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Mapping the potential of local food capacity in Southeastern Minnesota

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Abstract

The numerous benefits associated with localized food production have helped increase its popularity among a diverse cross-section of concerned citizens over the past few decades. Quantitative benefits are often attributed to local food systems, such as improvements to local economies or environmental benefits associated with decreased food transportation distances. Qualitative benefits play an equally vital role in the increasing popularity of local foods. The direct connection between people and agricultural land instills a sense of responsibility among consumers, there is a great deal of pride associated with creating a self-sustaining community, and increasing locally derived nutritional produce in our diet can improve health. This research attempts to analyze the feasibility of supplying the nutritional needs for an 11-county region in Southeastern Minnesota entirely from locally grown foods. The study also evaluates an alternative land-use scenario to illustrate how better utilizing land resources can yield environmental benefits in addition to those already inherent with local food production. Potential foodsheds are mapped to represent the theoretical spatial extent of agricultural resources needed to sustain population within the region. The foodshed model finds optimum locations for growing local food based on production potential and availability of agricultural resources to meet the demands of population centers, while minimizing the total distance to transport local foods to nearby distribution centers. Results show that it is theoretically feasible for Southeastern Minnesota to be entirely sustained on local food production. The average distance a unit of food travels in this theoretical baseline scenario is just under 12 km (7.5 miles). The foodshed model produces a surplus of agricultural supply in the region, thus an alternative land-use scenario was explored that involves removing marginal cropland from cultivation in vulnerable landscapes with high ecological value in an attempt to further increase the environmental benefits of locally grown foods. In comparison with the baseline foodshed model, the alternative land-use foodshed converts 68,000 ha (168,000 acres) of marginal cropland on vulnerable landscapes from annually cultivated land to perennial agriculture. This conversion not only reduces total distance traveled by a unit of food from 11.8 km (7.3 miles) in the baseline scenario to 10.8 km (6.7 miles) in the alternative scenario, but also reduces soil degradation, has positive impacts on surface water quality, and may lead to better wildlife habitat. The multiple benefits demonstrated by this study are encouraging to leaders of the local food movement in Southeastern Minnesota. Results of the study demonstrate that the methodology developed for mapping New York state foodsheds is adaptable to the Midwestern US, and should also be adaptable in other regions of the country.

Key words: foodshed, geographic information system (GIS), local food, land use

Introduction

The concept of localized food production is discussed in great detail in the literature. The original local food visionaries called attention to food security concerns[1], justice among farmers and consumers alike[2], and the loss of community and culture associated with a corporate-controlled food market[3]. These visions have undoubtedly cultivated changes in the way food markets exist today; local food cooperatives have seen a surge in popularity in the past two decades[4–7]. Utilizing local foods decreases food transportation distances from farm to plate, and can alleviate environmental concerns associated with fossil fuel use[8]. Local foods can also improve local economies by creating jobs, and eating fresh and less processed local foods can yield health benefits as well[9].

A very evocative concept related to local food production is that of a foodshed. This concept was originally introduced as an analog to watersheds, where instead of physical barriers guiding the flow of water, economical influences guide the flow of food[10]. Others have updated this concept with associations to local foods and sustainability[11–13]. The value of a foodshed is its ability to not only illustrate and quantify the geographic extent of where food is coming from, but to raise questions and stimulate thought on ways to decrease this extent. In the current food market, the average distance a unit of food travels in the US is well over 1600 km (1000 miles)[14,15]. More recently, Peters et al.[16] have mapped theoretical foodsheds in New York state based on food demands of population centers, and the production potential of the land resources surrounding them. A potential local foodshed is defined by Peters et al.[16] as 'the land that could provide some portion of a population center's food needs within the bounds of a relatively circumscribed geographic area'. This theoretical foodshed represents the 'best case' scenario and makes several assumptions about the eating habits of the average American. Due to the large population in New York city, the study found that 34% of the state's population could be fed by food grown in state; also the average distance this food would have to travel in New York state to get to consumers is 49 km (30 miles), a mere fraction of the 1600 km (1000 miles) each unit of food travels in the real world.

