FOODPRINTS AND FOODSHEDS
Models for evaluating dietary land requirements and the capacity for local and regional food

Foodprints & Foodsheds Project – Michigan Workshop

May 4, 2010

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AGENDA
Purpose of this session

1. **Introduce two tools** developed to explore the capacity of land to meet human food needs.
2. **Begin a discussion** of the potential for Michigan to supply its own food needs.
3. **Invite feedback** on the value of these methodologies and how they might be improved.

AGENDA
Outline and protocol

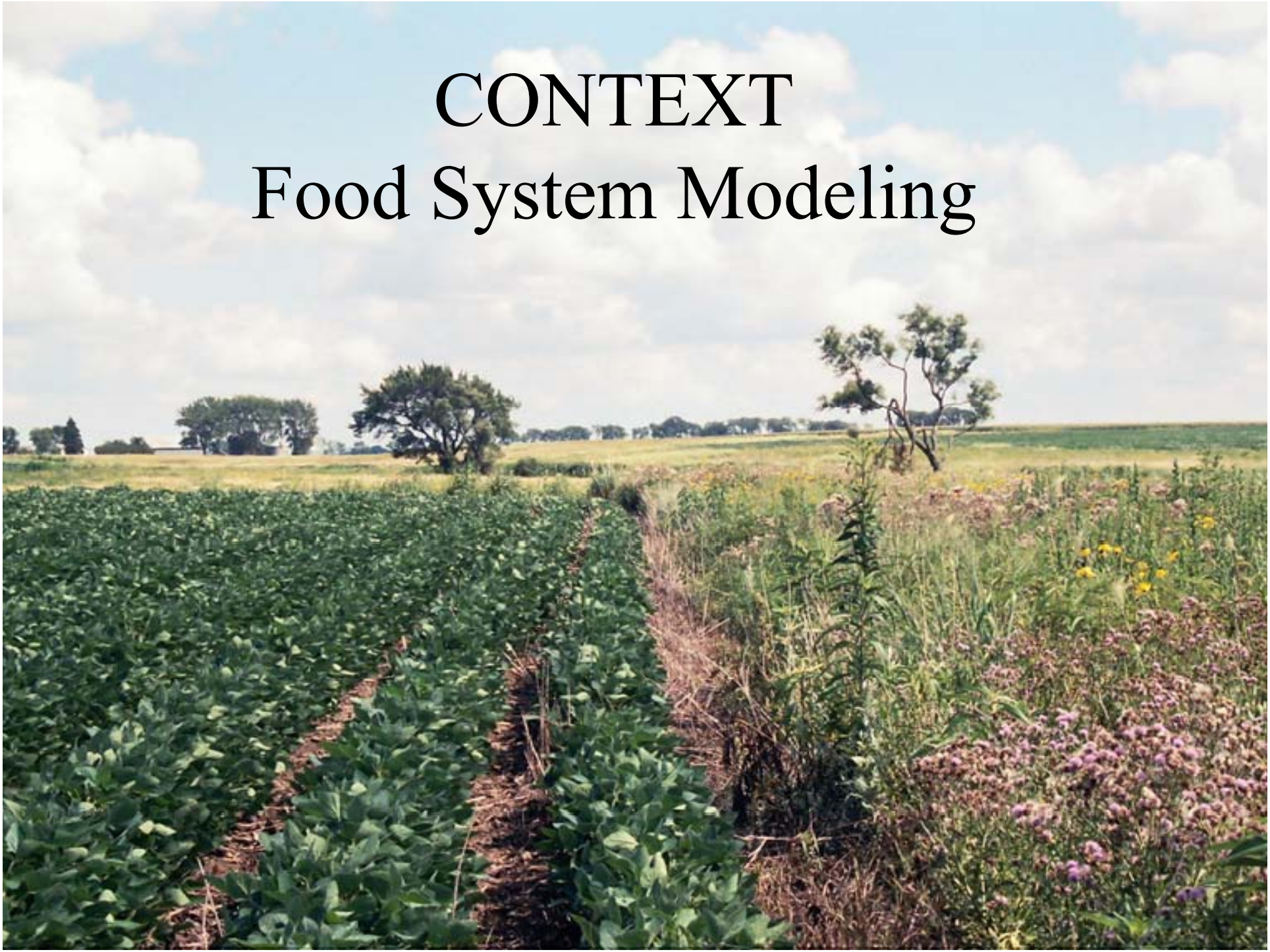
Presentation (75 minutes)

- Modeling dietary land requirements
- Modeling potential local foodsheds
- Conclusions and next steps

Q & A and discussion (30 minutes)

If something is unclear, please feel free to ask questions during the talk. General questions can be reserved for Q&A.

CONTEXT
Food System Modeling

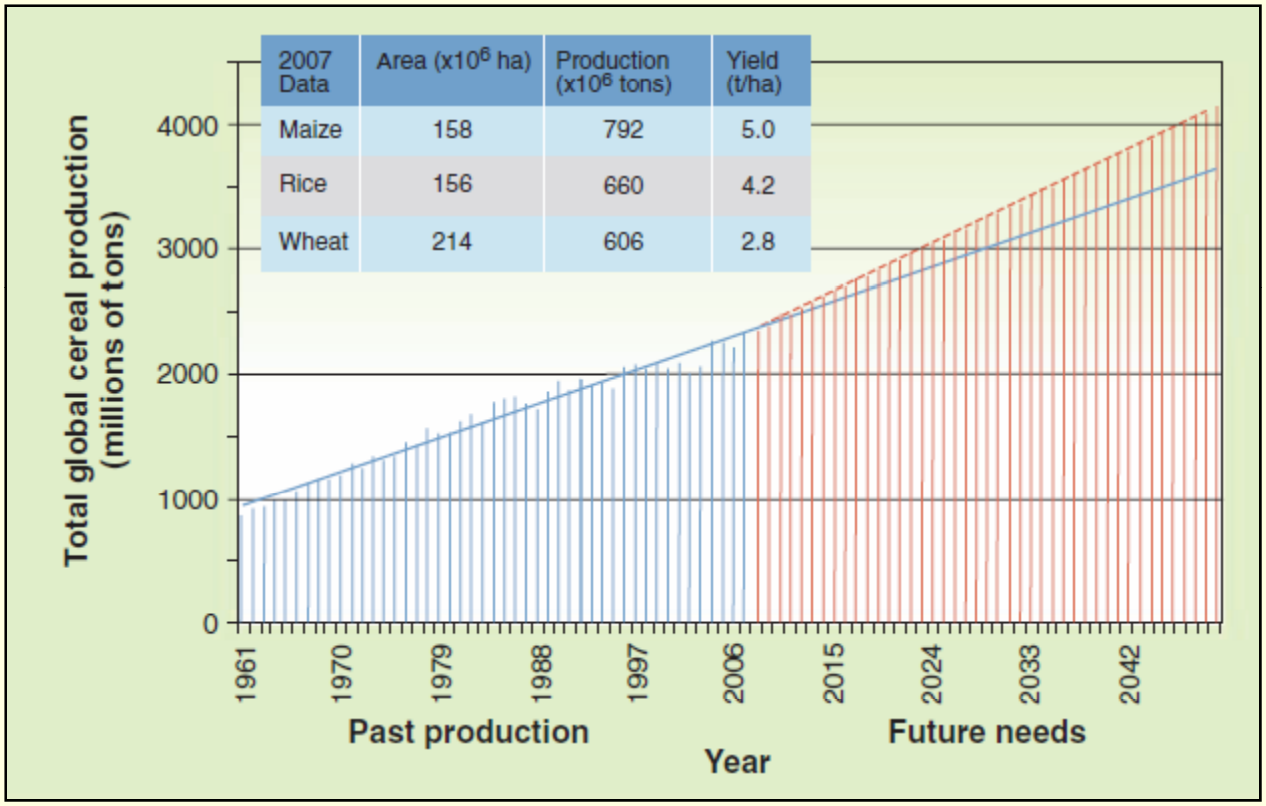


CONTEXT
Humanity faces a challenge

Six potentially irreconcilable issues:

1. Feeding a growing world population
2. Meeting demand for affluent diets
3. Addressing obesity and malnutrition
4. Adapting to a changing climate
5. Competition for land, water, and energy
6. Reducing environmental impact

CONTEXT
Challenge of global food demand



2007 Data	Area ($x10^6$ ha)	Production ($x10^6$ tons)	Yield (t/ha)
Maize	158	792	5.0
Rice	156	660	4.2
Wheat	214	606	2.8

SOURCE: Tester, M and Langridge, P. 2010. Breeding technologies to increase crop production in a changing world. Science 327: 818-822.

Can supply keep pace with demand?

Trend in cereal **production** diverges from projections of cereal **demand**

CONTEXT
Dietary change as a strategy

Difficult to determine how dietary change will influence food security because:

- Production efficiency differs among livestock classes
- Grazing lands and byproducts do not compete with production of plant-based foods
- Possible to improve feed conversion and better manage livestock
- Consumption of meat often consistent with improved health in poorer countries
- Production of livestock is an important source of rural income

SOURCE: Godfray et al. 2010. Food security: The challenge of feeding 9 billion people. Science 327: 812-818.

CONTEXT
Challenge of sustainability

Can diverse goals be achieved through local and regional food systems?

