travel time to facilities (60, 90, 120 min)	3	21
Seafood Processing Facilities		3	21
Highway Access	Travel time to access points (5, 15, 30 min)	4	28
Weighted Maximum Total Value			**140**

B. Last Mile

The weighting scheme for last-mile hubs was based on our theory of their priorities:

1. *proximity to concentrated areas of demand (either grocery retailers or other institutional buyers)*
2. *proximity and access to existing infrastructure*

Within the demand category, we weighted **population density** higher than **institutional density** because it was a more comprehensive dataset. (We have population data for each census tract, but do not have location and/or capacity data for all potential institutional food hub buyers.)

Weighting for Last-Mile Fruit & Vegetable Hubs

The un-weighted value range for last-mile fruit and vegetable hubs is 0 to 49; the maximum potential weighted value is 189.

Variable	Unit	Weight	Weighted Max.
Demand			
Population Density	People / sq. mi.	5	35
Institutional Buyer Density	Institutions / sq. mi.	4	28
Need			
Food Hub Access	Travel time to existing food hubs (120, 90, 60 min.)	5	35
Infrastructure			
Refrigerated Storage	Travel time to facilities (60, 90, 120 min.)	3	21
Non-Refrigerated Storage		3	21
F&V Processing Facilities		3	21
Highway Access	Travel time to access points (5, 15, 30 min.)	4	28
Weighted Maximum Total Value			**189**

Weighting for Seafood Last-Mile Hubs

The un-weighted value range for first-mile seafood hubs is 0 to 42; the maximum potential weighted value is 168.

Variable	Unit	Weight	Weighted Max.
Demand			
Population Density	People / sq. mi.	5	35
Institutional Buyer Density	Institutions / sq. mi.	4	28
Need			
Food Hub Access	Travel time to existing food hubs (120, 90, 60 min.)	5	35
Infrastructure			
Refrigerated Storage	Travel time to facilities (60, 90, 120 min.)	3	21
Seafood Processing Facilities		3	21
Highway Access	Travel time to access points (5, 15, 30 min.)	4	28
Weighted Maximum Total Value			**168**