This research utilizes a model developed for New York by Peters et al.[16] to map theoretical foodsheds, and updates the model using crop yields specific to Southeastern Minnesota. Most of the northern region of Minnesota is covered by forest, but the southern region boasts fertile soils formed under native prairie conditions. The Southeast region specifically has an active effort to increase the production and supply of local foods, centered on the city of Rochester, Minnesota (the largest population center in Southeastern Minnesota). Although the popularity of localized food markets is ever-increasing, data to investigate the feasibility of expanding local food production is lacking. Minnesota's agricultural productivity makes it a prime candidate for such a detailed analysis. When estimating the capacity of each state's ability to supply itself with local foods, Timmons et al.[17] found that Minnesota tops the list, where it is possible to produce 90% of the food needs demanded by its population.

Materials and Methods

The science of constructing a potential foodshed is quite theoretical, so several assumptions were made throughout the process. The study area was confined to the following 11 counties in Southeastern Minnesota: Dodge, Fillmore, Freeborn, Goodhue, Houston, Mower, Olmstead, Rice, Steele, Wabasha and Winona (Fig. 1). It was assumed that only foods produced within this region are available to supply its population. Although a local potential foodshed could likely extend to land across state lines, in this study we limited the foodshed to Minnesota because of differences in data availability and consistency between Minnesota, Wisconsin and Iowa.

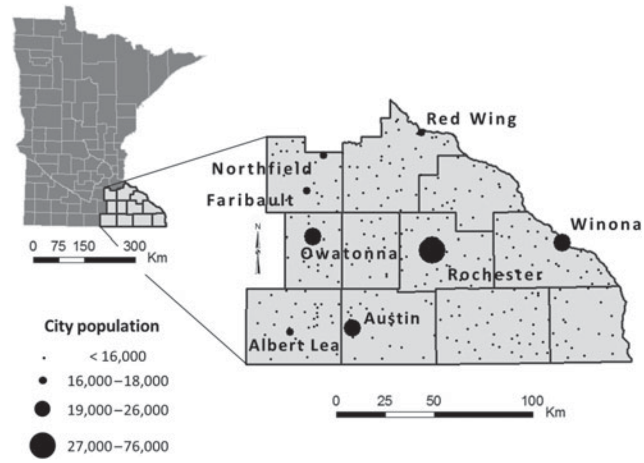

Figure 1. Extent of the study area in Southeastern Minnesota, populated places, and the eight largest cities used for distribution centers in the analysis.

To determine the potential food supply in the region, 5 km^2 production zones were created. These not only act as a convenient unit for determining production potential, but also they serve as appropriately sized supply points when the distances to distribution centers are calculated. Five-kilometer production zones were used in the original model, and were the smallest unit that could be used based on optimization software limitations in this study. The amount of perennial and annually cultivated agricultural land in each zone was calculated based on 2006 national land cover data[18] (Fig. 2). Perennial lands specifically refer to those excluded from annual cultivation, which are mostly pasture lands.

Determining food demand proved to be a more complicated problem. We were concerned with only theoretical foodsheds; in other words, we wanted to map an ideal diet and not attempt to analyze the current dietary trends in the region, due to lack of reliable data. Based on suggestions by Peters and his work testing a complete diet[19], a 2300 kcal day^{-1} diet was chosen that meets food-guide pyramid recommendations. This diet, termed a human nutritional equivalent (HNE), consists of 170 g (6 oz) of meat per person per day, with 40% of total calories from fat (Appendices 1 and 2). The constituents of the HNE can be subdivided into foods derived from annually cultivated land (HNEa) and foods derived from perennial agricultural land (HNEp), all of which can be grown or supported by agricultural land specific to the climate in Minnesota.