RURAL

Farm viability

Community development

URBAN

Food access

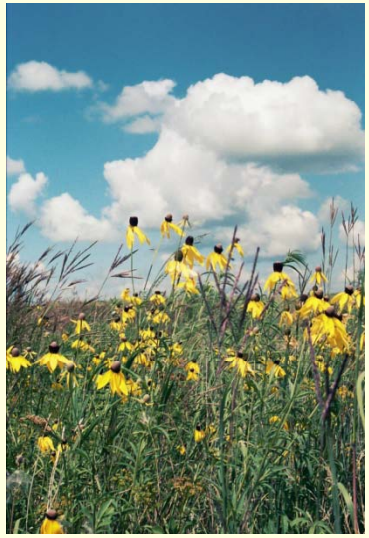
Food quality

Community empowerment

RESOURCES

Land, water, energy use

Energy production



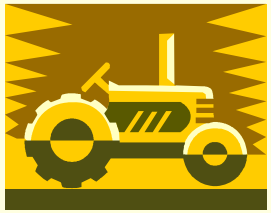
ECOLOGY

Greenhouse gas emissions

Land stewardship

CONTEXT
Changing food source as a strategy

Local food systems



Current system:
Less sustainable
Less just

→

Alternative system:
More sustainable
More just

To what degree can localizing the food supply serve as a vehicle for achieving these goals?*

*For extended discussion see Born, B. and Purcell, M. 2006. Avoiding the local trap: Scale and food systems in planning research. Journal of Planning Education and Research 26:195-207.

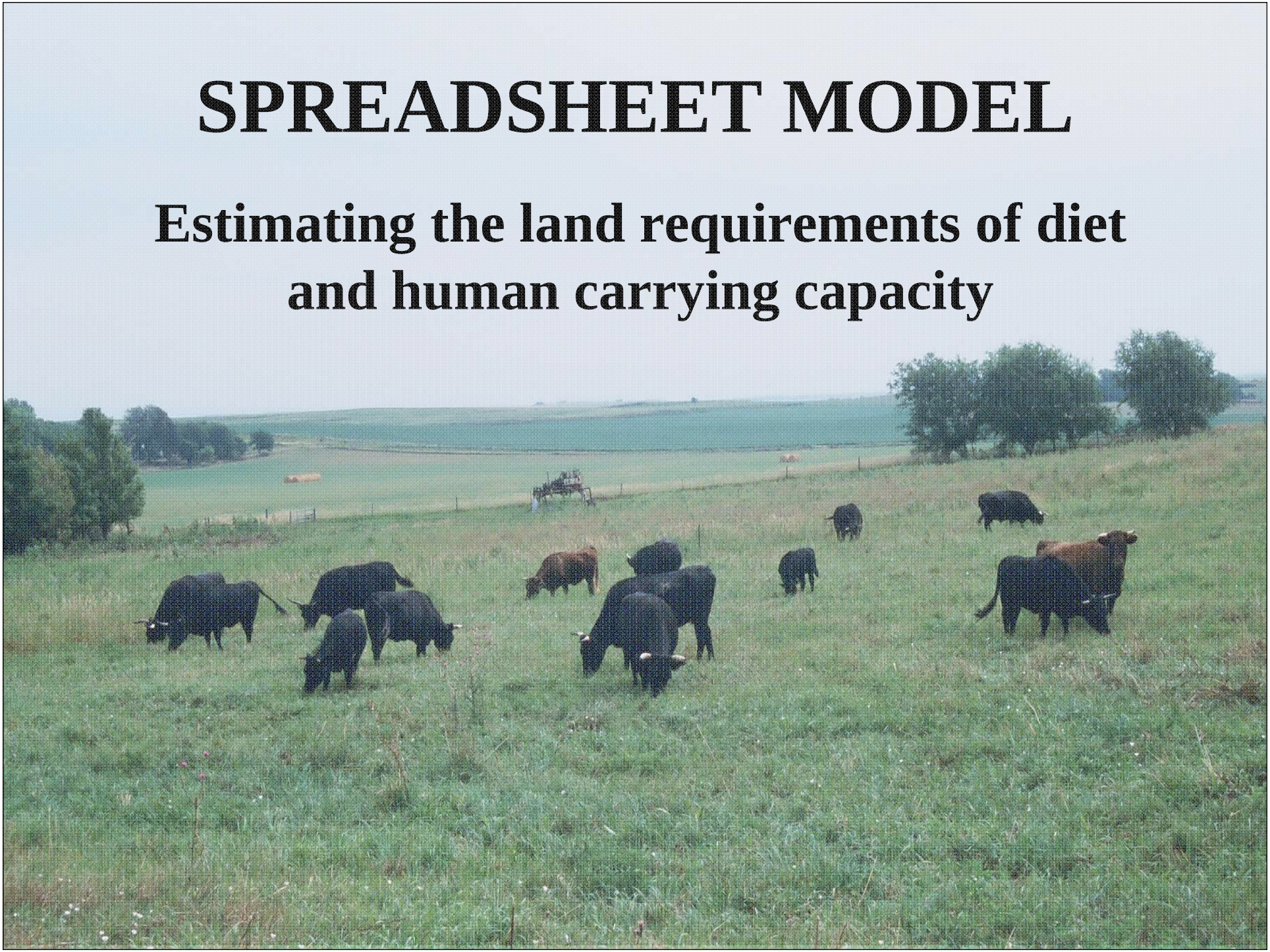
CONTEXT
Motivating questions

1. How do **dietary patterns** influence requirements for agricultural land and human carrying capacity?

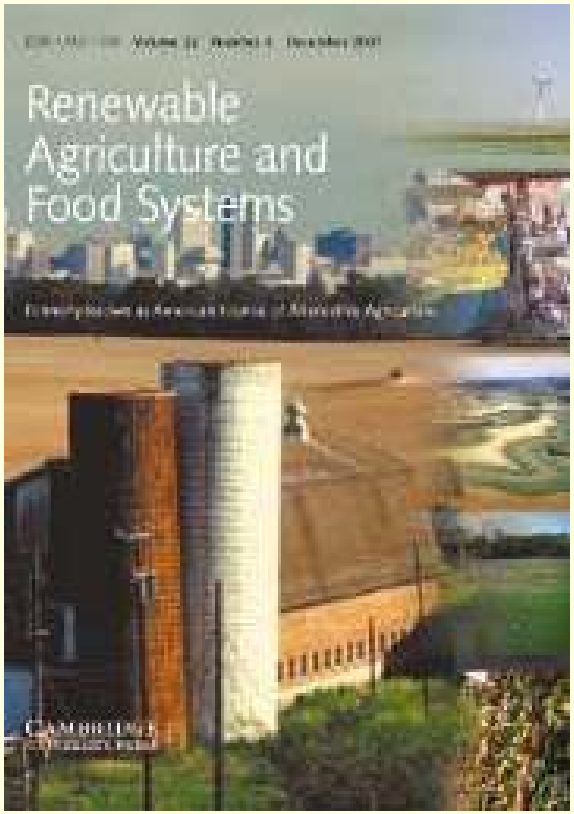
2. How much of our food could be supplied through **local and regional food** systems?