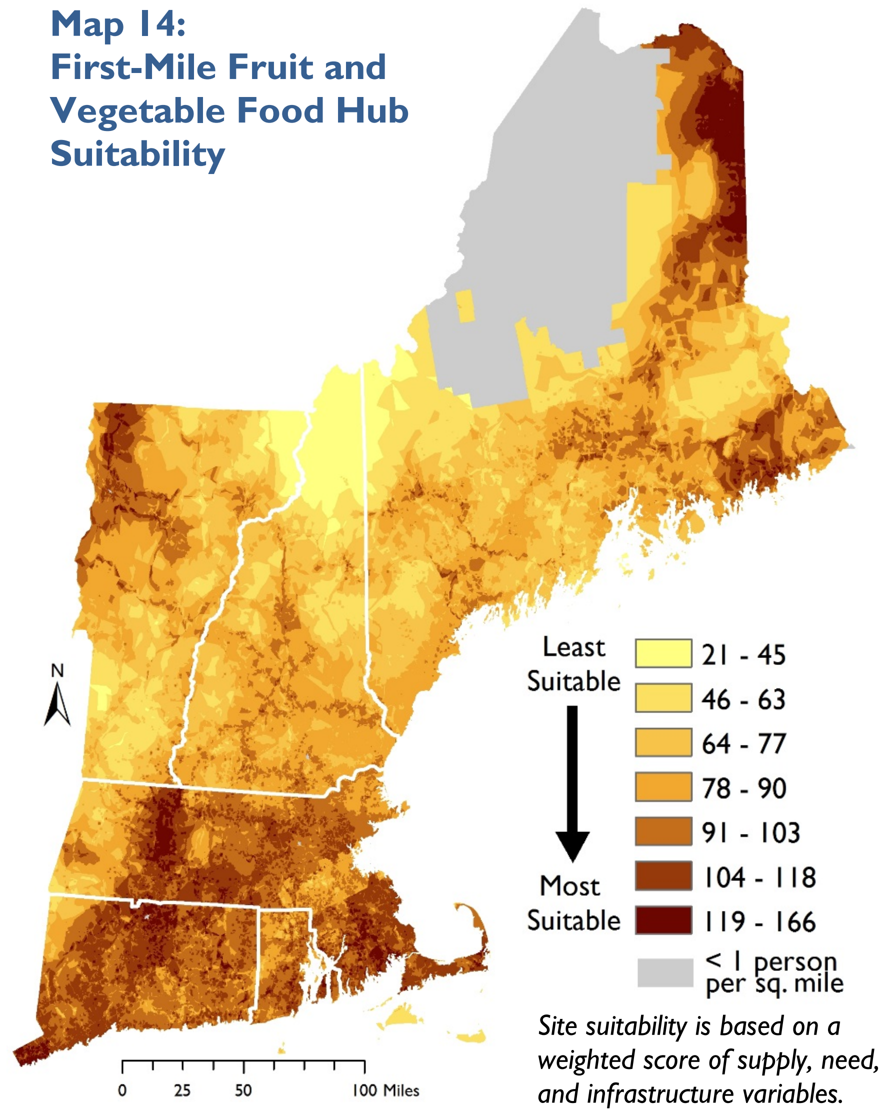
RESULTS

At the suggestion of one of the experts we consulted in our Phase I review, our results maps indicate in grey the areas of New England that have a population density (by census tract) of less than one person per square mile and are not likely to be suitable locations for food system infrastructure development.

A. First-Mile Fruit and Vegetable Hubs

Map 14 shows that the most suitable areas for first-mile fruit and vegetable hubs are located in northeastern Maine, southeast and central Massachusetts, central Connecticut, and northwest Vermont.

