Urban Forestry and Remote Sensing

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Cities

- United Nations, Instanbul , 2001, p. 1
  - Cities draw people
    - Services, resources, etc.
  - 1800 – only 2% lived in cities/urban centers
  - Currently ~ 6.4 billion – slightly less than ½ live in cities/urban centers
  - 2007 – over ½ will live in cities/urban centers
  - Demographic transformation

Urban Areas

- United States
  - 80% of the population
  - 25% of the nation's total tree canopy cover

U.S. Forest Service and U.S. Census Bureau

Why Study?

- 1970-1990 urban density *decreased* by 23% (AP)
- Changes in land use alter ecosystem
  - Structure
  - Function
  - Pattern
- Alter local climate

http://www.ci.atlanta.ga.us/skyline.htm

Major US Cities

1999 rank	1990 rank	Name	Population 1999 (est.)	Population 1990	% change
1	1	New York, N.Y.	7,428,162	7,322,564	1.40%
2	2	Los Angeles,	3,633,591	3,485,499	4.20%
3	3	Chicago, Ill.	2,799,050	2,783,660	0.60%
4	4	Houston, Texas	1,845,967	1,697,873	8.70%
5	5	Philadelphia, Pa.	1,417,601	1,585,577	-10.60%
6	6	San Diego, Calif.	1,238,974	1,111,031	11.50%
7	10	Phoenix, Ariz.	1,211,466	988,983	22.50%
8	9	San Antonio,	1,147,213	997,434	15.00%
9	8	Dallas, Texas	1,076,214	1,006,646	6.90%
10	7	Detroit, Mich.	965,084	1,027,946	-6.10%
11	11	San Jose, Calif.	867,675	783,324	10.80%
12	14	San Francisco,	746,777	723,959	3.20%
13	13	Indianapolis, Ind.	738,907	731,726	1.00%
14	16	Jacksonville, Fla.	695,877	635,042	9.60%
15	15	Columbus, Ohio	671,247	636,323	5.50%
16	12	Baltimore, Md.	632,681	736,014	-14.00%
17	22	El Paso, Texas	612,770	515,652	18.80%
18	18	Memphis, Tenn.	606,109	618,894	-2.10%
19	25	Austin, Texas	587,873	494,290	18.90%
20	17	Milwaukee, Wisc.	572,424	628,300	-8.90%
21	20	Boston, Mass.	555,249	574,289	-3.30%
22	21	Seattle, Wash.	537,150	516,332	4.00%
23	33	Charlotte, N.C.	520,829	426,984	22.00%
24	19	Washington, D.C.	519,000	606,900	-14.50%
25	26	Nashville-Davidson,	506,385	488,188	3.70%

Urban Sprawl

- Land use / land cover conversion
- Human habitat
- Urban forest
  - Concern

Urban Forests

- Trees and other vegetation that grow in urban and suburban areas
  - Public lands
  - Private lands
- Require investments

Source: Alachua County Visitors and Conventions Bureau

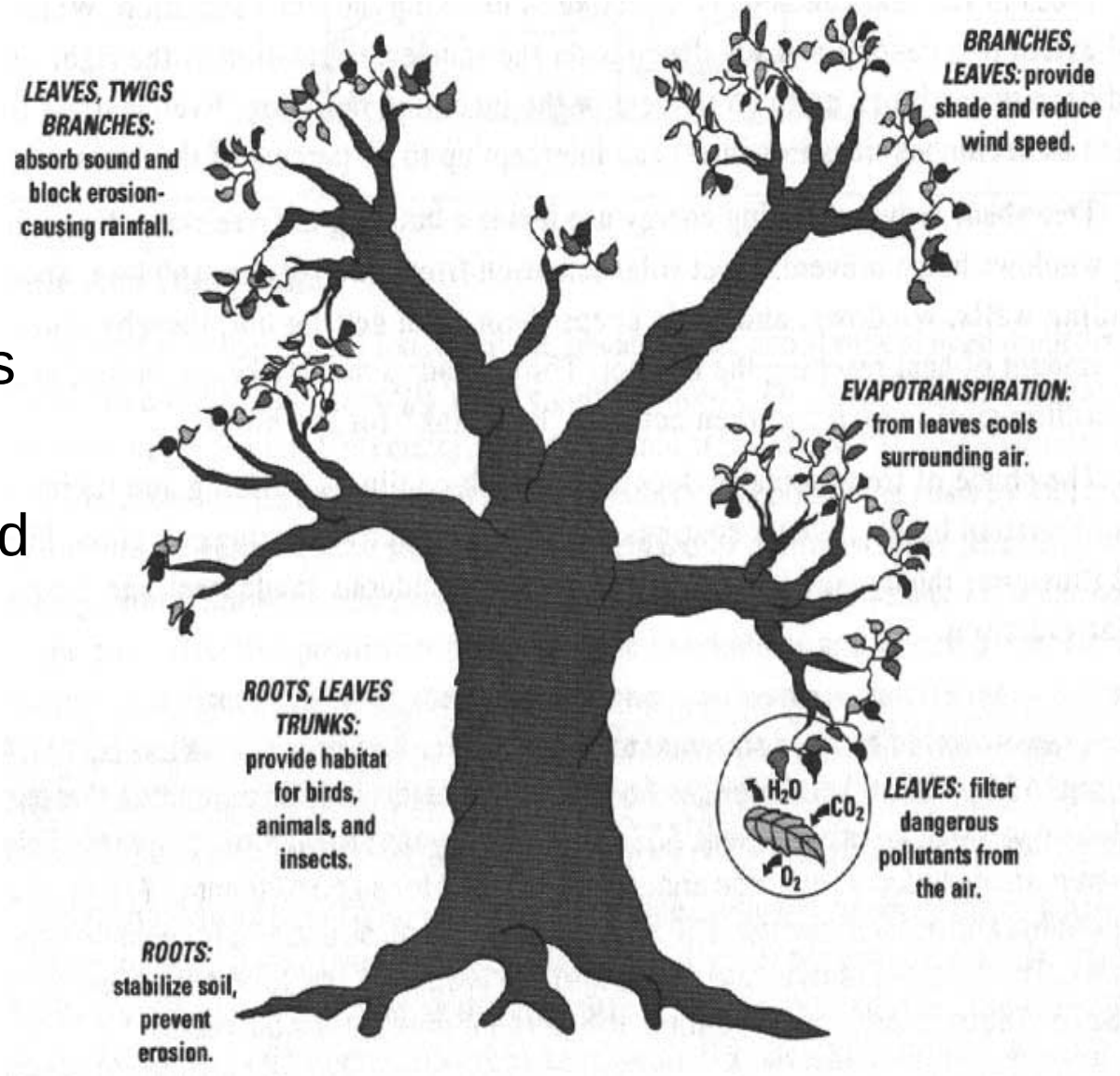
Urban Forests

- Valued for many reasons
  - Pleasant landscape
  - Peace and quiet
  - Screening and privacy
  - Recreation opportunities
  - Increase property values

Moeller Realty, Inc.

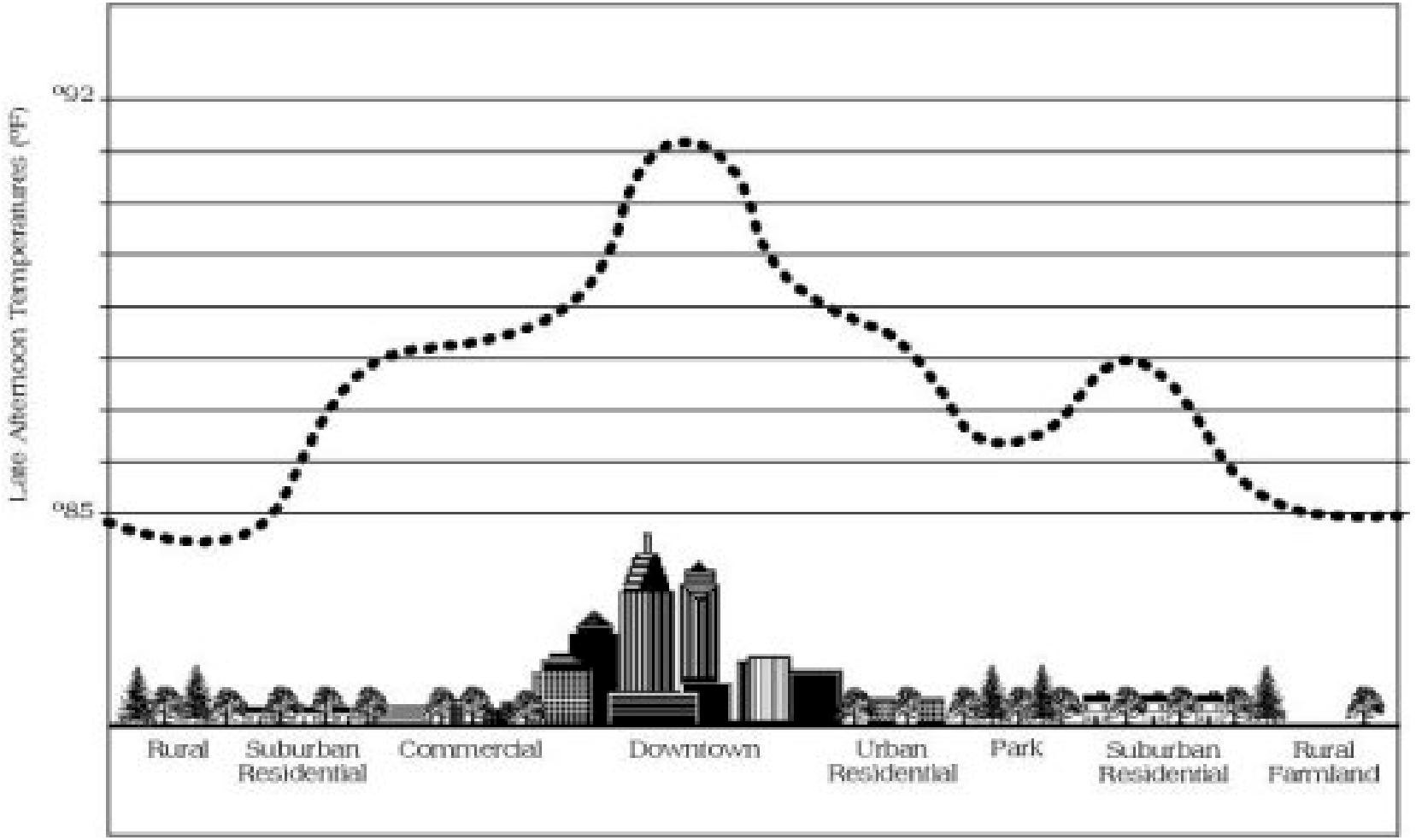
Environmental Benefits

- High urban leaf areas
  - Air-filtering systems
  - Reduce runoff
  - Reduce energy load
  - Wildlife habitat and diversity
  - Cool air
    - Shade
    - Evapotranspiration