SPREADSHEET MODEL

Estimating the land requirements of diet and human carrying capacity



INTRODUCTION
Replicating the New York State study

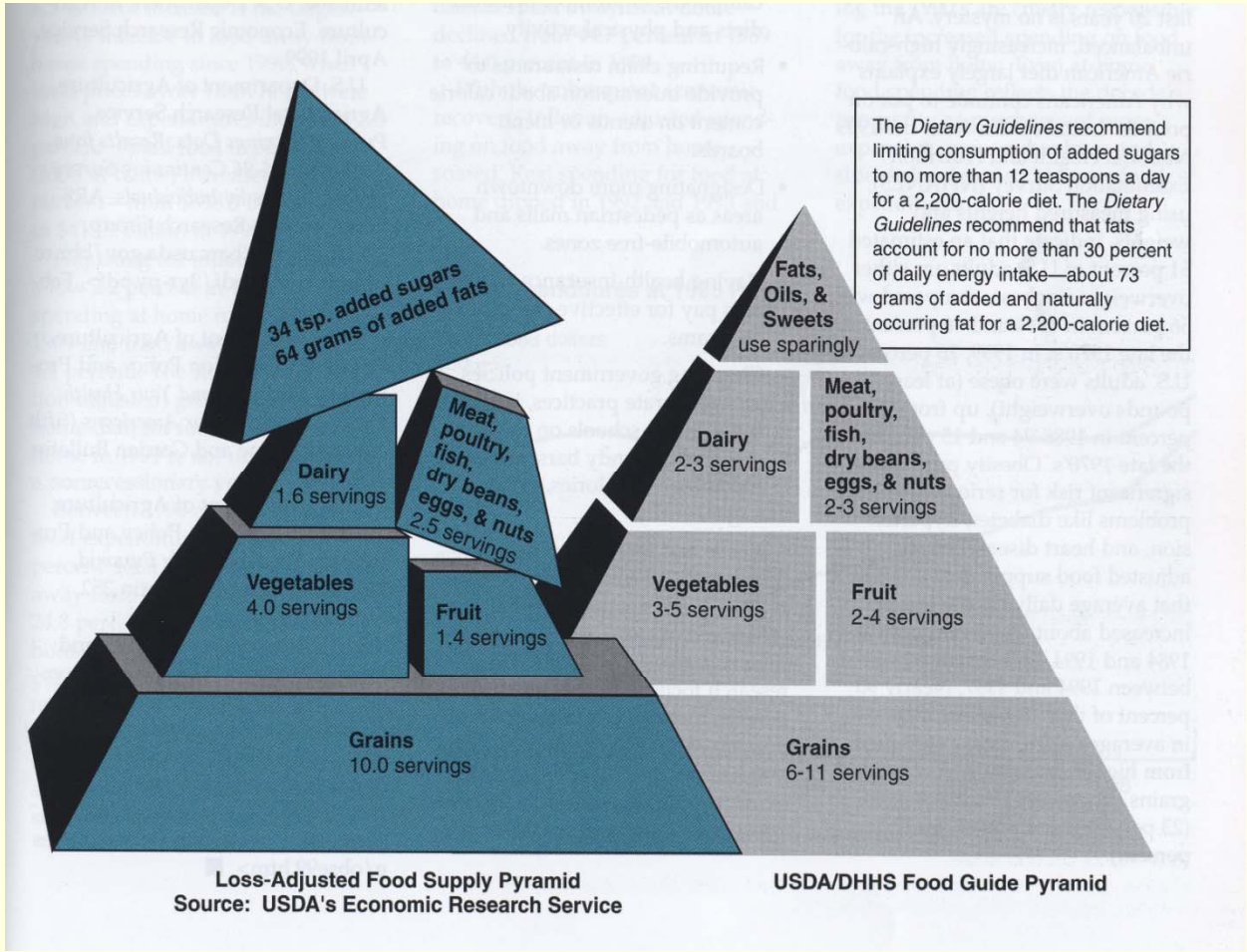


Peters CJ, Wilkins JL, Fick GW (2007) *Renewable Agriculture and Food Systems* 22(2): 145-153.

INTRODUCTION
Why model diet-land-carrying capacity?

1. **Changing consumption patterns** may need to be part of an overall food security and sustainability strategy
2. **Existing research** paints an incomplete picture of how diet influences both
3. **Modeling** can help improve our knowledge of these relationships

METHODS
A complete-diet approach



(Source: Putnam et al., 2000)

Incongruity of nutritional guidelines and agricultural production is well-documented.

Health should be an explicit goal of the food system.

METHODS
Experimental design

Fat consumed per capita per day (% of kcal)

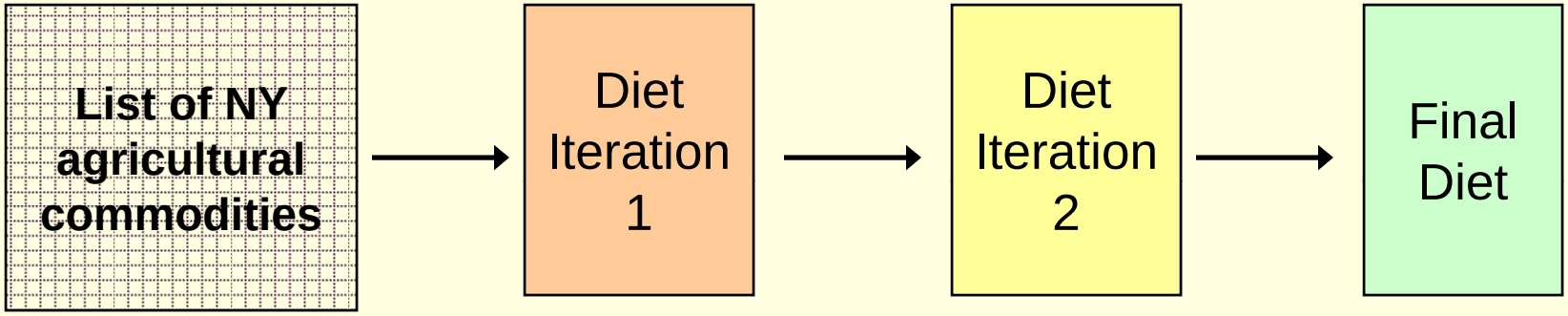
Meat and eggs consumed per capita per day (oz)	20	25	30	35	40	45
0						
2						
4						
6						
8						
10						
12						

6 oz cooked meat and eggs
40% calories from fat

Dietary energy

2,300 kcal

METHODS
Creating the diets



Step 1	Step 2	Step 3
COMPOSE FOUNDATION DIET	ADD FAT	BALANCE CALORIES
Dietary guidelines Food preferences Meat treatment levels	Full-fat dairy and meat, then plant oils	Add or remove carbohydrate-rich foods

METHODS
Estimating per capita land needs

$$A_{percap} = \sum \frac{(Q_i \times L_i)}{Y_i} + \sum \frac{(Q_j \times L_j \times R_{jk})}{Y_{jk}}$$