Map 14: First-Mile Fruit and Vegetable Food Hub Suitability

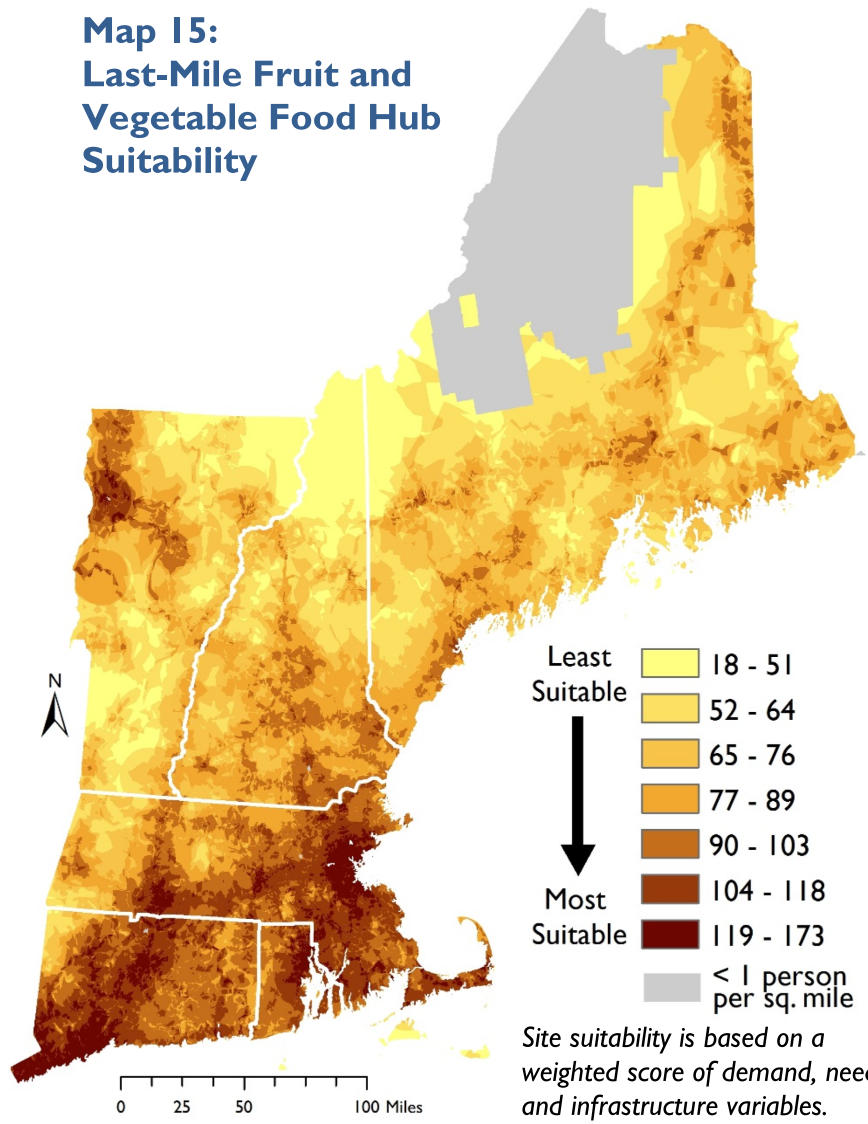


Site suitability is based on a weighted score of supply, need, and infrastructure variables.

B. Last-Mile Fruit and Vegetable Hubs

Map 15 shows that the most suitable locations for last-mile fruit and vegetable hubs in New England are in northwest Vermont, central Connecticut, south-central Massachusetts, and the metro areas around Providence, RI, and Boston, MA. There are also relatively high-scoring locations near population centers and transportation routes in New Hampshire and Maine.