This ideal diet was then translated into agricultural land demand by analyzing crop yields for each of the constituents of the HNE. The original model used in

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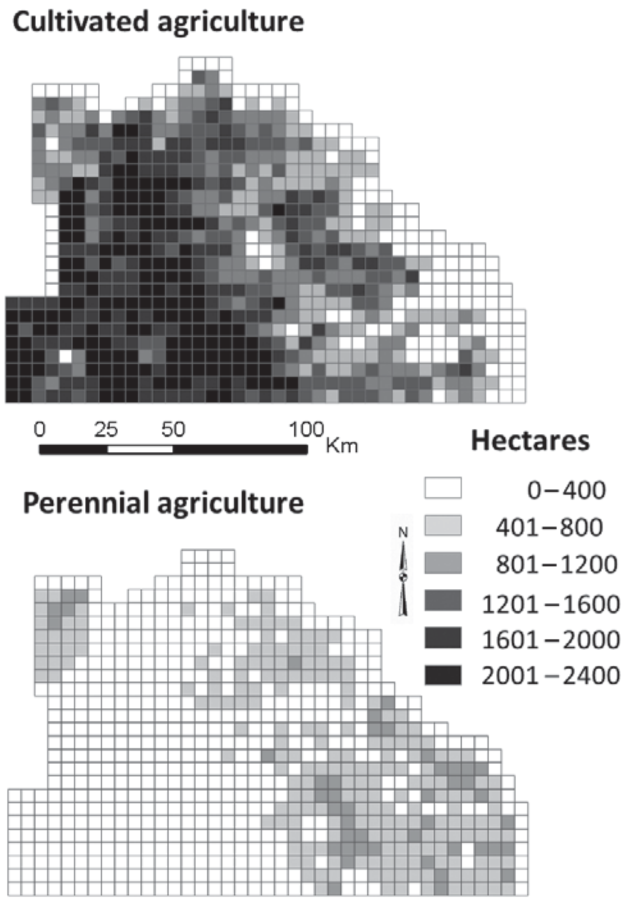

Figure 2. Five-kilometer production zones displaying the current distribution of annually cultivated and perennial agricultural lands in the region.

New York state contained crop yield data on each commodity that made up the HNE; the model was updated with Minnesota specific crop yields. Five-year National Agriculture Statistics Service (NASS) data were acquired for all counties in the region[20]. Crop yield goals were used when NASS data were not available[21]. Adjustments were made to account for inedible portions of agricultural commodities, and processing losses were also accounted for in the model. Furthermore, feed crops were considered when determining land demands; a serving of beef in the model not only includes the pasture land needed to raise the cattle, but also the annually cultivated land needed to grow feed crops for these cattle. Because of these considerations, meat and dairy products contribute to both the HNEa and HNEp.

Once the diet was chosen and land requirements for each constituent were calculated, food demand of the region can be determined with population data. First the 11-county region was divided into eight population zones. A simple Thiessen polygon analysis based on the eight largest cities determined the extent of these zones. All population data from the 2008 census[22] were then assigned to the appropriate population zone; it was assumed that all people would derive their food from the closest distribution point, or city within the zone. The total population for the region was determined to be just fewer than 500,000 persons.

Food demand was determined for each of the eight distribution centers, and supply was calculated based on the 5-km production zones, of which over 750 were created in the region. Distances from each production zone or supply point were then calculated to each distribution center so optimization software could be used to best allocate food supplies. The structure of the optimization problem was described previously by Peters et al.[16], and Frontline's Risk Solver Platform[23] was utilized within Microsoft Excel® to carryout optimization. A single spreadsheet was used containing a variable matrix that allowed the software to explore every possible allocation of food products expressed in HNEs from each of the 750 production zones to one of the eight specific population centers. This variable matrix was constrained by both the production potential within each zone and by the maximum production demanded by each population center. A distance matrix was also used that defined each straight line distance from the 750 production zones to each of the eight population centers. Finally, an equation summed the total distances for each allocation scenario to find the minimum distance food would have to travel while either meeting all of the populations' food needs or exhausting all of the production potential of agricultural land in the region.