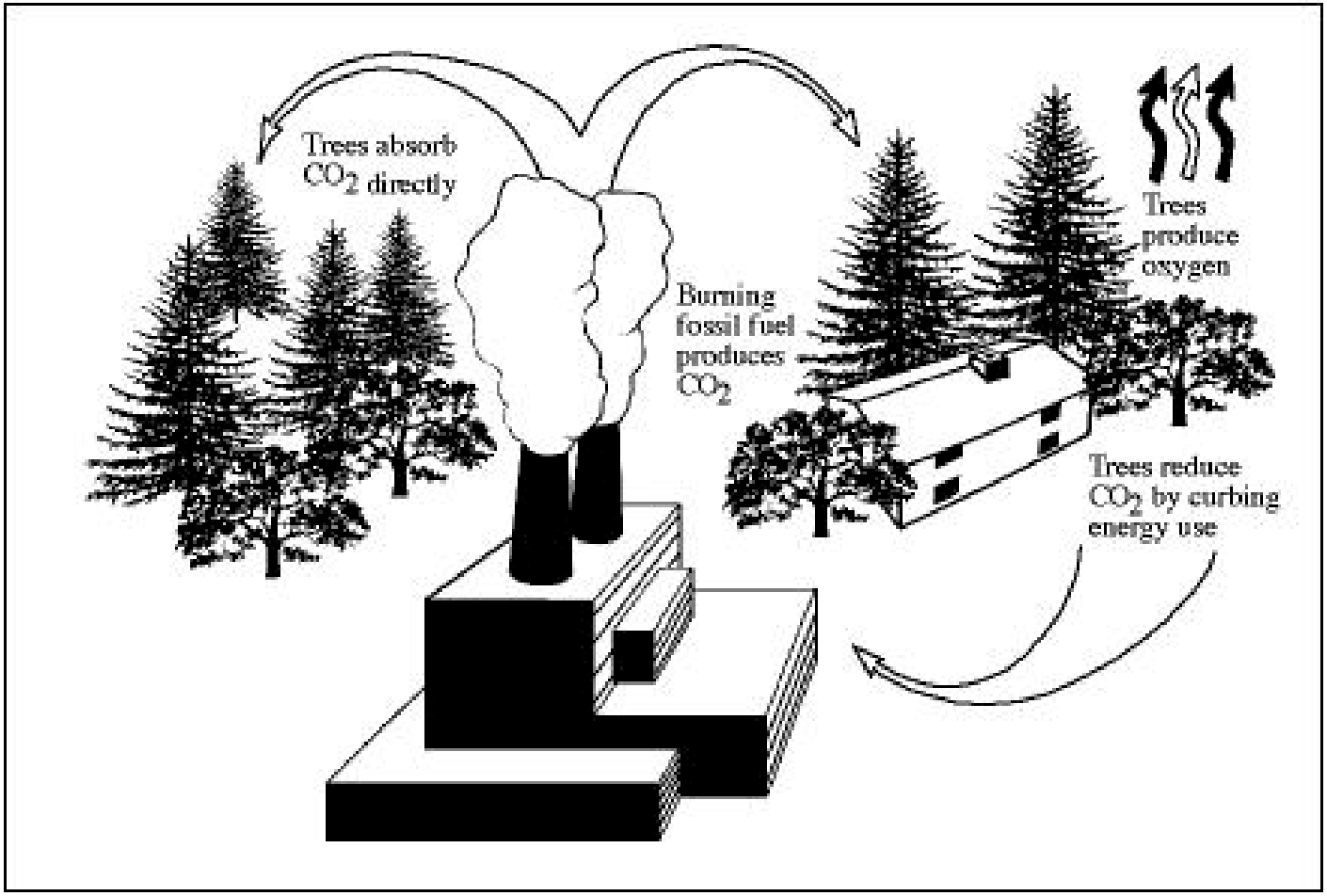
Akbari et al., 1992, p. 27, fig 2-1.

Urban-Heat Island



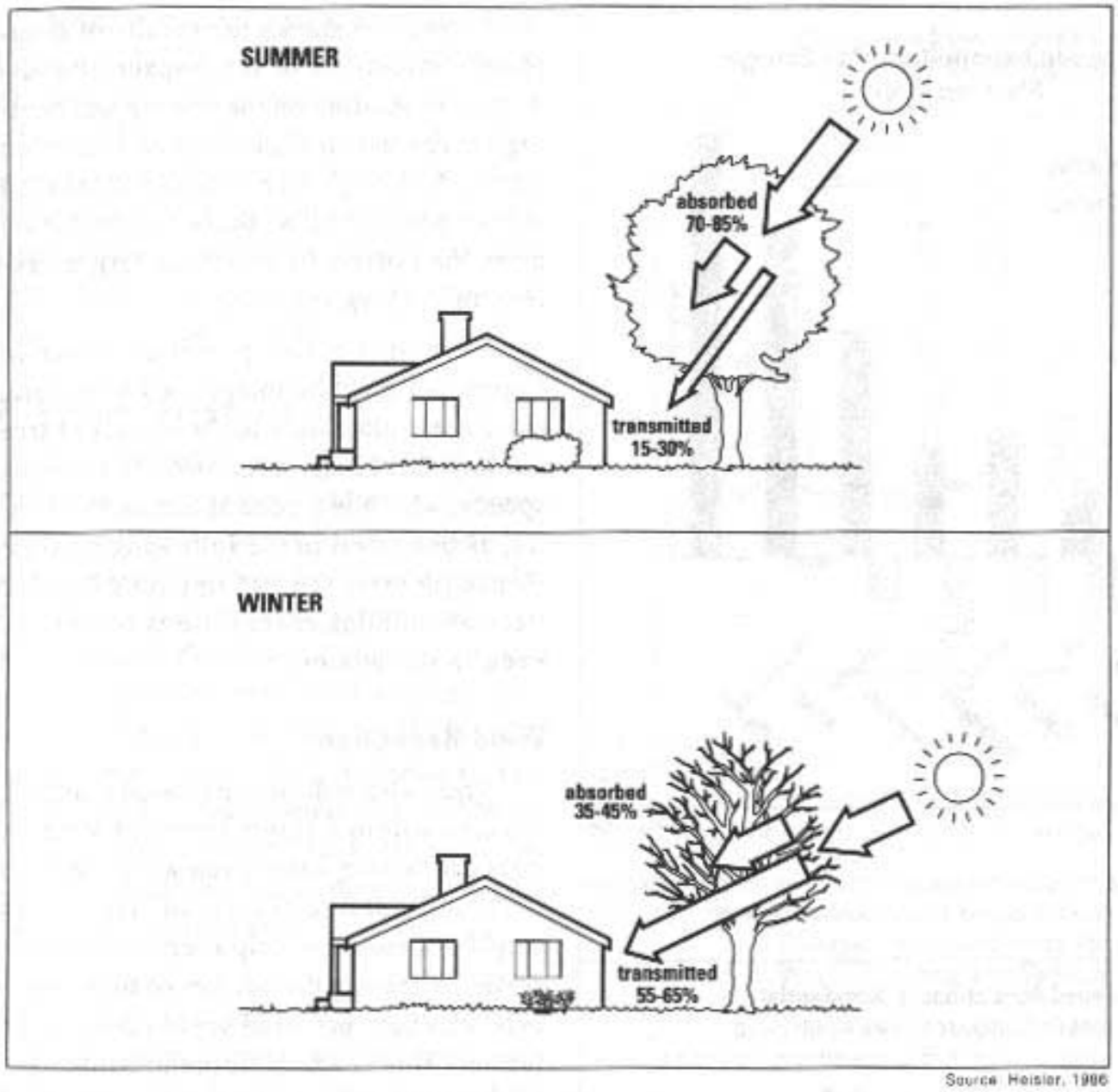
Akbari et al., 1992, p. 9, fig 1-4.

CO_2 Reduction



Akbari et al., 1992, p. 35, fig. 2-10

Energy Reduction



Akbari et al., 1992, p. 29, fig 2-2.