Map 15: Last-Mile Fruit and Vegetable Food Hub Suitability

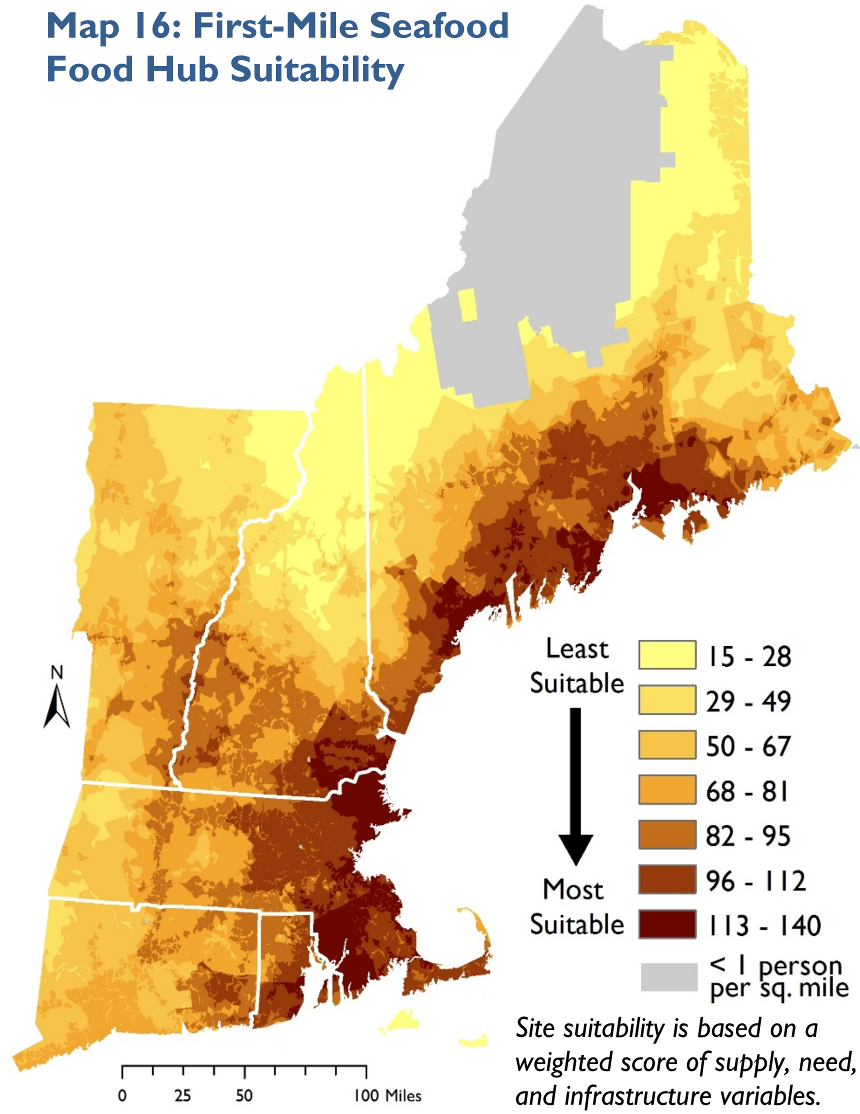


Site suitability is based on a weighted score of demand, need, and infrastructure variables.

C. First-Mile Seafood Food Hubs

Map 16 shows that the most suitable locations for first-mile seafood hubs in New England are concentrated along the coast, particularly in southern Maine and northeast and southeast Massachusetts.

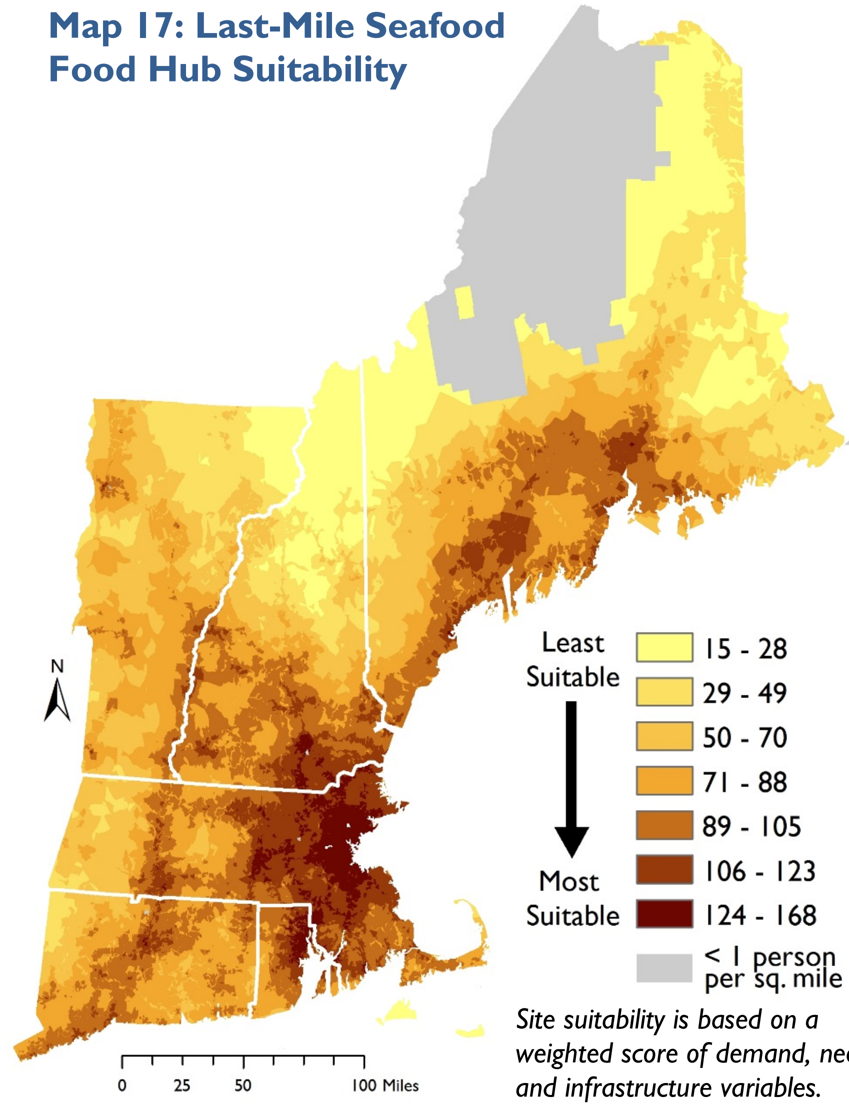
Map 16: First-Mile Seafood Food Hub Suitability