Alternative land-use scenario

An alternative land-use scenario was explored to determine if removing marginal cropland from production in environmentally vulnerable landscapes could increase the benefits of local foods. Based on the constituents of the HNE, perennial agriculture land is in higher demand and is also in shorter supply in the region (Table 1). In the alternative scenario, a portion of annually cultivated lands was converted to perennial lands on marginal cropland in environmentally vulnerable landscapes, based on two indices described below. Annually cultivated lands can produce environmental concerns, such as soil degradation and surface water contamination[24]. By converting a portion of annually cultivated lands to perennial agriculture, not only is foodshed size decreased, implying reduced food delivery distances, but also there is the potential for further direct environmental benefits.

Two indices were employed when selecting potential lands to be converted from annually cultivated land to perennial agriculture. The crop productivity index (CPI) was developed by the Natural Resources Conservation Service in Minnesota and represents a rating of potential yield of one soil against another. Ratings range from 0, or low productivity, to 100, or the highest productivity[25]. Due to a marginal production potential, pixels of land based on 30-m grid cells with CPI ratings of 50 or less were

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Table 1. Demand of agricultural land and the foodshed extent to meet this demand for annual foodsheds (HNEa) and perennial foodsheds (HNEp).

	Regional agricultural land (ha)		Foodshed extent (ha)	
	Supply	Demand	Current land-use scenario	Alternative land-use scenario
HNEa	2,329,530	74,200	247,500	262,500
HNEp	387,278	108,199	1,237,500	950,000

set aside for consideration of conversion to perennial agriculture.

A second index, the environmental benefits index (EBI), ranks lands based on their potential ecological benefit. The EBI places a high value on lands that would benefit from being removed from production, based on three different ecological concerns. The first represents the risk for soil degradation based on the Universal Soil Loss Equation. The EBI also values lands that have a high potential for providing quality habitat, based on several terrestrial habitat considerations. Finally a high value is given to lands associated with a surface water quality risk, based on overland flow patterns and proximity to surface waters. Each component can contribute 100 points to the EBI, with total values ranging from 0 to 300[26]. The higher scores represent land parcels that would most strongly benefit from a cessation of annual cropping practices.

Lands where CPI is under 50 were intersected with areas that had EBI scores above 150 to represent not only low-productivity lands, but lands that would also provide the most ecological benefits when removed from annual cropping. Characteristics of marginal lands suitable for this conversion include cultivated areas with steep slopes, shallow topsoil, in close proximity to surface waters or in areas important for local biodiversity.

Results

According to the Environmental Protection Agency's National Land Cover Dataset, the 11-county study area in Southeastern Minnesota contains over 1,150,000 ha (2,850,000 acres) of agricultural land cover, including both perennial land, such as pasture, and annually cultivated land. Within the region, 80% of all agricultural land is devoted to the latter[18]. Most of the cultivated land is located in the western portion of the region where the landscape is relatively flat and soil is productive. The eastern edge of the region is dominated by high-relief bluff lands draining into the Mississippi River, and contains a higher proportion of perennial agriculture (Fig. 2).

The region is dominated by rural communities and small cities. The largest population center in the region is Rochester with just over 75,000 persons. The average population of the remaining seven cities used in the model is just under 20,000 persons[22]. The largest eight urban areas represent less than half of the total population in the region; the remainder is dispersed across rural areas and small towns.

Based on the constituents of the ideal diet and Minnesota specific crop yields (Appendices 1 and 2), each person in the region demands 0.16 ha (0.40 acre) of cultivated land per year and 0.23 ha (0.58 acre) of perennial land, totaling just under 0.4 ha $person^{-1} yr^{-1}$ (1 acre $person^{-1} yr^{-1}$). Perennial land is in higher demand due to its lower nutritional equivalent per acre food yields. Based on this demand, the 1,150,000 ha of agricultural land in the region should be more than adequate to support the population of under 500,000; however, distribution of the type of land plays a large role in determining foodshed size in the region.