Municipal Tree Ordinances

- Necessary
  - Education alone does not guarantee action
- Some residents don’t appreciate the value of tree ordinances
- Very difficult to prove $ saved or gained
  - How to quantify $ saved

Disadvantages of Urban Forests

- Fill landfills
  - 20% of municipal waste (EPA)
    - Compost soil amendment
    - Wood chips for fuel
    - Increased shade could decrease ground cover
- Higher water demand – not true
  - Native trees
  - Lawns use more water than trees

Disadvantage

Disadvantage

Disadvantage

Challenge

- Convince people
- Money
- Penalties
- Geospatial technologies
  - Remote sensing
  - GIS

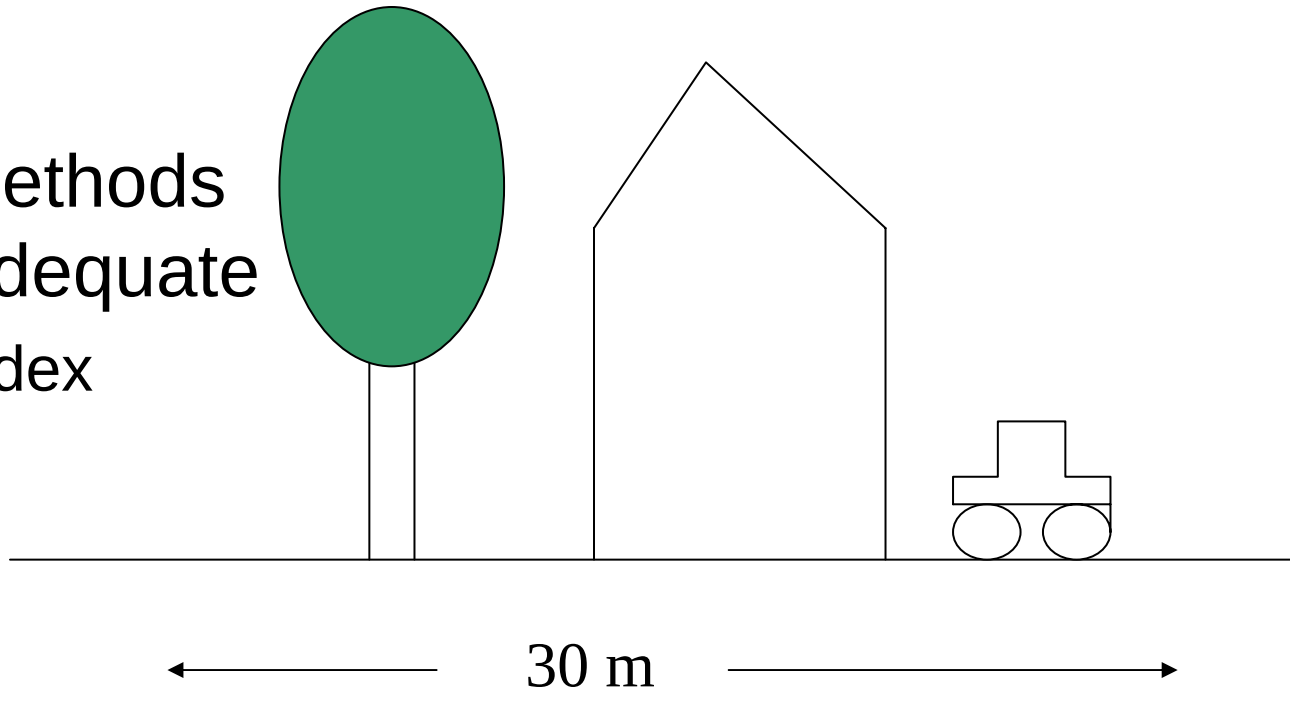
http://www.dec.state.ny.us/website/environmentdec/2004a/kidstree.jpg

Urban Remote Sensing

- Implemented by many agencies
  - Planners
  - Tax assessors
  - Transportation
  - Utility companies
  - Departments of parks, recreation, and tourism
- Accuracy

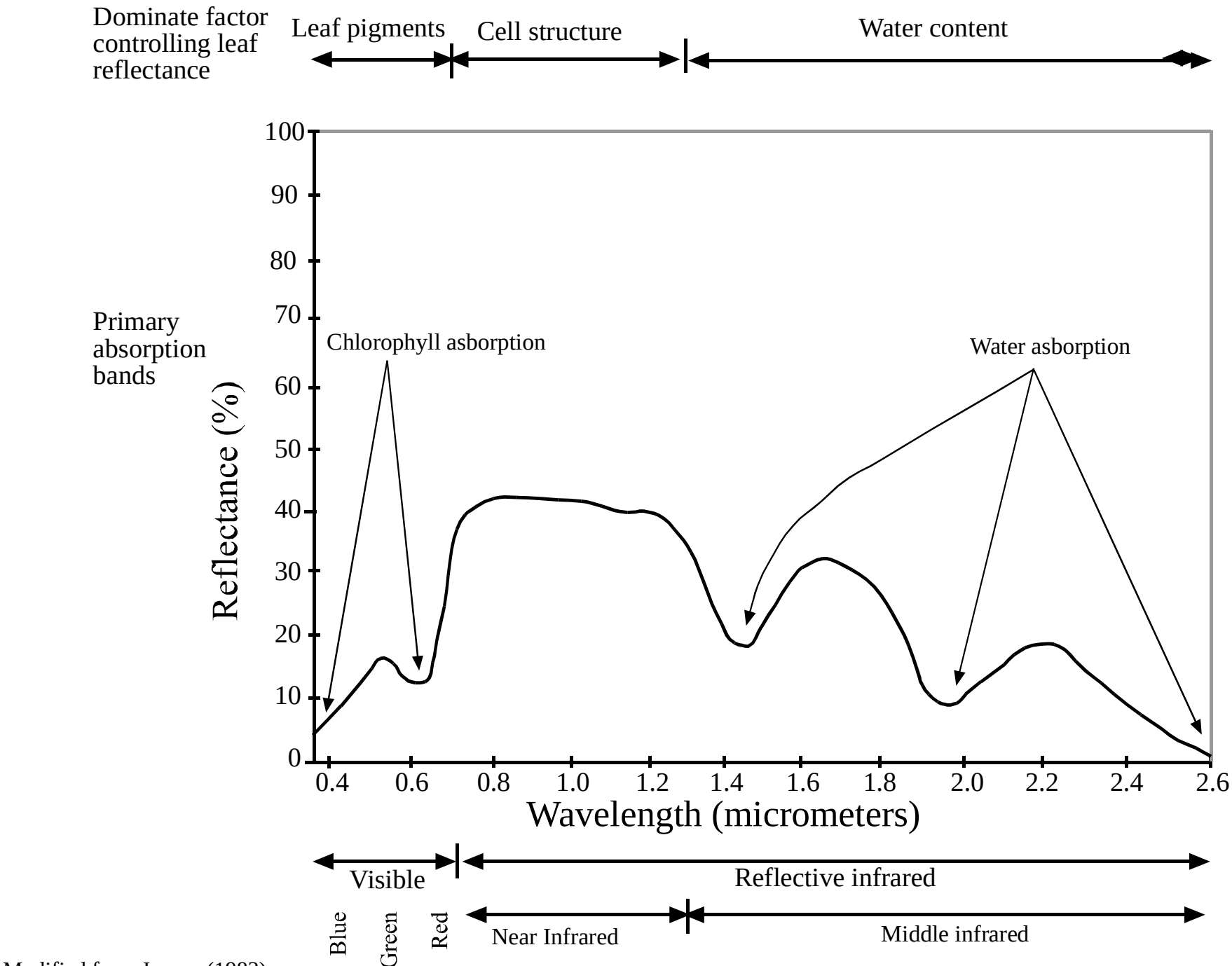
Urban Remote Sensing

- Careful in interpretation
- Parametric methods may not be adequate
  - Leaf Area Index



Leaf Area Index

- Useful in ecosystem analysis
- Related to biological processes
  - Primary productivity
  - Canopy gas exchange
- Used in global circulation models
- Estimated via RS



Modified from Jensen (1983)

