Parallel Dasymetric Mapping for GIS Modeling

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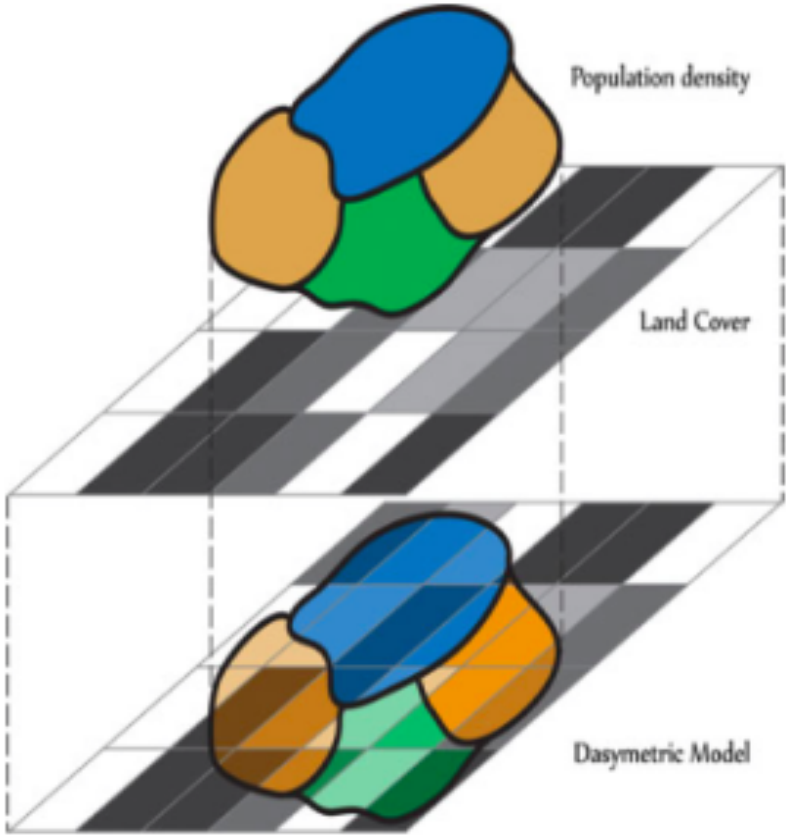
Overview



Population data

Ancillary-level data
(land type data)

High-resolution
population data

Why parallel?

- Time: It will cost a long time to do dasymetric mapping for the whole US according to all kinds of features.

- Space: All the data (50GB for the whole states using my method, maybe need more space if using more complicated algorithms) can hardly be fit into a single memory.

Stages

- Stage 1: Data preparation

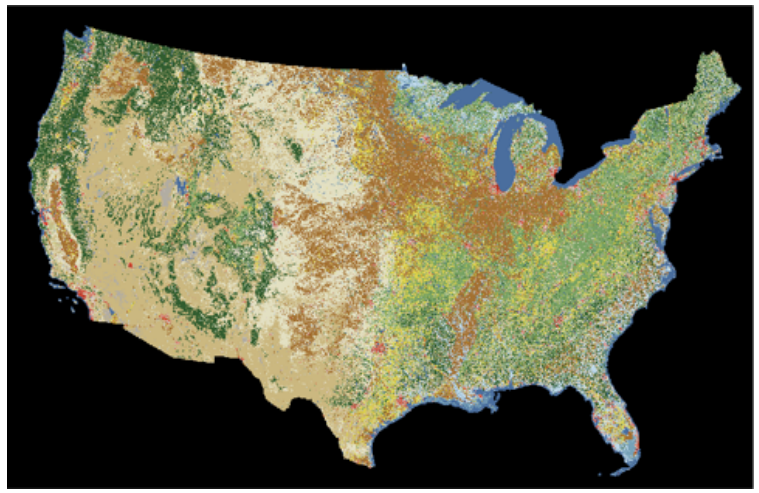
- Stage 2: Implement the serial method

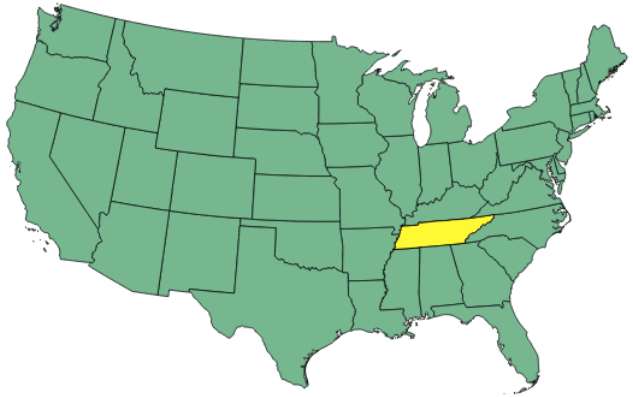
- Stage 3: Implement the method in parallel
- Stage 4: Run the method on a larger scale