Based on food demands and land availability in Southeastern Minnesota, the model showed the feasibility of feeding all residents on locally grown foods. The extent of each foodshed is determined largely by the higher demand and shorter supply of perennial agriculture in the region. Foodsheds based on annually cultivated lands are relatively small, whereas perennial foodsheds cover a majority of the available land in the region (Fig. 3). To meet the demand for HNEa in the region, just under 75,000 ha (185,000 acres) of annually cultivated land is needed; based on the demand for HNEp in the region, almost 110,000 ha (270,000 acres) of perennial land is needed (Table 1). The areal coverages of annual and perennial agriculture are much smaller than their corresponding foodshed extent. These land areas demanded by each HNE do not include other land uses that may be mixed in with agricultural land. The foodshed extent is much larger because it includes all non-agricultural land use such as urban, wetland, forest and open water. The extent of the annually cultivated foodshed spans nearly 250,000 ha (620,000 acres). The perennial foodshed spans 1,240,000 ha (3,000,000 acres). The difference in demands on cultivated and perennial lands can also be seen in the distance a unit of food travels in the foodshed. The average distance traveled by an HNEa is 9.4 km (6 miles), whereas an HNEp travels over 22 km (14 miles). Overall, a total HNE travels 11.8 km (7.3 miles) based on the model (Table 2). This is in sharp contrast to the 1600 km (1000 miles) that food is calculated to travel in the current corporate-controlled food system[14,15].

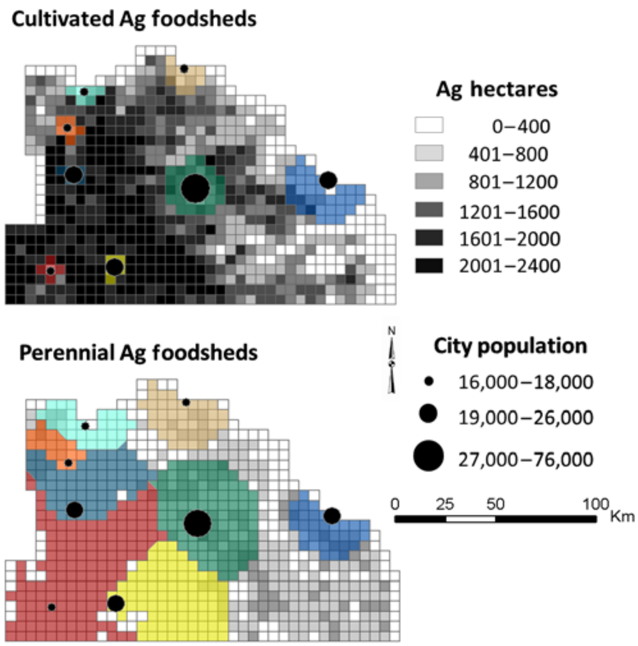

Figure 3. Five-kilometer production zones displaying the current distribution of agricultural land overlaid with annually cultivated and perennial foodsheds (foodsheds are in color online) based on current land-use practices.

Table 2. Average food distances traveled for annual foodsheds (HNEa), perennial foodsheds (HNEp) and the total (HNE).

	Current land-use scenario	Alternative land-use scenario
HNEa food distance (km)	9.4	9.8
HNEp food distance (km)	22.3	15.3
Total HNE food distance (km)	11.8	10.8

Alternative land-use scenario

In the alternative land-use scenario, lands marginal for annual cropping that are also vulnerable to soil erosion and water quality degradation are considered for perennial food production. In total, this alternative land-use scenario converts 68,000 ha (168,000 acres), or less than 10%, of the annually cultivated lands in the area to perennial agriculture, resulting in reductions in soil erosion and improvements in water quality. In this scenario, some cultivated lands are lost, which is reflected by a slight increase in foodshed size and average distance each HNEa travels. The size of annually cultivated foodsheds increases from 247,500 ha (612,000 acres) in the baseline foodshed model to 262,500 ha (649,000 acres) in the alternative foodshed model (Table 1). The average distance an HNEa travels increases from 9.4 km (5.8 miles) to 9.8 km (6.1 miles) (Table 2). However, this small increase in annual foodshed size and travel distance is compensated by the large reductions in perennial