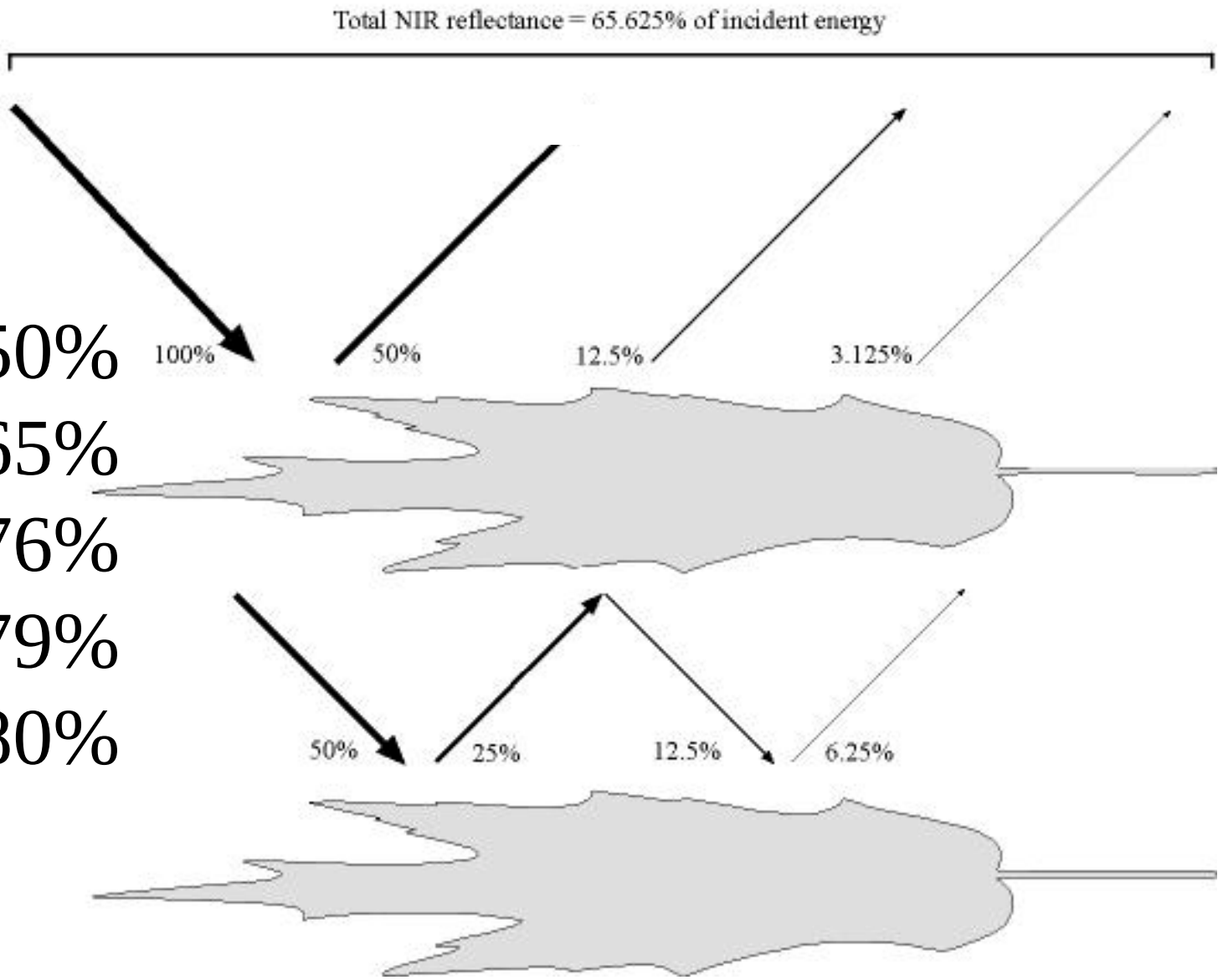
1 leaf = 50%

2 leaves = 65%

3 leaves = 76%

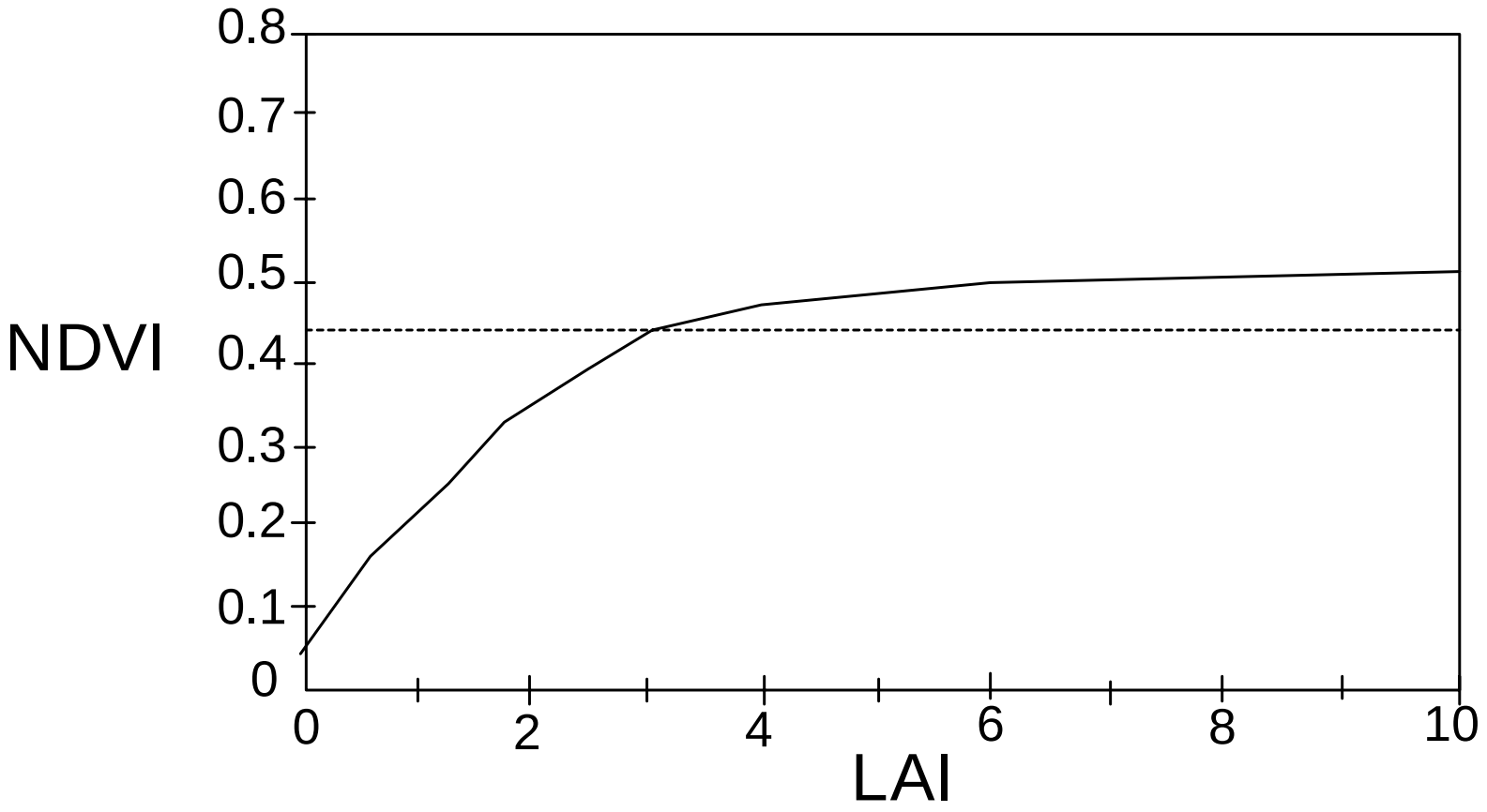
4 leaves = 79%

5 leaves = 80%



Modified from Jensen (2000)

NDVI Saturation



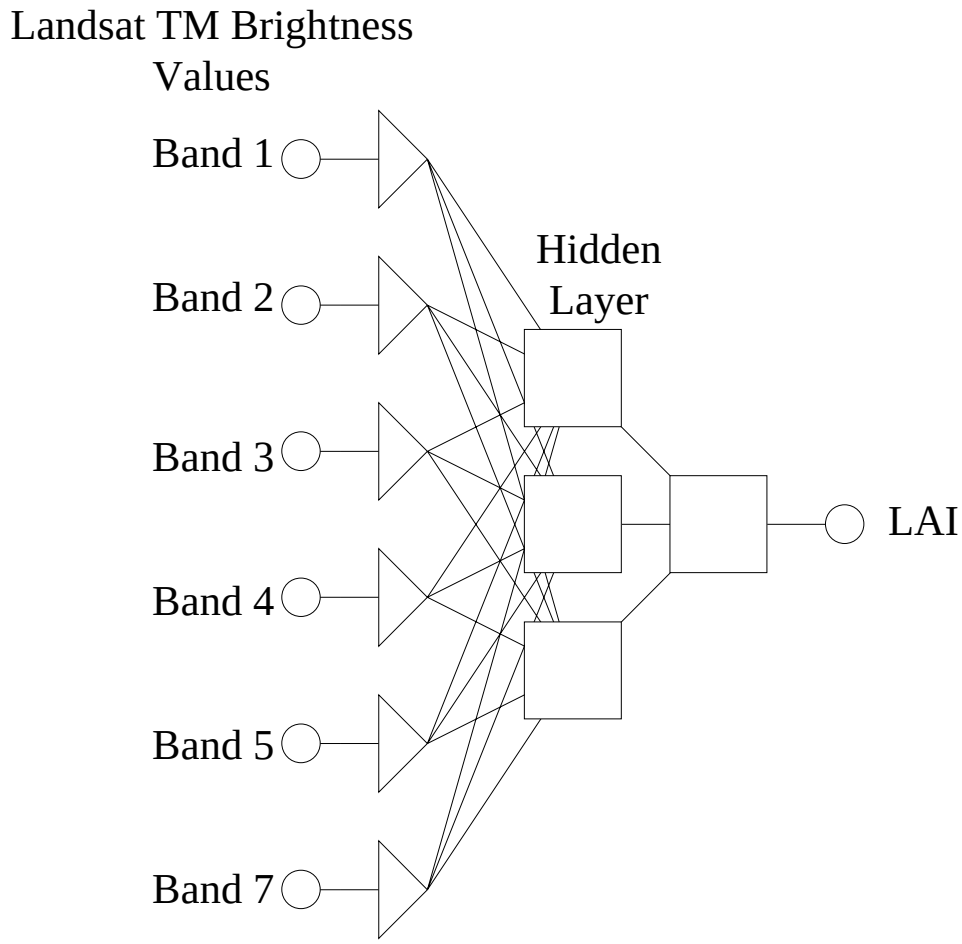
(adapted from Carlson and Ripley, 1997).

Remote Urban LAI Estimation

- Good indicator of urban canopy
- Input into local, regional, and global models
- Terre Haute, Indiana
  - 145 random points
- Accuracy?