Plant-based

Animal-based

<u>Where:</u>

A = Area of land required

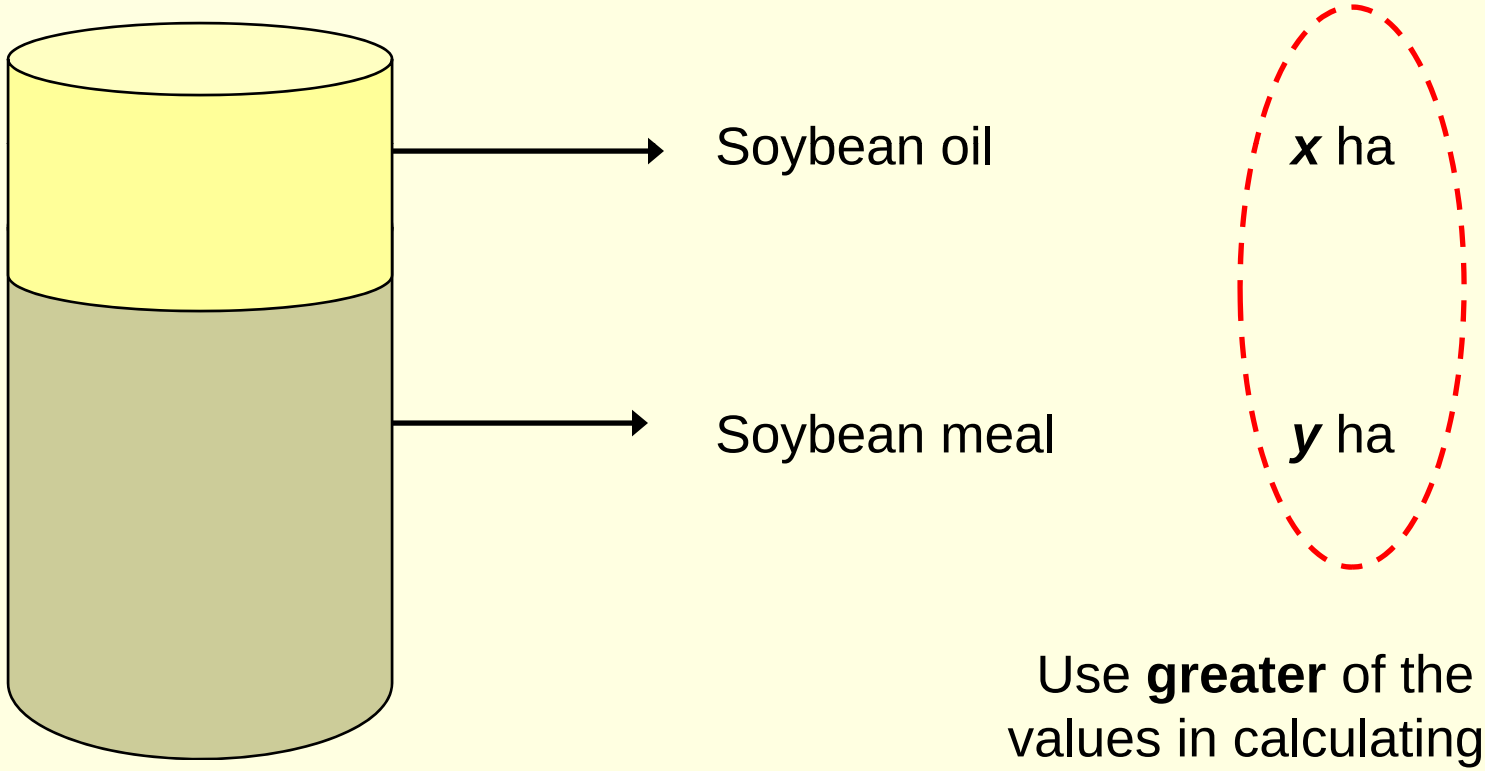
Q = Quantity of food eaten

L = Losses and other conversions

R = Feed requirements for livestock

Y = Yield of crops

METHODS
Adjusting for extra soybeans



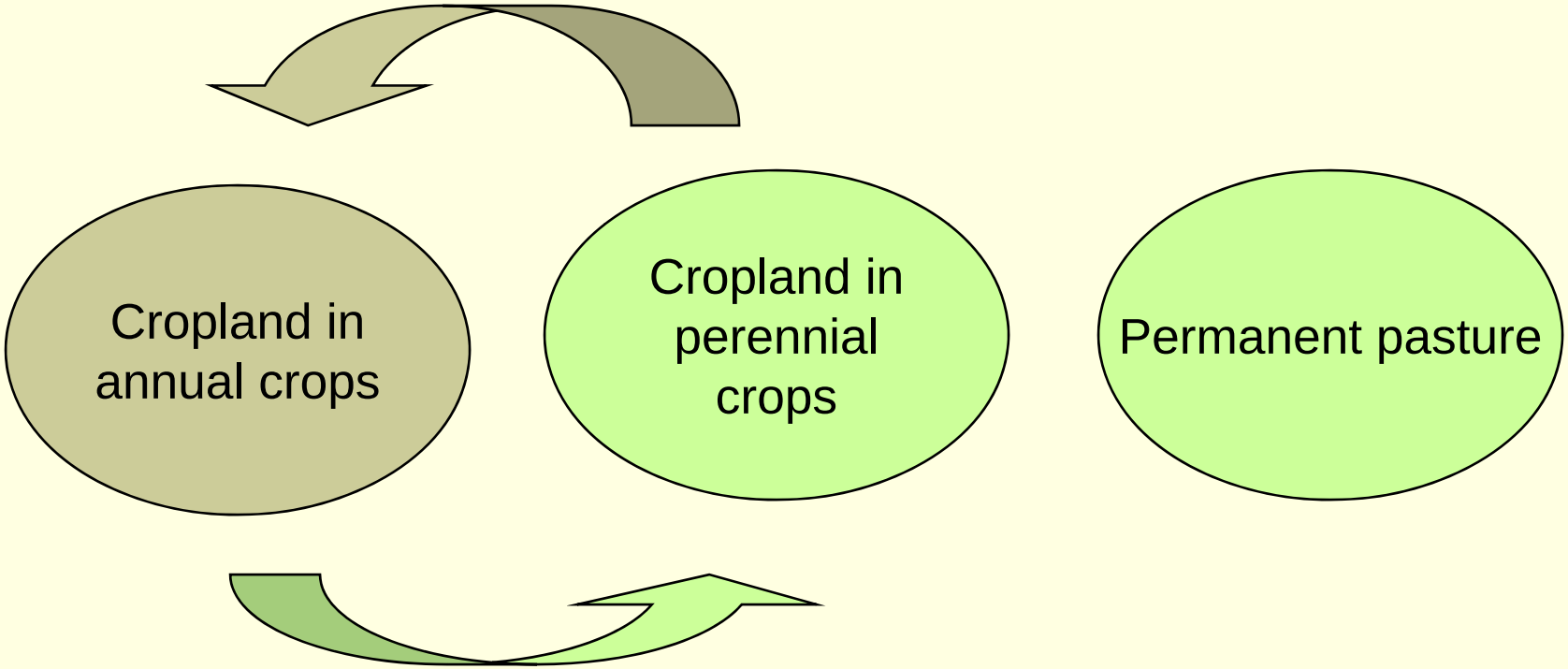
Use **greater** of the two values in calculating land needs

METHODS
Area of agricultural land available

LAND USE	AREA 2007 (10^6 acres)	AREA 2007 (10^6 ha)
Land in farms	10.03	4.06
Total cropland	7.80	3.16
Harvested cropland	**6.86**	**2.78**
Cropland pasture	**0.31**	**0.13**
Other cropland	0.64	0.26
Permanent pasture	**0.38**	**0.15**
Woodland	1.20	0.48
Other land	0.66	0.27
Land available to model	**7.54**	**3.05**

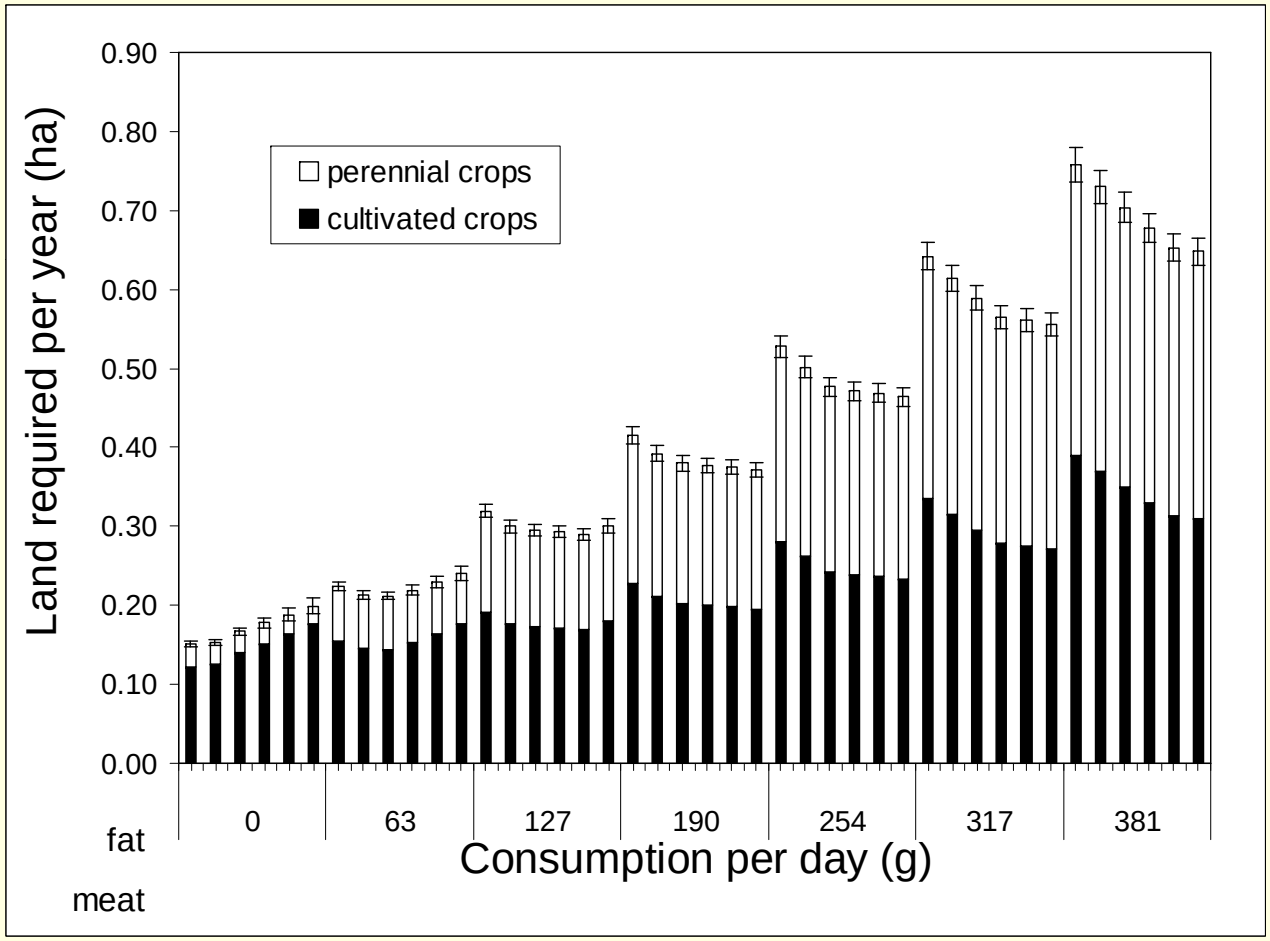
(Source: derived from 2007 Census of Agriculture)

METHODS
Land-diet-population relationship



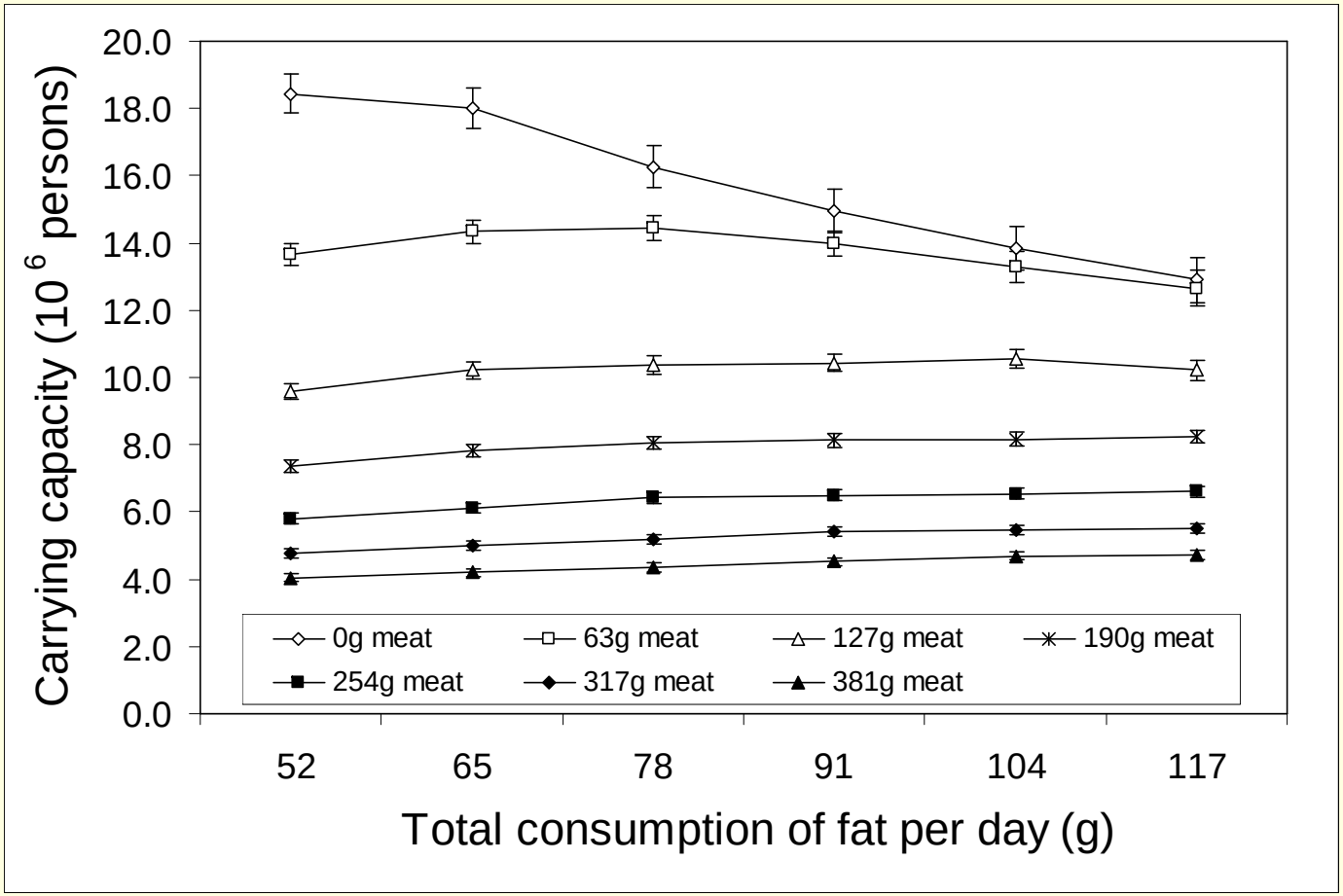
No restrictions	Perennial only	Pasture only
74%	21%	5%