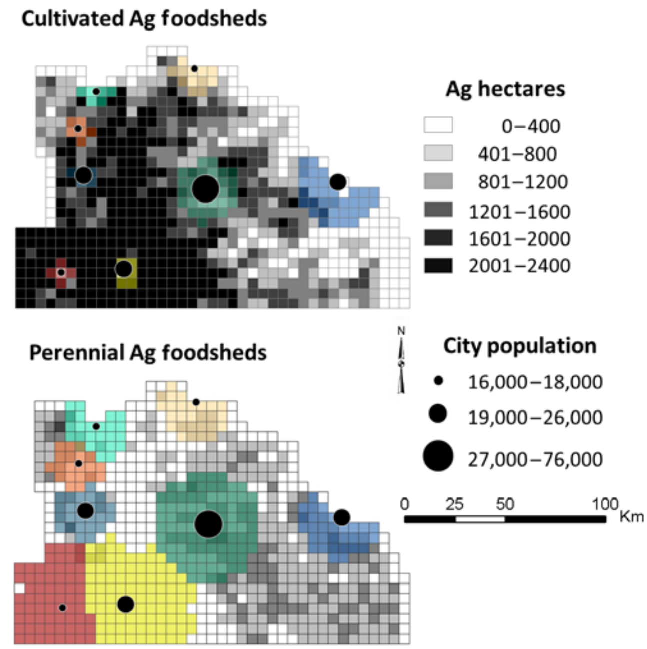

Figure 4. Five-kilometer production zones displaying the distribution of agricultural land overlaid with annually cultivated and perennial foodsheds (foodsheds are in color online) based on an alternative land-use scenario where marginally productive and environmentally sensitive annually cultivated land is converted to perennial agriculture.

foodshed size and delivery distances (Fig. 4). Perennial foodsheds are reduced from a total area of 1,237,500 ha (3,060,000 acres) in the baseline foodshed model to 950,000 ha (2,350,000 acres) in the alternative foodshed model. The average distance traveled by an HNEp also decreases from 22.3 km (13.9 miles) to 15.3 km (9.5 miles), whereas the average distance traveled for the total HNE drops from 11.8 km (7.3 miles) to 10.8 km (6.7 miles).

Discussion

The foodshed model used in this analysis is quite theoretical and makes several assumptions. The largest, and possibly the farthest from reality, is the diet used. A perfectly balanced 2300 kcal diet with small servings of meat and minimal fat and sugars is not typical for most of the population in this region, or anywhere in the country for that matter. Social obstructions to the food system in the model, such as resistance to dietary changes, are ignored and would be nearly impossible to account for. The model also ignores consumer preferences for inexpensive and processed foods, which are not accounted for in the ideal diet. Foodsheds that would display realistic dietary habits in the region would likely cover a larger area than foodsheds created by the ideal model because of the probable increase in total calories. Due to a lack of reliable data, further study is recommended to determine current regional dietary trends in order to create a more realistic diet. Furthermore, the model delivers food based on straight line distances from supply points to distribution centers, of which there are only eight for the relatively large area in Southeastern Minnesota. In reality, local food systems would work on a much smaller level, where nearly every small town would act as a farmer's market hub for purchasing local produce and other foods. Although several caveats exist within the model, it represents a best-case scenario, which provides results that are encouraging to leaders of the local foods movement, and offers tangible goals that are easily visualized when designing local food systems.

The alternative land-use scenario is one of many possible alternatives to explore, and environmental benefits are merely one of several positive outcomes. For example, one could also explore the economical benefits agriculture could provide for the region. The surplus in annually cultivated food in the region is enough to supply 5.3 million HNEa, which means the region could provide all of the cultivated food needs for the entire population of Minnesota. The surplus in perennially cultivated foods could provide an additional 0.5 million HNEp. Due to economics of agriculture, the surplus in agricultural land cover would likely be devoted to growing commodity crops for export nationally and internationally. However, this study provides evidence that environmental benefits can be explored while still feeding Southeastern Minnesota's population and creating a surplus for export.