ANN Method

- Artificial Neural Network
  - Backpropagation



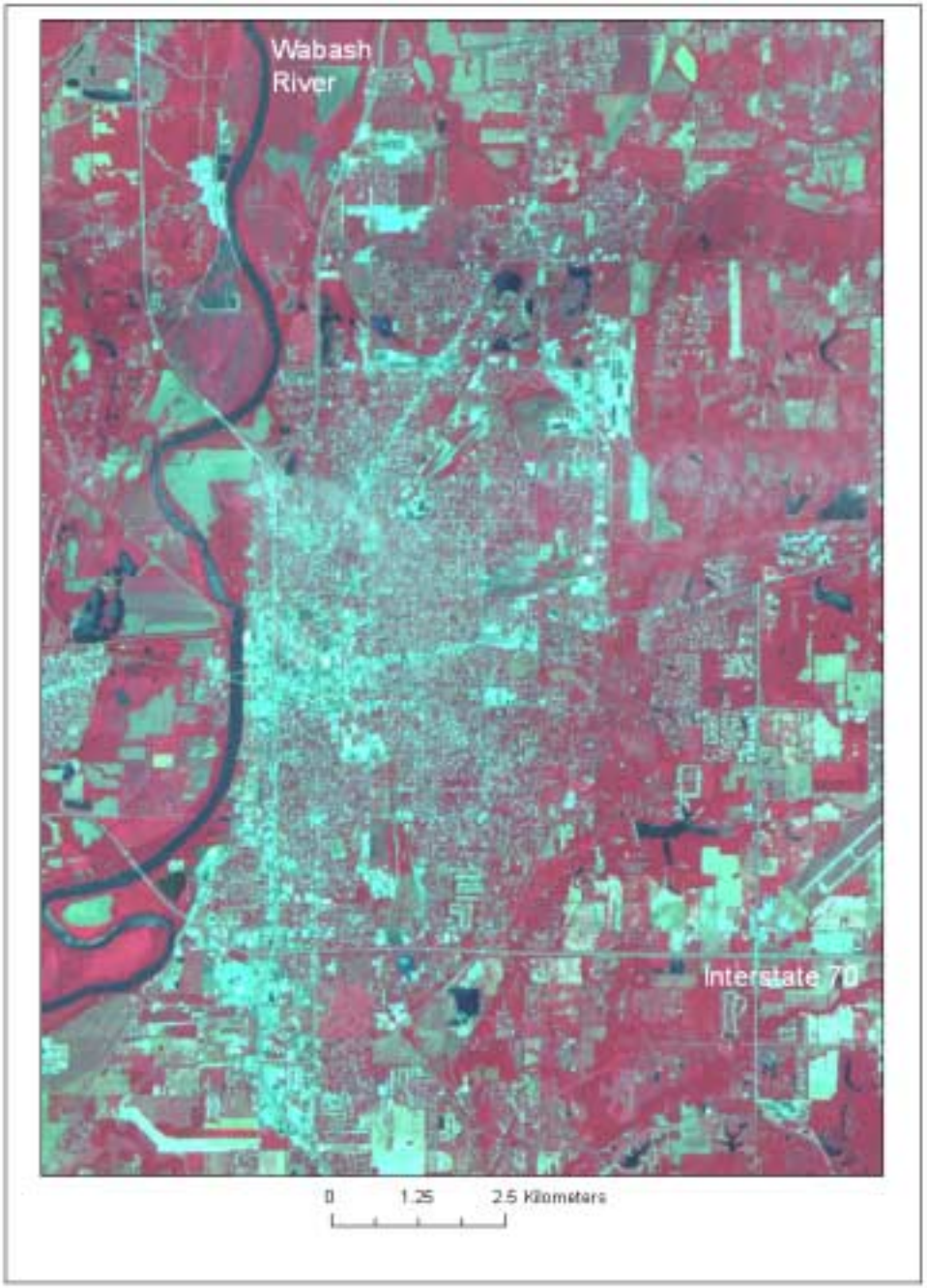
Other Remote LAI Estimation Methods

- Parametric
- Regression
  - Vegetation indices
  - All band
  - Band ratios

Terre Haute, Indiana, USA

Terre Haute

- Population ~ 65,000
- Wabash River and Interstate 70
- County seat of Vigo County

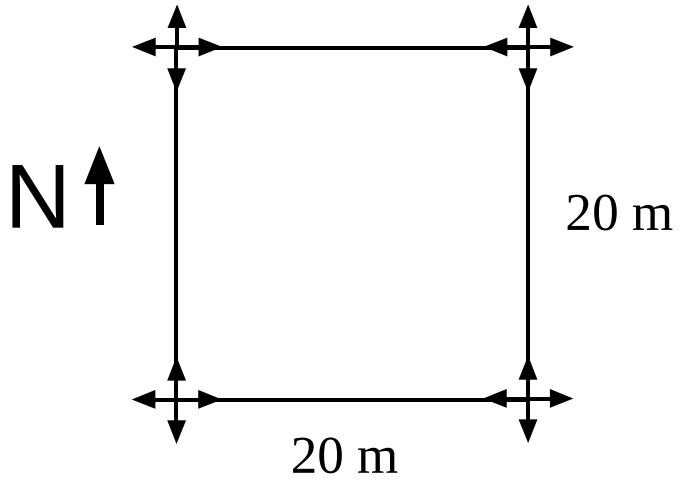


Terre Haute’s Urban Forest

- Fairly strict ordinance
- Rotating tree board
- City forester

Sampling Method

- 20 meter quadrats
- GPS point



$$LAI = \frac{-\ln \frac{Q_1}{Q_2}}{k}$$

- Ceptometer

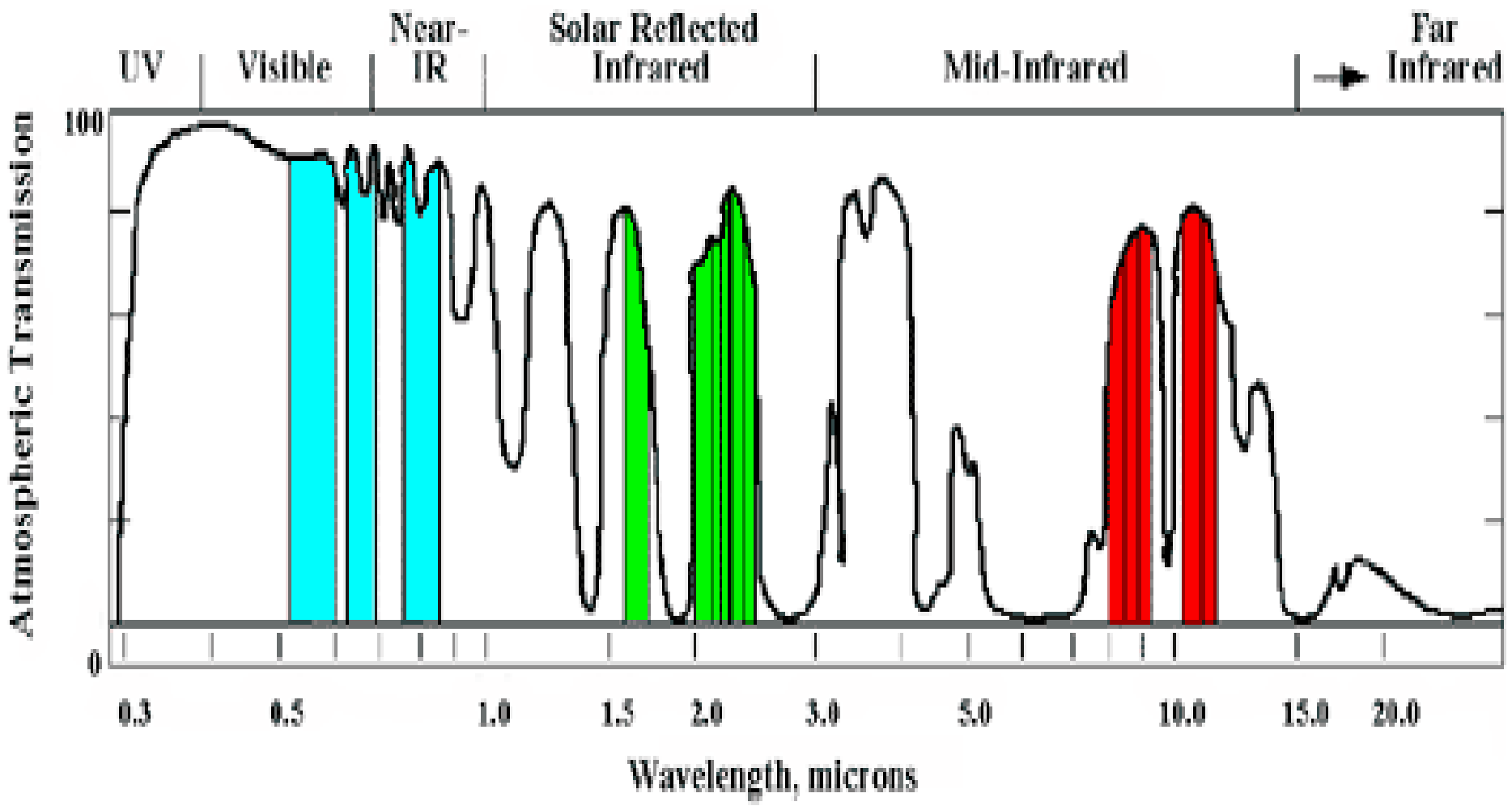
Methods

- Regression
  - Multiple inputs and ratios
- Artificial Neural Network
  - Multiple inputs and ratios

ASTER

Subsystem	Band No.	Spectral Range (µm)	Spatial Resolution
VNIR	1	0.52 - 0.60	15 m
	2	0.63 - 0.69	
	3N	0.78 - 0.86	
	3B	0.78 - 0.86	
SWIR	4	1.600 - 1.700	30 m
	5	2.145 - 2.185	
	6	2.185 - 2.225	
	7	2.235 - 2.285	
	8	2.295 - 2.365	
	9	2.360 - 2.430	
TIR	10	8.125 - 8.475	90 m
	11	8.475 - 8.825	
	12	8.925 - 9.275	
	13	10.25 - 10.95	
	14	10.95 - 11.65	