RESULTS
Land requirements by diet



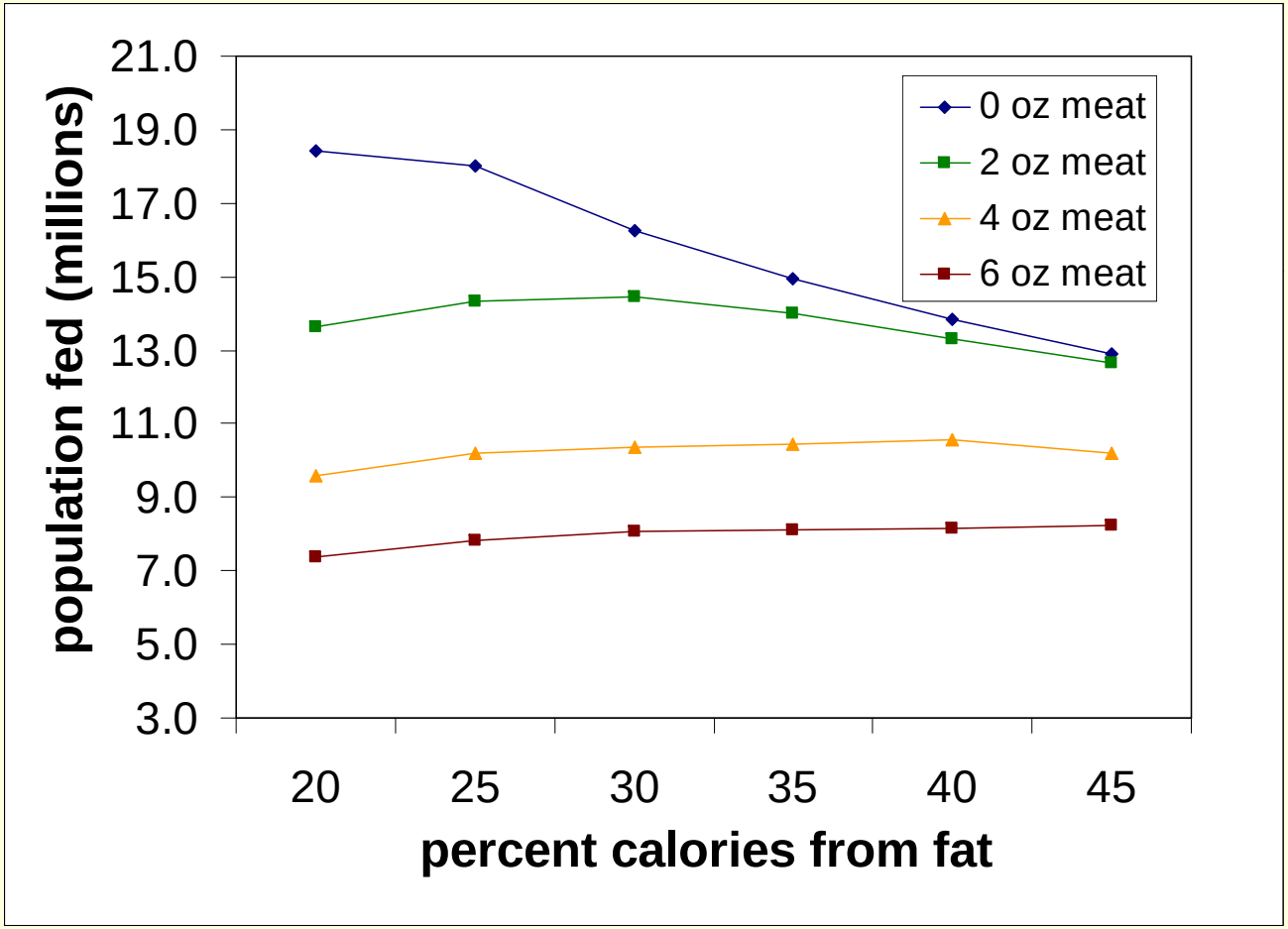
Peters, CJ (unpublished data)

RESULTS
Carrying capacity by diet



Peters, CJ (unpublished data)

RESULTS
Closer look at diets with ≤6oz meat



Peters, CJ (unpublished data)

DISCUSSION & CONCLUSIONS
Take home lessons on land

1) **Land requirements for complete diets** display a **5-fold** difference between highest and lowest diets
2) **Meat** tends to increase the land requirements for complete diets BUT more of the land is used for perennial crops and pasture.
3) **Fat** can either increase or decrease land requirements depending on the level of meat.
4) **A person** who eats like the average American would require **0.38ha (0.93 acres)** of cropland and pasture.

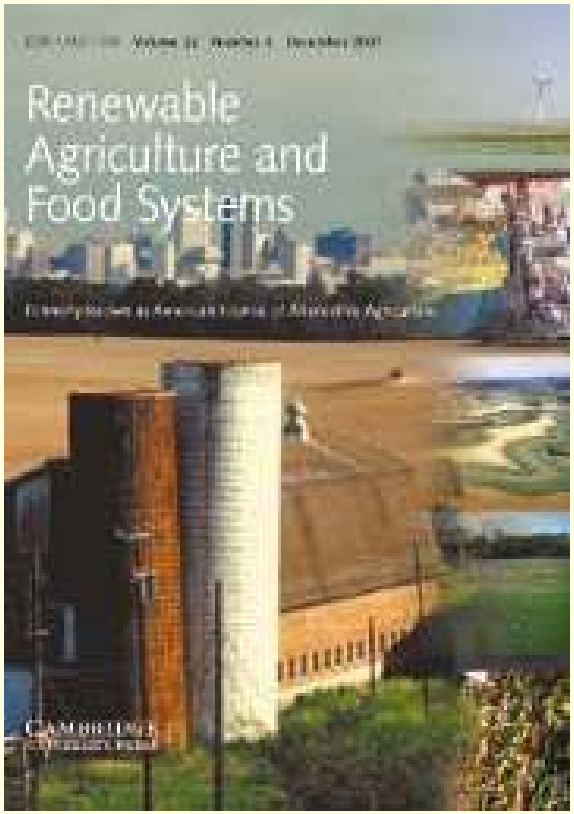
DISCUSSION & CONCLUSIONS
Take home points on carrying capacity

1) **Carrying capacity** varied slightly less than total land requirements, displaying a **4.6-fold** difference between lowest and highest diets.
2) **Meat** tended to reduce carrying capacity BUT there was some overlap between vegetarian and 2oz meat diets.
3) **Fat** either increased or decreased carrying capacity depending on the level of meat.
4) **Michigan** agricultural land could feed **8.2** million people, about **4/5** of the population, a diet similar to that of the average American.
5) **Greater capacity** than New York to meet in-state food needs.

SPATIAL MODEL

Mapping potential local foodsheds

INTRODUCTION
Replicating New York analysis



Peters CJ, Bills NL, Lembo AJ, Wilkins JL, Fick GW. In press. *Renewable Agriculture and Food Systems* 24.

BACKGROUND
What is a foodshed?

Earliest use:

"By analogy [to watersheds], we may conceive of the flow of foodstuffs to consuming markets as determined by foodsheds."

- W.P. Hedden. 1929. *How Great Cities Are Fed*

Recent Use:

"The elements and properties of that preferred emergent alternative [food system].."