Foodsheds in this study were created with easily acquired data. The model used was originally designed for New York, but was transferred to Minnesota by updating crop yield data. These data are available for most of the country. Census data as well as land cover data are also available nationwide. Although crop yields vary based on soil and climate characteristics, this study should be replicable across the country with relative ease. This may lead to encouraging results for leaders of the local food movement in other regions, and stimulate interest in local foods across the country.

Conclusions

Based on the assumptions made, the 11-county region in Southeastern Minnesota can feasibly feed its entire population on locally grown foods. The New York study found that only one-third of the state could be fed locally. The large urban population of New York city clearly affects how much of the state's population can be fed locally, but it is interesting to note the encouraging results in Southeastern Minnesota in the absence of a very large metropolitan area. Under current land-use practices, the average distance a unit of food will travel from supply point to distribution center is 11.8 km (7.3 miles), compared to 49 km (30 miles) in the New York study. With current land-use practices, the region is experiencing a potential food surplus. Alternative land management techniques can be employed to convert 68,000 ha (168,000 acres) of marginal cropland on vulnerable landscapes from annually cultivated land to perennial agriculture, while still feeding the local population. This conversion not only reduces total distance traveled by a unit of food from 11.8 km (7.3 miles) to 10.8 km (6.7 miles), but it will also reduce soil degradation, have positive impacts on surface water quality and may lead to better wildlife habitat.

Although, based on the model, it is feasible to feed this region with local foods, several assumptions have been made that push the bounds of reality. Drastic changes in the way consumers acquire their foods are needed, along with changes in the diets themselves to be more focused on a well-balanced diet of fresh foods. Although the exact foodsheds displayed by this model will likely never become a reality, they are encouraging to local planners. The results illustrate that there are enough land resources to feed the population of Southeastern Minnesota using local foods. These results will contribute to further planning by the local foods movement in Southeastern Minnesota, and rural communities across the country.

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Appendix 1. Constituents of the ideal diet for summer months as well as average yields for Southeastern Minnesota and estimated consumption for each processed constituent.

	Average yield	Estimated consumption (g person^{-1} day^{-1})
GRAINS		
Wheat	43 bu acre^{-1}	178.7
Rye	30 bu acre^{-1}	1.2
Corn	145 bu acre^{-1}	14.2
Oats	73 bu acre^{-1}	8.9
VEGETABLES		
Carrots (fresh)	400 cwt acre^{-1}	31.7
Endive/escarole (fresh)	180 cwt acre^{-1}	0.6
Lettuce (fresh)	300 cwt acre^{-1}	41.9
Spinach (fresh)	150 cwt acre^{-1}	4.1
Squash, winter (fresh)	300 cwt acre^{-1}	7.4
Beets (canned)	10 t acre^{-1}	2.2
Bell peppers (fresh)	200 cwt acre^{-1}	4.5
Cabbage (fresh)	400 cwt acre^{-1}	4.3
Cauliflower (fresh)	150 cwt acre^{-1}	1.5
Cucumbers (fresh)	250 cwt acre^{-1}	6.2
Eggplant (fresh)	250 cwt acre^{-1}	0.9
Onions (fresh)	500 cwt acre^{-1}	22.1
Snap beans (fresh)	3 t acre^{-1}	8.1
Tomatoes (fresh)	270 cwt acre^{-1}	69.7
Green peas (frozen)	1.5 t acre^{-1}	5.8
Green peas (canned)	1.5 t acre^{-1}	6.2
Potatoes (fresh)	167 cwt acre^{-1}	78.2
Sweet corn (fresh)	7 t acre^{-1}	21.3
FRUIT		
Blueberries (fresh)	50 cwt acre^{-1}	4.7
Strawberries (fresh)	100 cwt acre^{-1}	17
Apples (fresh)	140 cwt acre^{-1}	61.9
Cherries (fresh)	45 cwt acre^{-1}	2.2
Grapes (fresh)	60 cwt acre^{-1}	13.6
Plums (fresh)	80 cwt acre^{-1}	23.6
Pears (fresh)	100 cwt acre^{-1}	22.5
Apple juice	8840 lbs acre^{-1}	144
Grape juice	4180 lbs acre^{-1}	63.2
DAIRY		
Milk—whole (3.7%)[1]	4917 lbs acre^{-1}	536.8
PULSES		
Beans—black	2361 lbs acre^{-1}	1.2
Beans—kidney	2361 lbs acre^{-1}	1.1
Soybeans	47 bu acre^{-1}	1.3
NUTS and SEEDS		
Sunflower seeds	1105 lbs acre^{-1}	0.5
MEAT and EGGS		
Beef[1]	1561 lbs acre^{-1}	66.9
Pork[1]	1800 lbs acre^{-1}	32.2
Chicken[1]	1577 lbs acre^{-1}	44.9
Eggs[1]	3721 lbs acre^{-1}	46.5
OILS		
Canola oil	1527 lbs acre^{-1}	1.3
Soyabean oil	2823 lbs acre^{-1}	20.1
Sunflower oil	1517 lbs acre^{-1}	0.1
SUGARS		
Beet sugar	30,000 lbs acre^{-1}	59.6