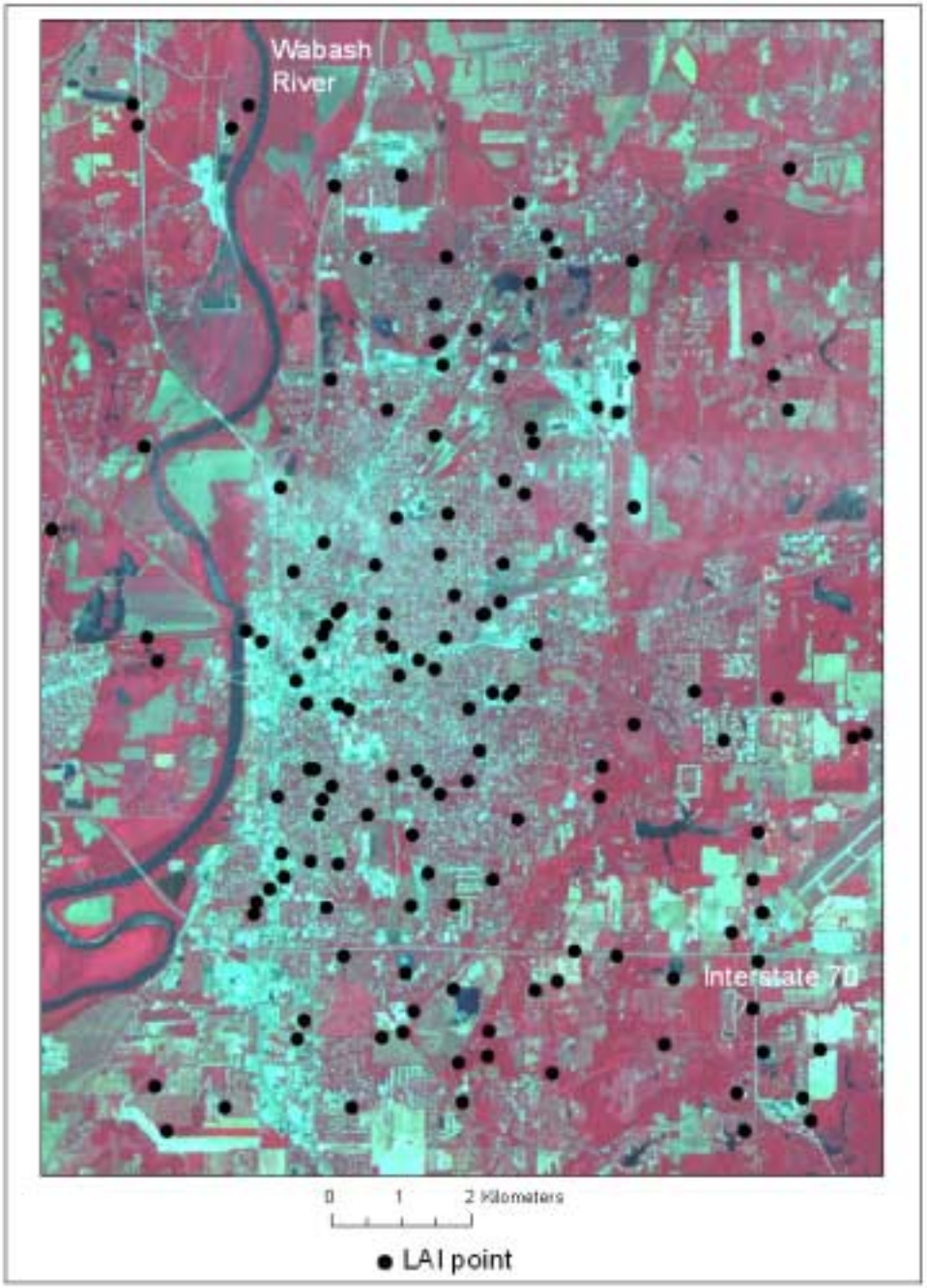
ASTER Spectral Bands



Source: NASA, JPL

Leaf Area Index

- 145 random points
  - Regression
  - Artificial neural network

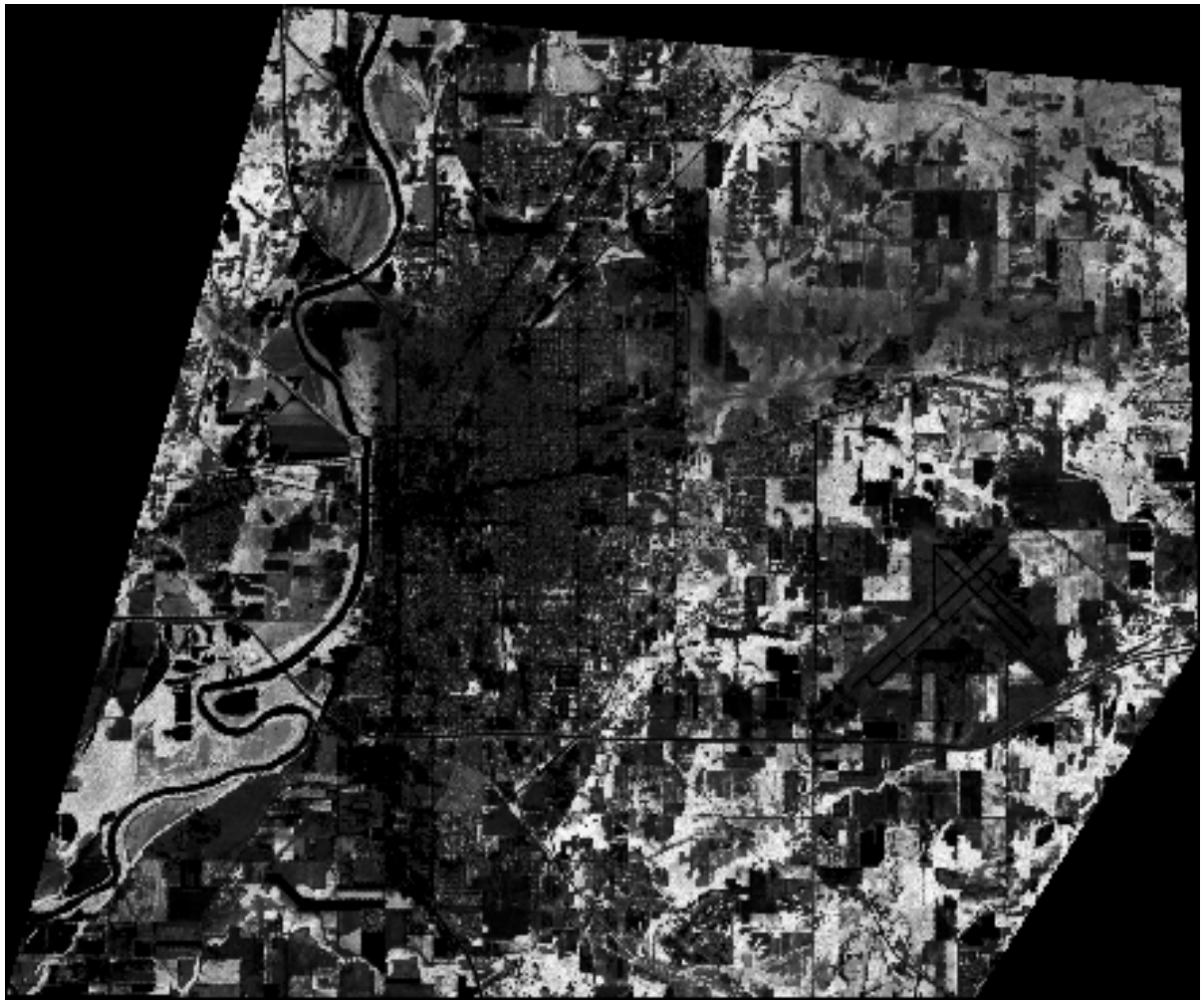


Results

Method	**Inputs**	***R***	***SEE***
Regression	*Green : Red*	0.60	1.54
Regression	*Green : Red, Infrared*	0.62	1.51
ANN	*GREEN*	0.69	1.39
ANN	*NDVI*	0.68	1.39
ANN	*Red : Infrared*	0.69	1.39
ANN	*GREEN, Red : Infrared*	0.71	1.35

LAI Map

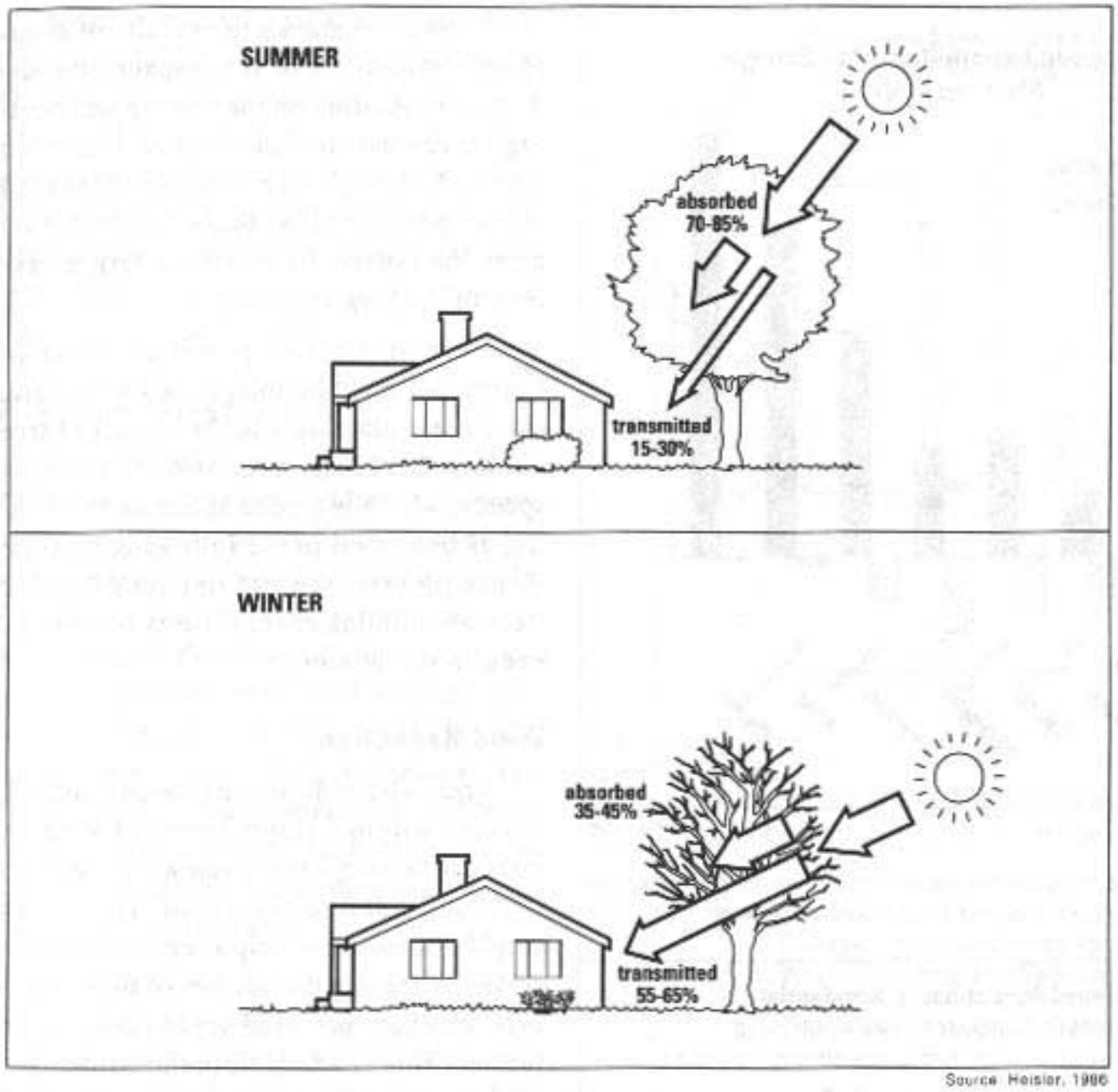
- Derived from ANN



Questions

- Measurable difference in summer residential electricity use that can be attributed to the urban forest
- Relationship between urban leaf area and UHIE
- Equitable distribution of urban leaf area

Energy Reduction



Akbari et al., 1992, p. 29, fig 2-2.