- Kloppenburg, Hendrickson, and Stevenson. 1996. "Coming into the foodshed" *Agriculture and Human Values*

Our use:

A **foodshed** is the area of land that feeds, or could potentially feed, a population

INTRODUCTION
Foodshed map circa 1929

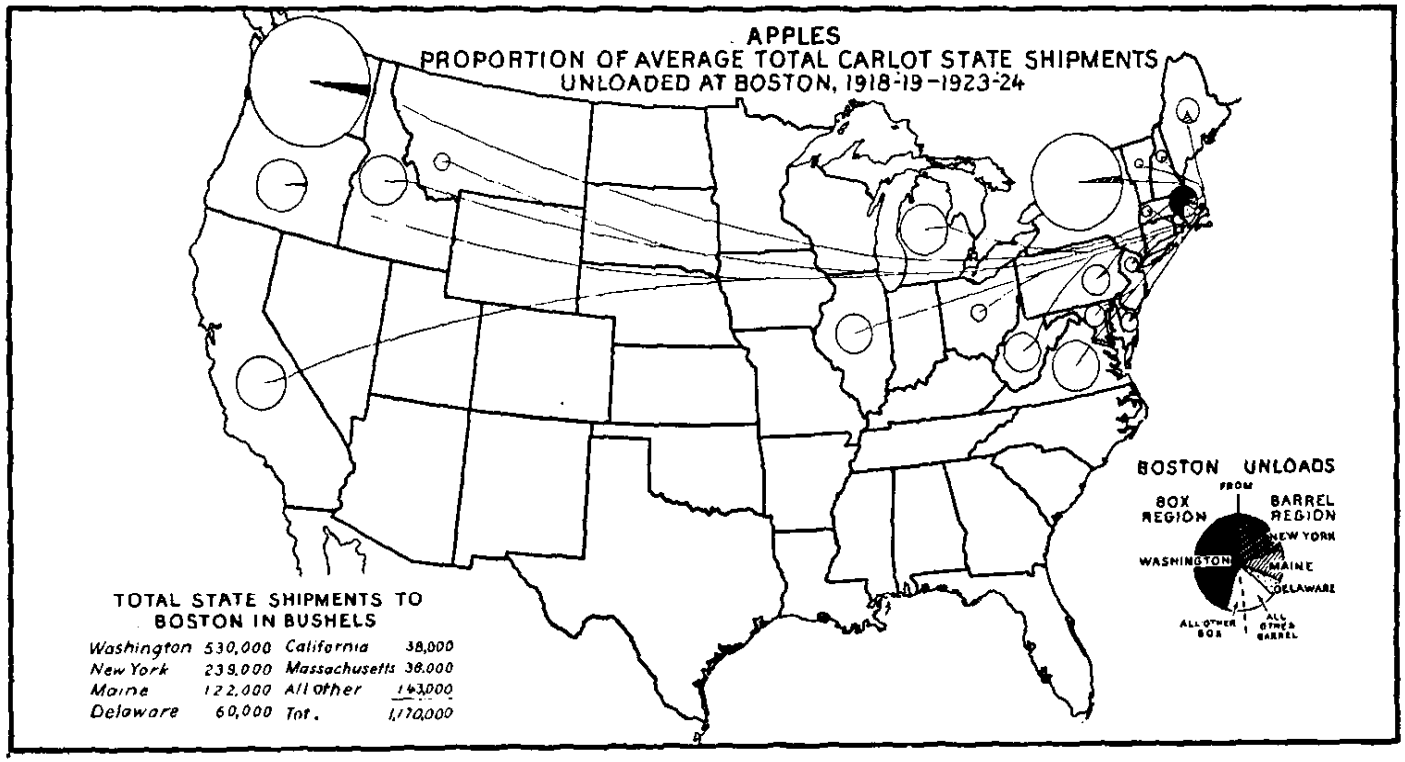


FIG. 9*b*.

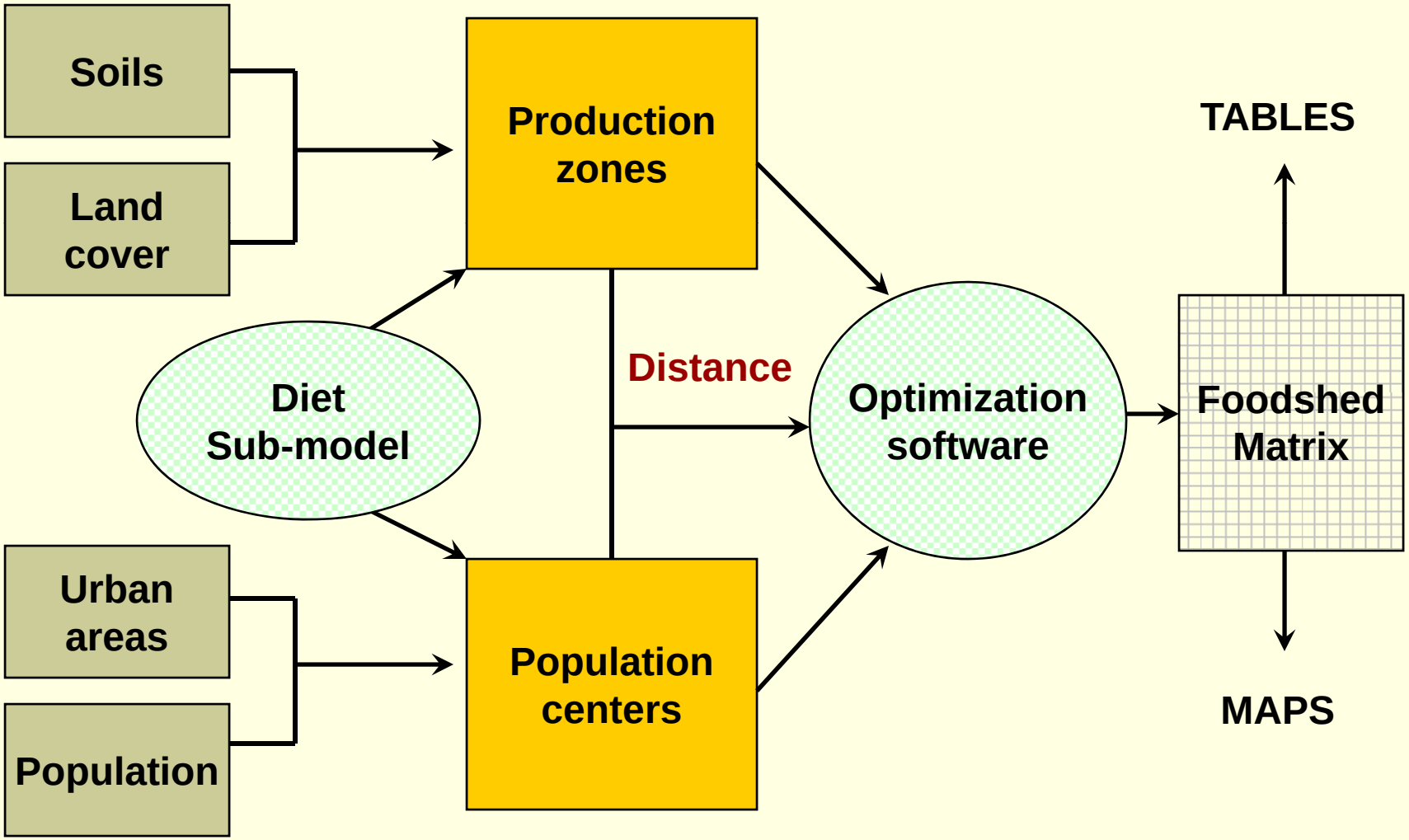
SOURCE: Hedden, W.P. 1929 (p.27). How Great Cities Are Fed. D.C. Heath and Company, New York.

OBJECTIVES
A work in progress

- **Examine** a state very different from New York
- **Identify** challenges to replicating the work in another geographic area
- **Explore** opportunities for making the methodology more efficient
- **Test** the methodology in a study region capable of meeting all food needs

METHODS

Overview of the approach



(Source: derived from Peters et al., in press)

METHODS

Optimization equation and constraints

GOAL: Minimize distance food travels **(DFT)**

$$\mathbf{DFT = \Sigma\ (F_{ij} \times D_{ij})}$$

F = Q of food shipped from **(i)** to **(j)**

D = distance between **(i)** and **(j)**

CONSTRAINTS:

1) Consumption = food requirement

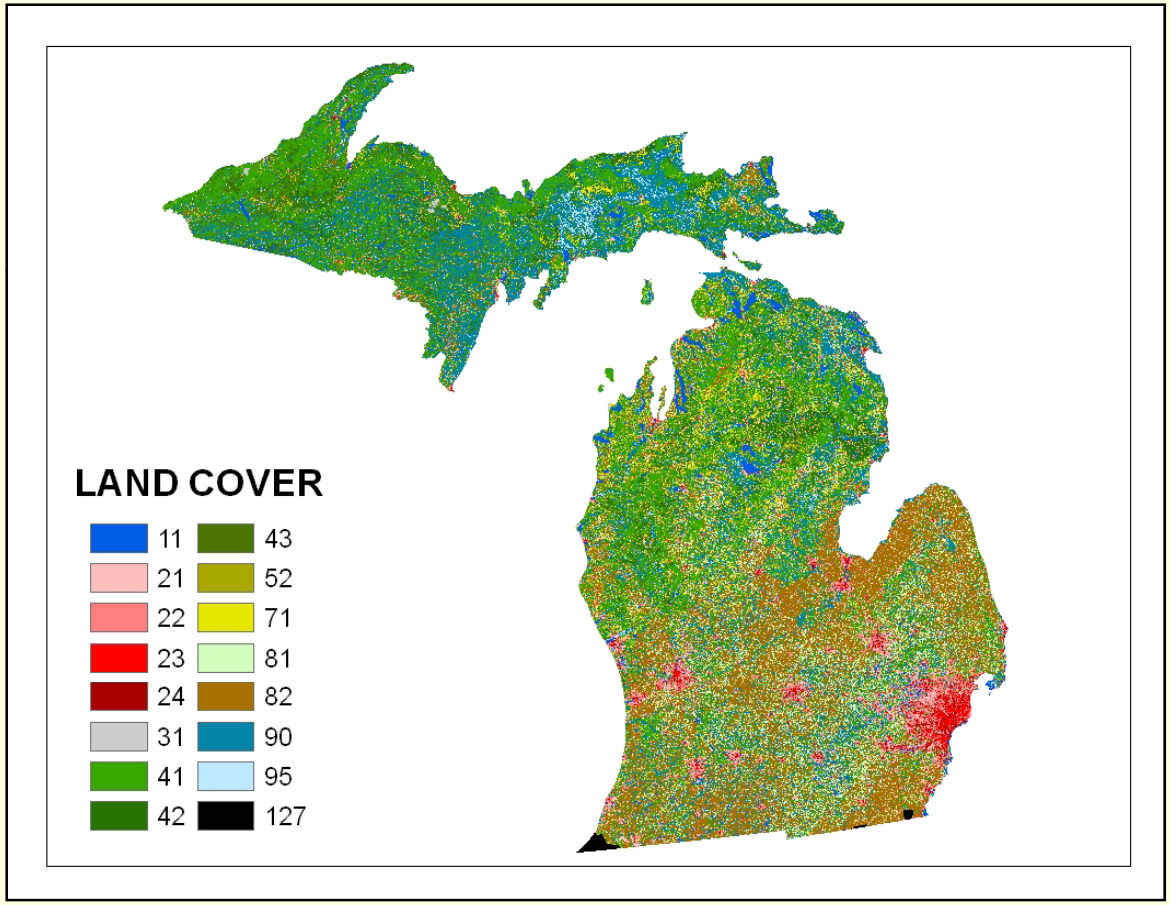
2) Production $\leq$ potential capacity

METHODS
A new unit for representing food

Human Nutritional Equivalent (HNE): the amount of food needed to meet the nutritional needs of one person for one year.

Food group	Estimated need (lbs)
Grains	205
Vegetables & pulses	439
Fruits	392
Dairy	580
Meat & eggs	209
Oils	41
Sweeteners	45
Total	1911

METHODS
Land cover versus land use



SOURCE: 2001 National Land Cover Dataset

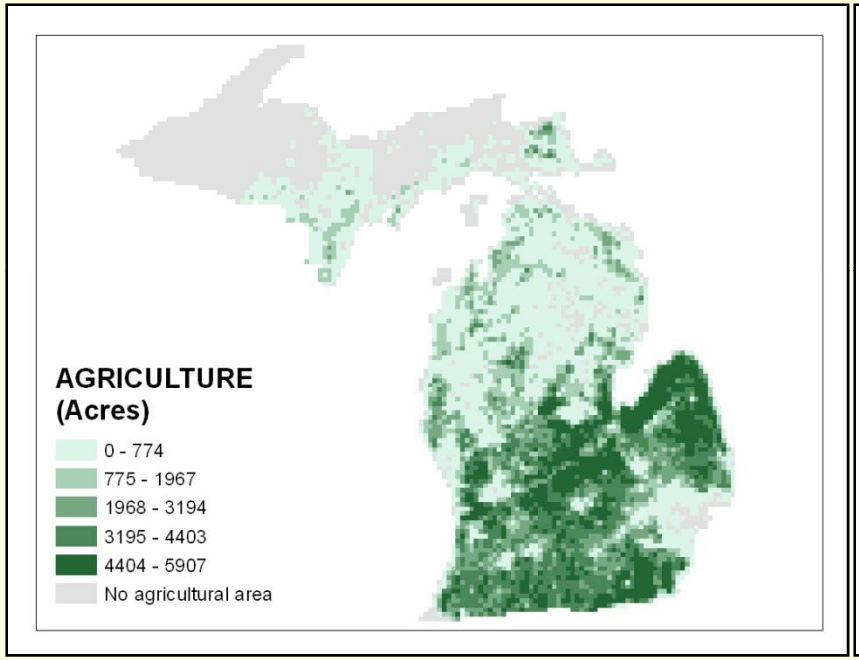
Cropland:
7.0 million acres

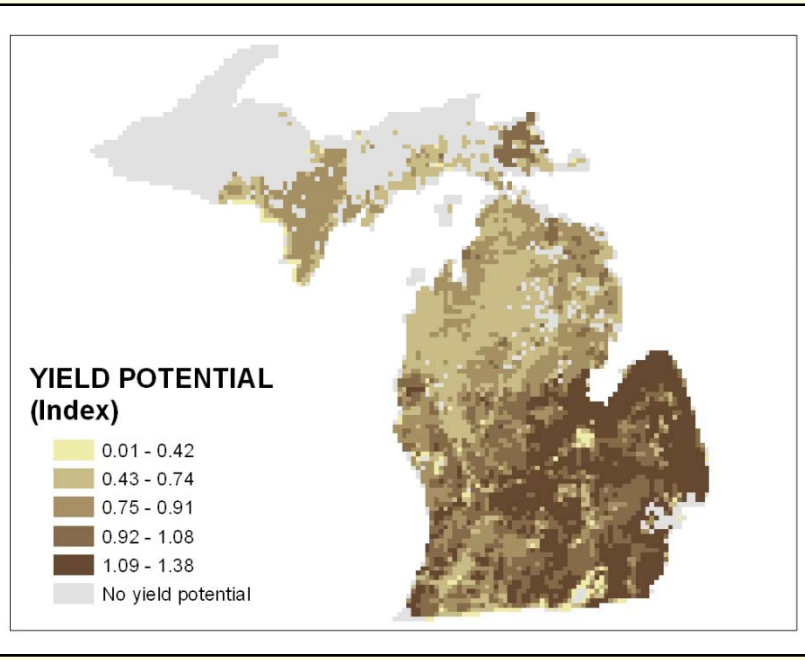
Hay and pasture:
2.5 million acres

Total agriculture:
9.5 million acres

27% greater than land use

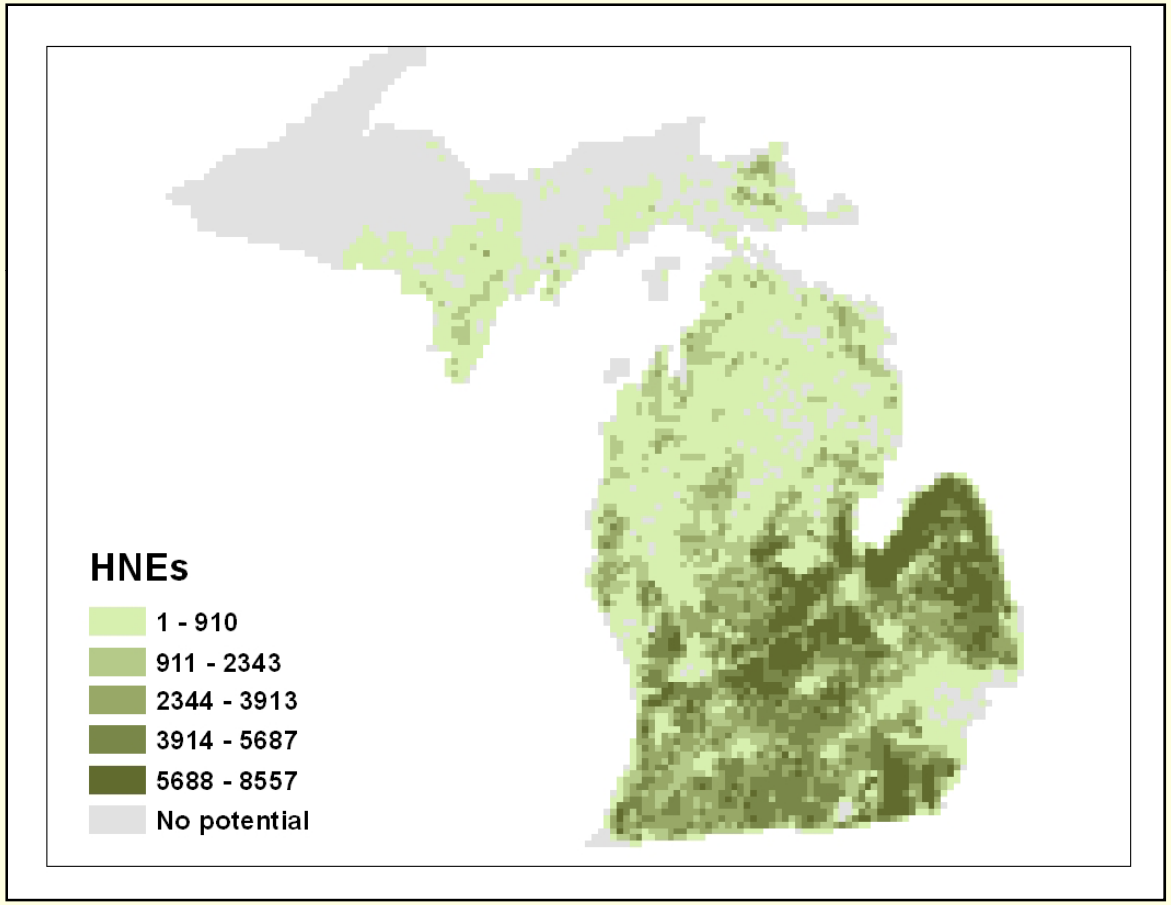
RESULTS
Agricultural area and yield potential





Data were summarized at the level of production zones to provide input to the optimization model.