D. Last-Mile Seafood Food Hubs

Map 17 shows that the most suitable locations for last-mile seafood hubs in New England are in the Boston metro area, along the southern coast of Maine, and in the I-91 corridor through central Connecticut and Massachusetts.

Map 17: Last-Mile Seafood Food Hub Suitability



Site suitability is based on a weighted score of demand, need, and infrastructure variables.

DISCUSSION AND FURTHER RESEARCH

The results maps above indicate the most (and least) suitable locations for particular types of food hubs in New England. Our results are intended to provide guidance and direction to food hub founders, investors, and supporters throughout the region on assessing what types of food hubs should be placed in what general locations. These results hold within the context of our site suitability models and the datasets we were able to compile and use for this project.

Food hub founders, policy makers, and investors can use the models and information provided in this report as critical input to frame their decision-making on food hub placement, design, and support. Since food markets are not bound by state borders, decisions on food hub placement and support should similarly transcend state boundaries and be made in the context of a region.

As discussed in the Data Limitations sections throughout this report, there are limits to the conclusions that can be drawn from this analysis due to gaps in our data and the large geographic scale of this project. One takeaway of this research process is that there are significant gaps in our knowledge about existing food system infrastructure and the need for expansion and/or new business development. In addition to supporting the development of particular food hubs, investors and policymakers might consider supporting region-wide research efforts to address knowledge gaps, especially projects that bring together the same information for multiple states in compatible formats. This kind of support would allow stakeholders to develop a truly multi-state regional perspective on food hub development.

Future progress on this work, in New England and in other regions, should include:

- Input from producers and buyers about their need for food hub services;
- Input from existing food hubs about the geographic area they currently serve and their capacity and desire to expand; and
- More comprehensive datasets of existing infrastructure. This could include making phone calls to determine which of the food processor businesses in the state license databases would be willing and able to partner with (or lease space to) new or expanding food hubs; gathering on-the-ground information about on-farm aggregation and/or processing efforts; and/or surveying existing supply chain businesses about their current partnerships and distribution routes.

Finally, most decisions about where to locate a new food hub will be made at a much smaller scale (e.g., choosing between counties or among certain parcels of land or facilities). These results can help a state or area identify a potential macro location, but then further work should occur to collect detailed information from existing value chain entities (producers, processors, aggregators, distributors, buyers) about their current capacity, need, and interest in collaboration, in order to make more precise location decisions.

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APPENDIX

A. Data Sources

Background layers such as state, county, and ocean shapefiles were downloaded from the ESRI DataMap 10 files in the Tufts University GIS library. Links to the other data sources used in this project are listed below.

Fruit and Vegetable Production
2012 Cropland Data Layer http://nassgeodata.gmu.edu/CropScape

Mid-Size Farms
2007 Census of Agriculture
http://www.agcensus.usda.gov/Publications/2007/index.php

Seafood Production
Atlantic Coastal Cooperative Statistics Program http://www.accsp.org/

Food Hubs
USDA Food Hub Database http://www.ams.usda.gov/AMSv1.0/foodhubs

Processing and Aggregation Facilities
ReferenceUSA U.S. Business Database (Tufts University Subscription)
http://www.referenceusa.com/
2012 NAICS Index, Definitions, and Code Files
http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012