Terre Haute

- Relationship between LAI and summer energy consumption
- 300 random addresses
  - Issues of privacy
  - Cinergy PSI
  - 534 N. 6th Street

Standardize

- Residential meters are generally read once each month, but not all on the same day.
  - Some residences appeared to have been missed one month with a make-up the next month
  - Some residences appeared to have been turned off for a month or more during the study time
- Kilowatt-hours/day.

Correlation

- Slight correlation between LAI and household energy consumption
  - For every one unit increase in LAI, KwHr per day usage decreases by 4.17368

Accuracy

- Summer time energy usage could depend on
  - Thermostat
  - Windows
  - Window units or central air
  - # of occupants
  - Insulation
  - Television

Significance

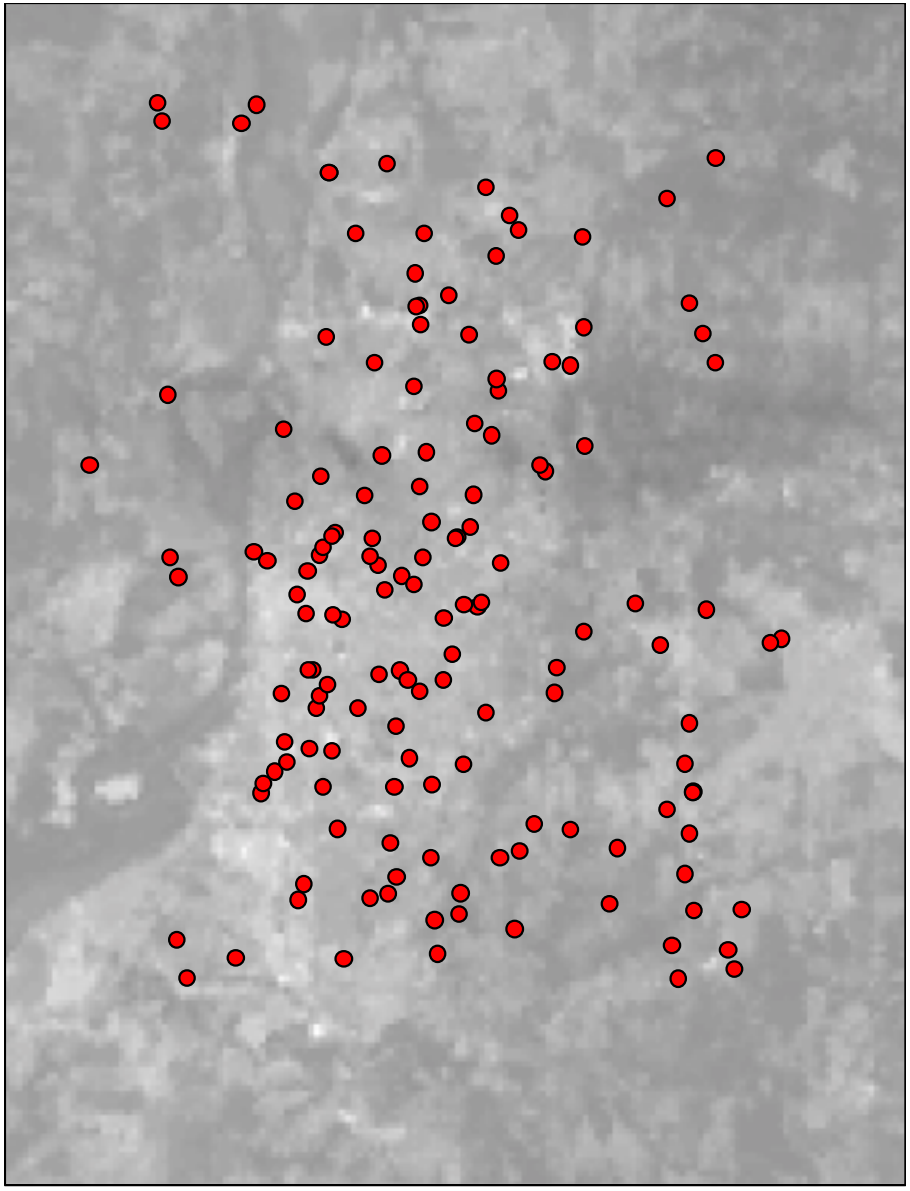
- Money!
- ~ 120 cooling days
- $0.075 / KwHr
  - One unit increase in LAI
    - $37.53 season savings
  - Four unit increase in LAI
    - $150.12

Urban Heat Island

- Urban temperatures
- LAI

Urban Temperature and LAI

- Same LAI dataset
  - 145 points
- Relationship with urban temperature



Urban Temperature and LAI

- Explains 19.3% of variance
  - R^2 = 19.3%
- Celsius = 33.0 - 1.17 * LAI
- Cooler temperatures as leaf area increases

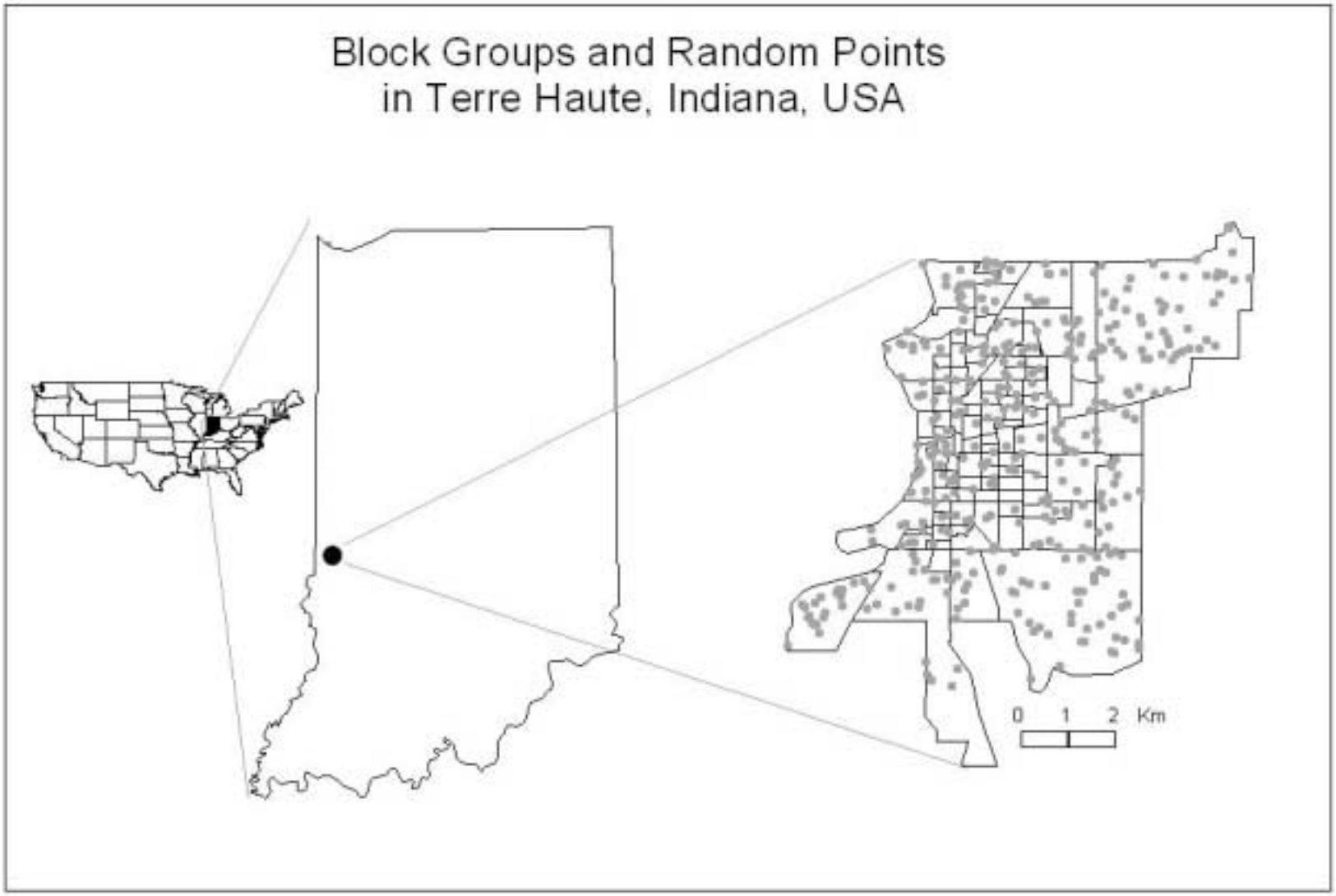
Equitable Distribution of UF

- Environmental justice
- Urban quality of life
- Distribution?
- 250 points
- ANN-derived urban LAI

Methods

- Census block groups
  - 2000
- Socio-economic patterns
  - Median income
  - Median housing value
  - Population density
  - % African American
  - Owner-occupied