[1] Yield values represent pounds of processed edible product.

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Appendix 2. Constituents of the ideal diet for winter months as well as average yields for Southeastern Minnesota and estimated consumption for each processed constituent.

	Average yield	Estimated consumption (g person^{-1} day^{-1})
GRAINS		
Wheat	43 bu acre^{-1}	172.1
Rye	30 bu acre^{-1}	1.2
Corn	145 bu acre^{-1}	13.7
Oats	73 bu acre^{-1}	8.6
VEGETABLES		
Carrots (fresh)	400 cwt acre^{-1}	63.4
Squash, winter (fresh)	300 cwt acre^{-1}	14.8
Spinach (frozen)	150 cwt acre^{-1}	26.1
Beets (canned)	10 t acre^{-1}	2.4
Cabbage (fresh)	400 cwt acre^{-1}	4.9
Cauliflower (frozen)	150 cwt acre^{-1}	2.9
Onions (fresh)	500 cwt acre^{-1}	24.9
Snap beans (frozen)	3 t acre^{-1}	4.9
Snap beans (canned)	3 t acre^{-1}	4.9
Tomatoes (canned)	270 cwt acre^{-1}	104.5
Green peas (frozen)	1.5 t acre^{-1}	5.6
Green peas (canned)	1.5 t acre^{-1}	6.0
Potatoes (fresh)	167 cwt acre^{-1}	75.3
Sweet corn (frozen)	7 t acre^{-1}	10.9
Sweet corn (canned)	7 t acre^{-1}	10.9
FRUIT		
Apple juice	8840 lbs acre^{-1}	138.7
Grape juice	4180 lbs acre^{-1}	60.8
Blueberries (frozen)	50 cwt acre^{-1}	5.6
Strawberries (frozen)	100 cwt acre^{-1}	27.1
Apples (fresh)	140 cwt acre^{-1}	68.8
Cherries (frozen)	45 cwt acre^{-1}	2.6
Plums (canned)	80 cwt acre^{-1}	34.2
Pears (fresh)	100 cwt acre^{-1}	25
DAIRY		
Milk—whole (3.7%)[1]	4917 lbs acre^{-1}	536.8
PULSES		
Beans—black	2361 lbs acre^{-1}	1.2
Beans—kidney	2361 lbs acre^{-1}	1.1
Soybeans	47 bu acre^{-1}	1.3
NUTS and SEEDS		
Sunflower seeds	1105 lbs acre^{-1}	0.5
MEAT and EGGS		
Beef[1]	1561 lbs acre^{-1}	66.9
Pork[1]	1800 lbs acre^{-1}	32.2
Chicken[1]	1577 lbs acre^{-1}	44.9
Eggs[1]	3721 lbs acre^{-1}	46.5
OILS		
Canola oil	1527 lbs acre^{-1}	1.3
Soybean oil	2823 lbs acre^{-1}	20.1
Sunflower oil	1517 lbs acre^{-1}	0.1
SUGARS		
Beet sugar	30,000 lbs acre^{-1}	59.6

[1] Yield values represent pounds of processed edible product.

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