Road Networks
ESRI StreetMap Premium (Tufts University Subscription)
http://www.esri.com/data/streetmap
NH GRANIT
http://www.granit.unh.edu/data/downloadfreedata/category/databycategory.html
Maine Office of GIS http://www.maine.gov/megis/catalog/

Population
2010 Census, via American Fact Finder http://factfinder2.census.gov/

Institutions
Connecticut Hospitals, Schools, Colleges
- UCONN MAGIC Connecticut GIS Data http://magic.lib.uconn.edu/connecticut_data.html#places

Connecticut Nursing Homes and Long-Term Care Facilities
- LocalNursingHomes.com http://local-nursing-homes.com/nursing-homes/connecticut
- My Place CT http://www.myplacect.org
- Medicare Data https://data.medicare.gov/data/nursing-home-compare

Connecticut Prisons and Correctional Facilities
- CT Department of Corrections http://www.ct.gov/doc/cwp/view.asp?a=1502&Q=265422&docNav=|

Maine Correctional Facilities, Hospitals, Nursing Homes, and Schools:
- Maine Office of GIS: http://www.maine.gov/megis/catalog/

Massachusetts Acute Care Hospitals, Colleges and Universities, Long Term Care Residences, Prisons, and Schools (Pre-K to 12):
- MassGIS http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/layerlist.html

New Hampshire Colleges and Universities

- NH Department of Education http://www.education.nh.gov/highered/colleges/index.htm
- NH Resources for Residents http://www.nh.gov/residents/college.html

New Hampshire Hospitals, Nursing Homes, Prisons

- NH Granit http://www.granit.unh.edu/data/downloadfreedata/category/databycategory.html

New Hampshire Schools

- NH Department of Education http://www.education.nh.gov/data/school_sau.htm

Rhode Island Colleges and Universities, Correctional Institutions, Hospitals, Schools

- RIGIS Facilities and Structures Data http://www.edc.uri.edu/rigis/data/data.aspx?ISO=structure

Rhode Island Nursing Homes

- Medicare Data https://data.medicare.gov/data/nursing-home-compare

Vermont Colleges, Hospitals, Schools

- Vermont Center for Geographic Information http://vcgi.vermont.gov/warehouse

Vermont Correctional Facilities

- Vermont Department of Corrections http://www.doc.state.vt.us/custody-supervision/facilities

Vermont Nursing Homes

- Vermont Health Care Association http://www.vhca.net/facility_locator.htm
- Vermont Department of Disabilities, Aging, and Independent Living, Division of Licensing and Protection http://www.dlp.vermont.gov/nursing-list
- Medicare Data https://data.medicare.gov/data/nursing-home-compare

B. GIS Tools and Methods

The projected coordinate system used for all maps in this analysis is NAD 1983 UTM Zone 19N. The resolution for our input and results raster files is 30 meters by 30 meters.

We conducted this analysis in ESRI's ArcMap 10.1 with the Network Analyst and Spatial Analyst extensions enabled. Specific tools included:

- Display XY Data (to create point shapefiles from spreadsheets with longitude and latitude data)
- Network Analyst (to create service areas around facility points)
- Dissolve (to combine all areas within a given travel time into one layer)
- Spatial Analyst (to calculate point density of cropland and institutions)
- Intersect (Analysis) and Append (Data Management) (to identify major intersections and create one road network layer)
- Raster-to-Polygon, Point-to-Polygon, Polygon-to-Point, and Polygon-to-Raster (to convert file formats at various stages of the analysis)
- Recalculate tool (to convert all rasters to the same 0-7 scale for the final analysis)
- Model Builder (to create and run the four Site Suitability models)

To create point shapefiles based on address data we used Google Maps (https://maps.google.com/) and BatchGeo (http://batchgeo.com/). We formatted those files for use in ArcMap through Google Earth and the KMZ to KML and KML to Layer tools.

For more information on the data, tools, and methods used in this analysis, contact Joanna Hamilton (joanna@joannamhamilton.com) or Kai Ying Lau (kaiying.lau@gmail.com).