Random Points



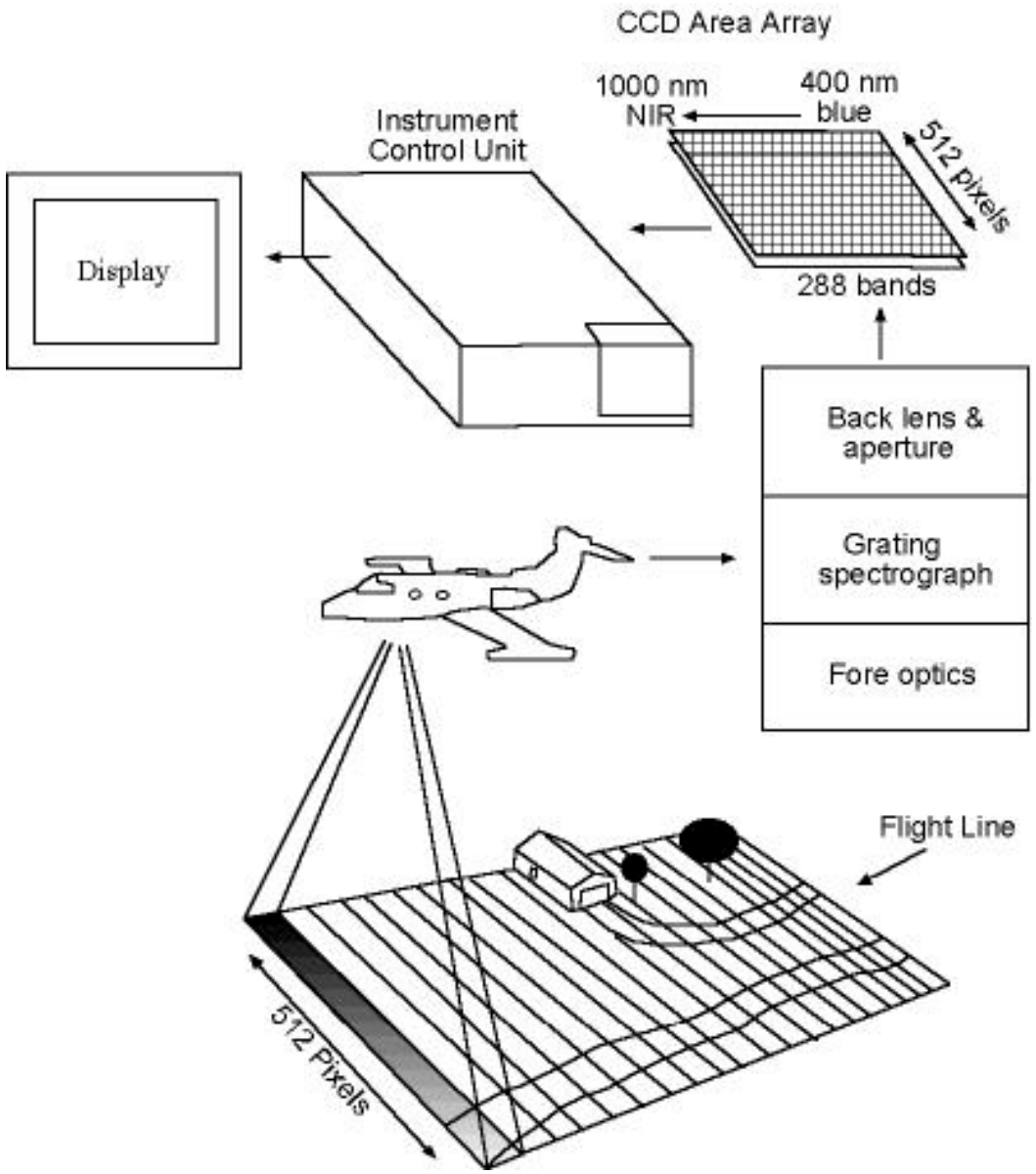
Results

	LAI	Home Value	Median Income	Density	Percent AA
LAI	1				
Home Value	0.321	1			
significance	*0.000*	*0.000*			
Median Income	0.401	0.710	1		
significance	*0.000*	*0.000*	*0.000*		
Density	-0.325	-0.465	-0.489	1	
significance	*0.000*	*0.000*	*0.000*	*0.000*	
Percent AA	-0.064	-0.232	-0.232	0.392	1
significance	*0.225*	*0.000*	*0.000*	*0.000*	*0.000*
Owner Occ.	-0.156	-0.386	-0.326	0.078	0.324
significance	*0.004*	*0.000*	*0.000*	*0.137*	*0.000*

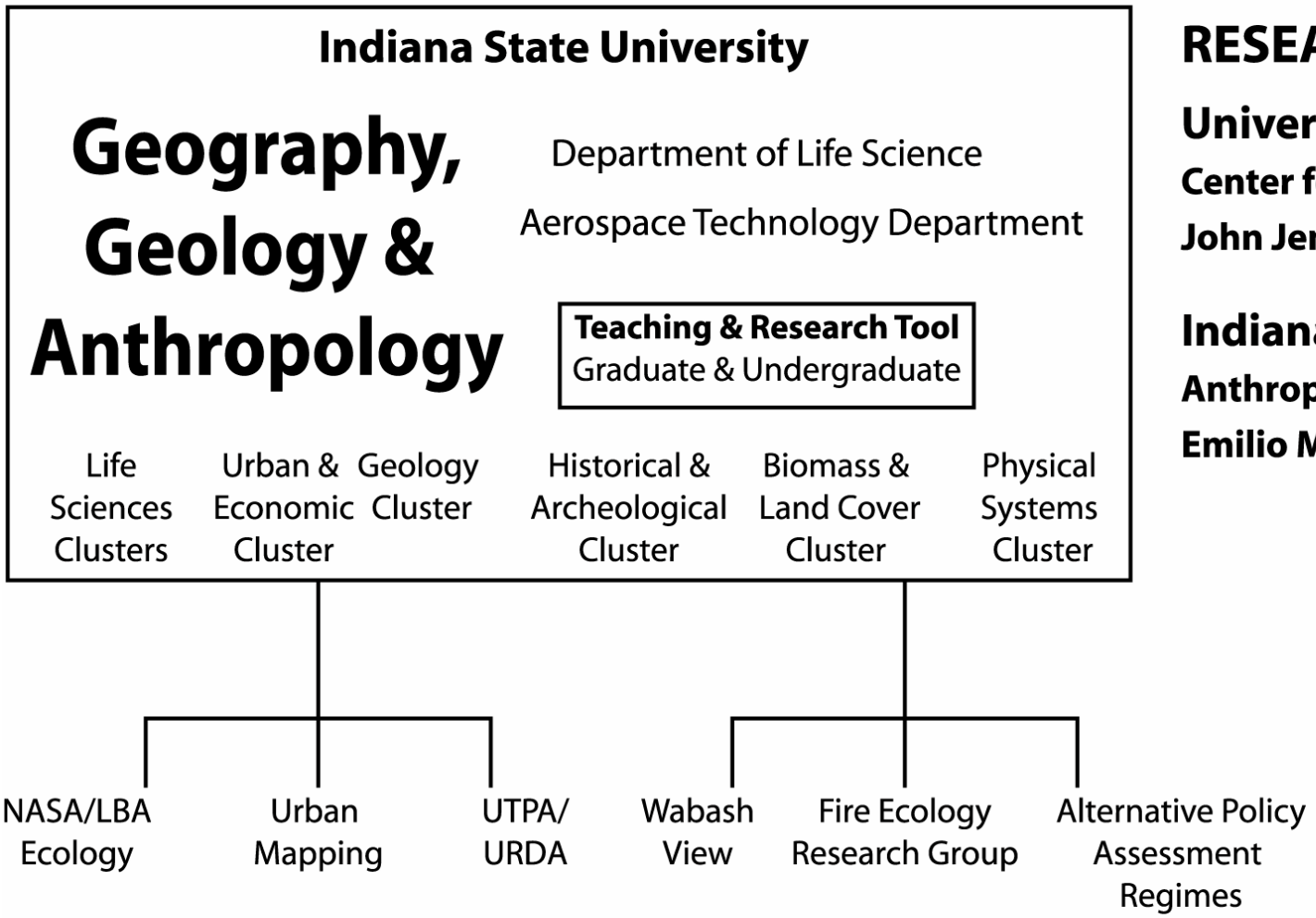
New Urban Image Data

- AISA+ Hyperspectral Sensor
  - Recently awarded to ISU from National Science Foundation
  - 400 – 900 nm
    - Spectral bandwidth 2.3 nm
- Portable
- Bands are fully programmable

AISA+ Hyperspectral Sensor



AISA+ Hyperspectral Sensor



RESEARCH PARTNERS

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Anthropological Center for Training
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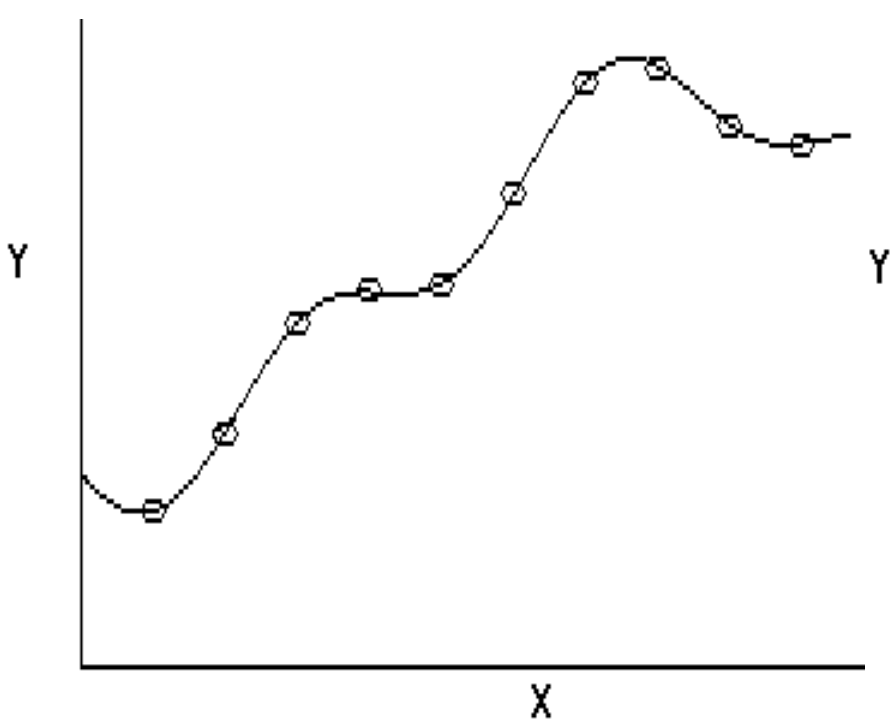
Conclusions

- Remote sensing
- Different kinds of studies
- ASTER
- Hyperspectral
- Qualitative research
- Reliable field data

How many neurons?

Overfit



Goodfit