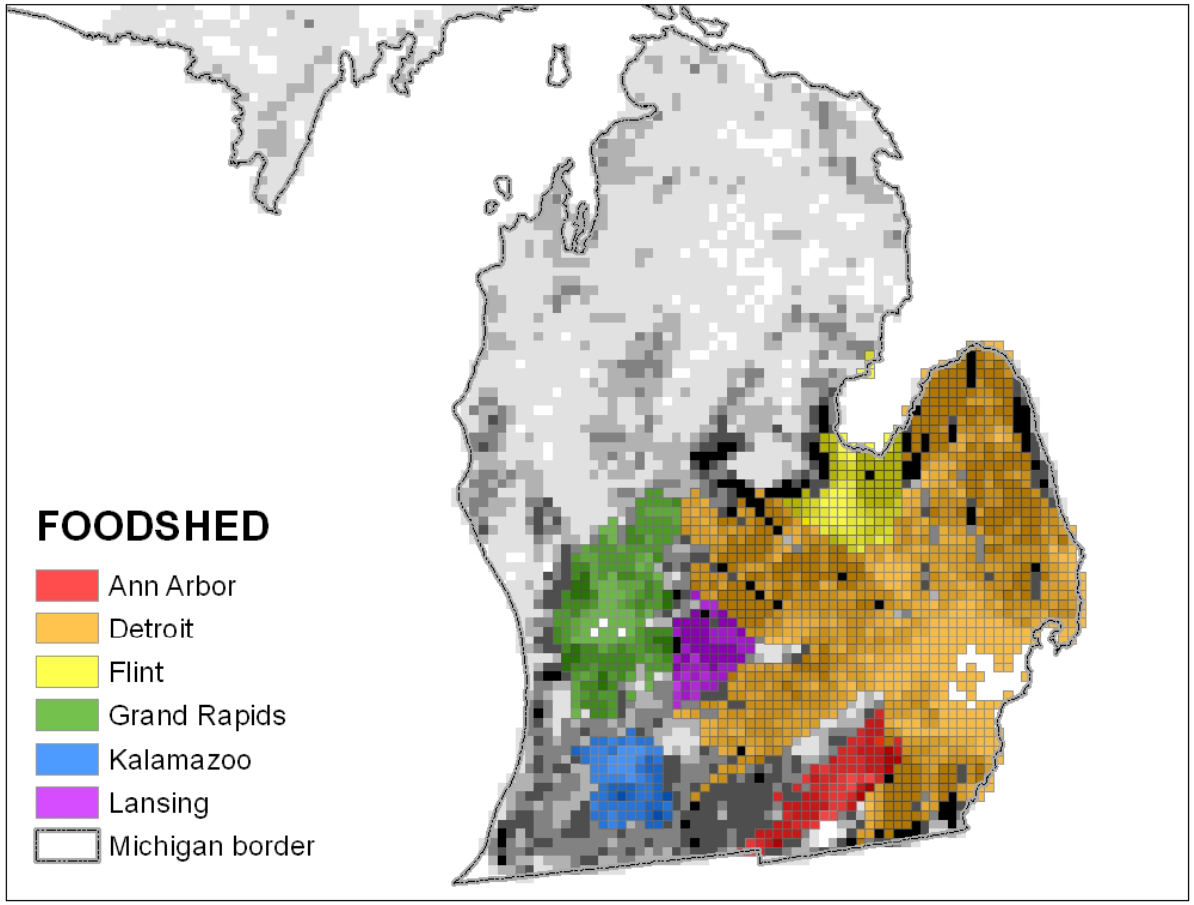
RESULTS
Food production potential



Food production potential was summarized by production zone.

One **HNE** is enough food for one person for one year.

RESULTS
Map of potential local foodsheds



Map displays the models allocation of land to six largest cities in Michigan.

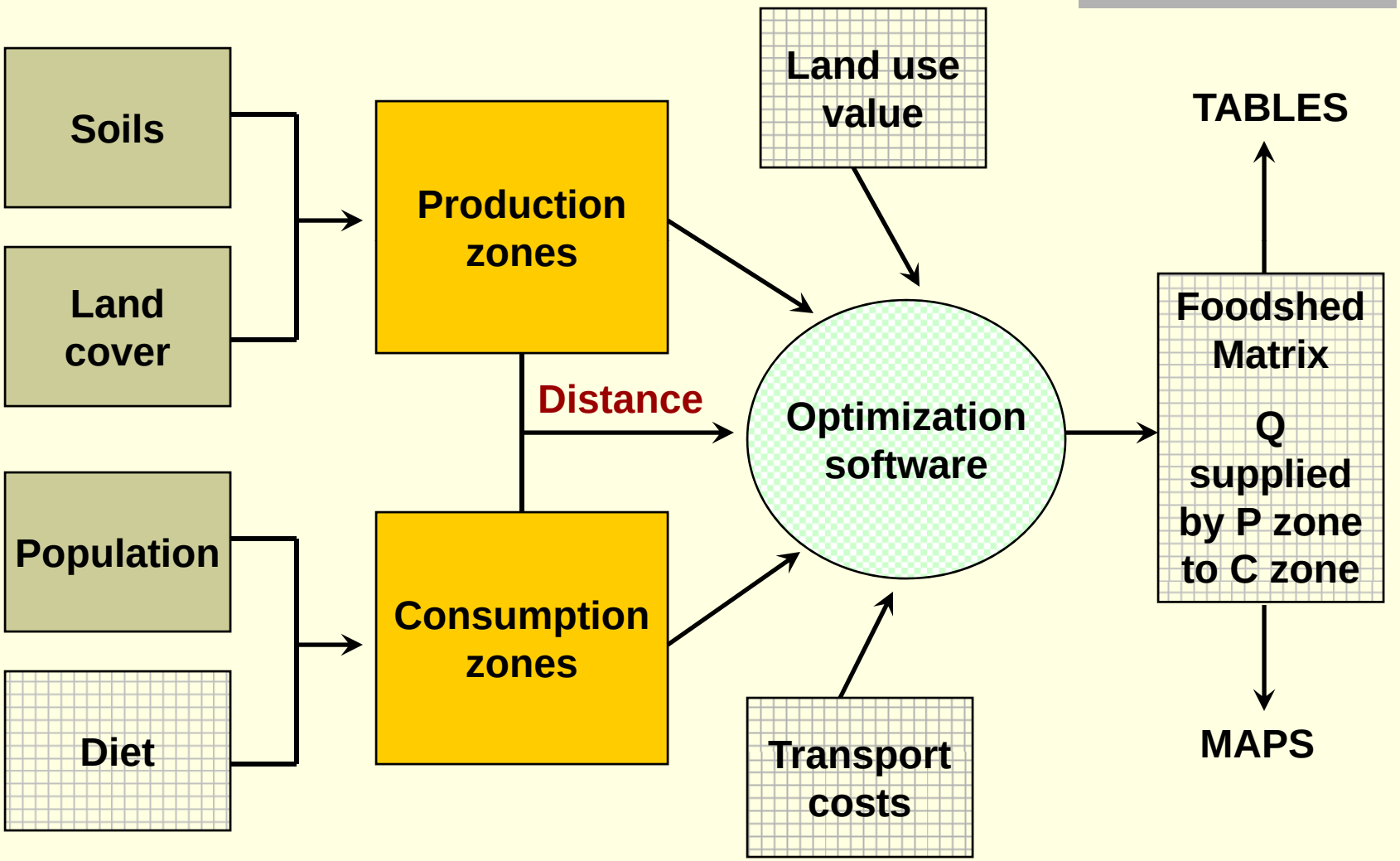
All cities received 100 percent of food needs

RESULTS

Average distance food travels

Population center	HNE_a	HNE_p	HNE_t
	----------*Km*----------		
Buffalo	51	44	50
Rochester	40	33	39
Syracuse	NOT YET AVAILABLE FOR MICHIGAN		
Albany	52	107	68
New York	32	266	264
Poughkeepsie	20	154	126
All other cities	26	52	31
TOTALS	35	94	49

METHODS
A hybrid spatial-optimization model



DISCUSSION & CONCLUSIONS
Take home points on foodsheds

1. **Foodshed maps** enable us to visualize the geography of a city's food supply
2. **Foodshed analysis** provides perspective on the capacity to meet food needs locally and regionally
3. **Methodology** is new and will provide more valuable information as it is further developed

FUTURE DIRECTIONS

FUTURE DIRECTIONS
Questions begged by the research

- **Analytical**:
  - Changes over space and time (i.e. crop yields)
  - Different production systems (i.e. organic)
  - Further changes to diet (i.e. types of meat)
- **Practical**:
  - What should be grown locally?
  - Where should food be grown locally?
  - What about bio-energy?

FUTURE DIRECTIONS
Fruitful areas for further work

1. Need for consistent methodologies
2. Sensitivity of relationships to input data
3. Application across a wider geographic area
4. Model food system more realistically
5. Use more meaningful optimization functions
6. Grow the network of collaborators

FUTURE DIRECTIONS
Growing the network

Thanks to funding from the Leopold Center, a group of researchers at Iowa State will be conducting a foodshed analysis of Iowa