Input data

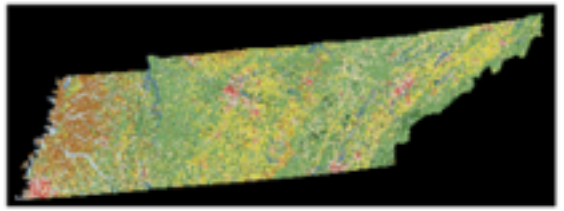
- National Land Cover Data(NLCD) dataset
- Block group boundary file
- American Community Survey(ACS) Summary Table

National Land Cover Data



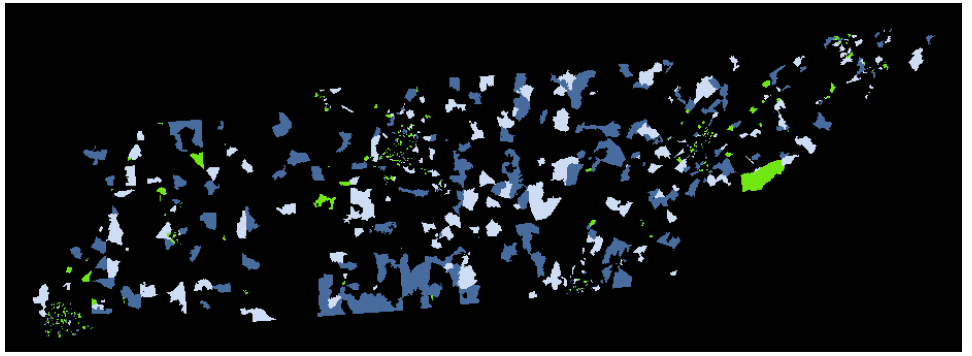


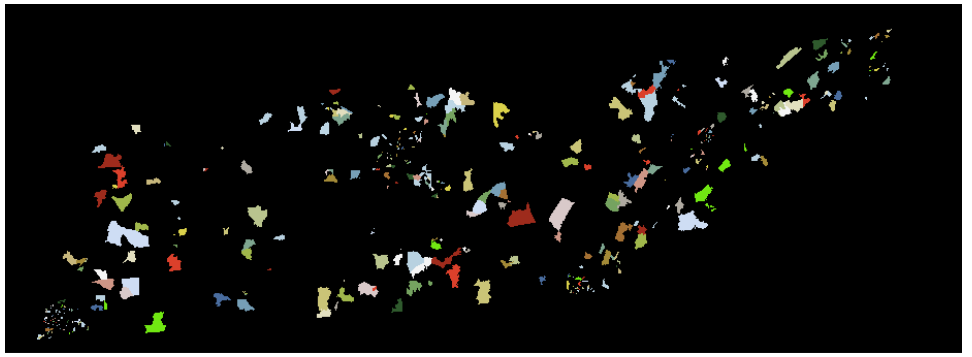
GDAL
+
QGIS



gdal_translate –projwin 503195 1616420
0 1284342 1332116 /Users/bhh/Desktop/GIS/nlcd_
2011_edition.img
……

Block group boundary file





gdal_rasterize -b 1 -b 2 -b 3 -burn 0 -burn 0 -burn 0 -l another / Users/bhh/Desktop/GIS-ZHANG/ cb_2015_47_bg_500k/ yourinputfile.shp /Users/bhh/ Desktop/youroutputfile.tif .....

American Community Survey(ACS) Summary Table

Total population → Processes 1,2,3,4

Asian population → Processes 5,6,7,8

White population → Processes 9,10,11,12

Black population → Processes 13,14,15,16

Doing dasymetric mapping for different groups simultaneously

Work Distribution

NLCD data

Block group boundary file

ACS Summary Table

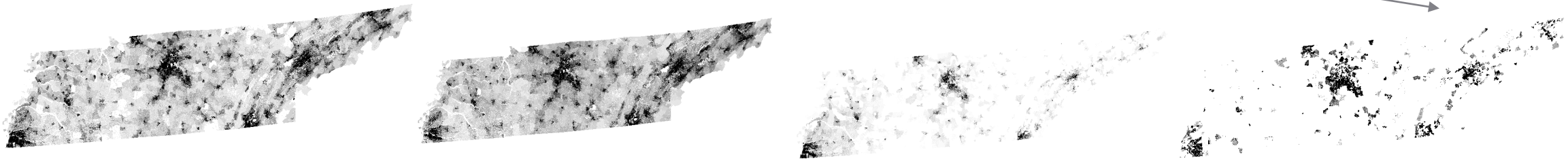
Input file

1,2,3,4

5,6,7,8

9,10,11.12

13,14,15,16



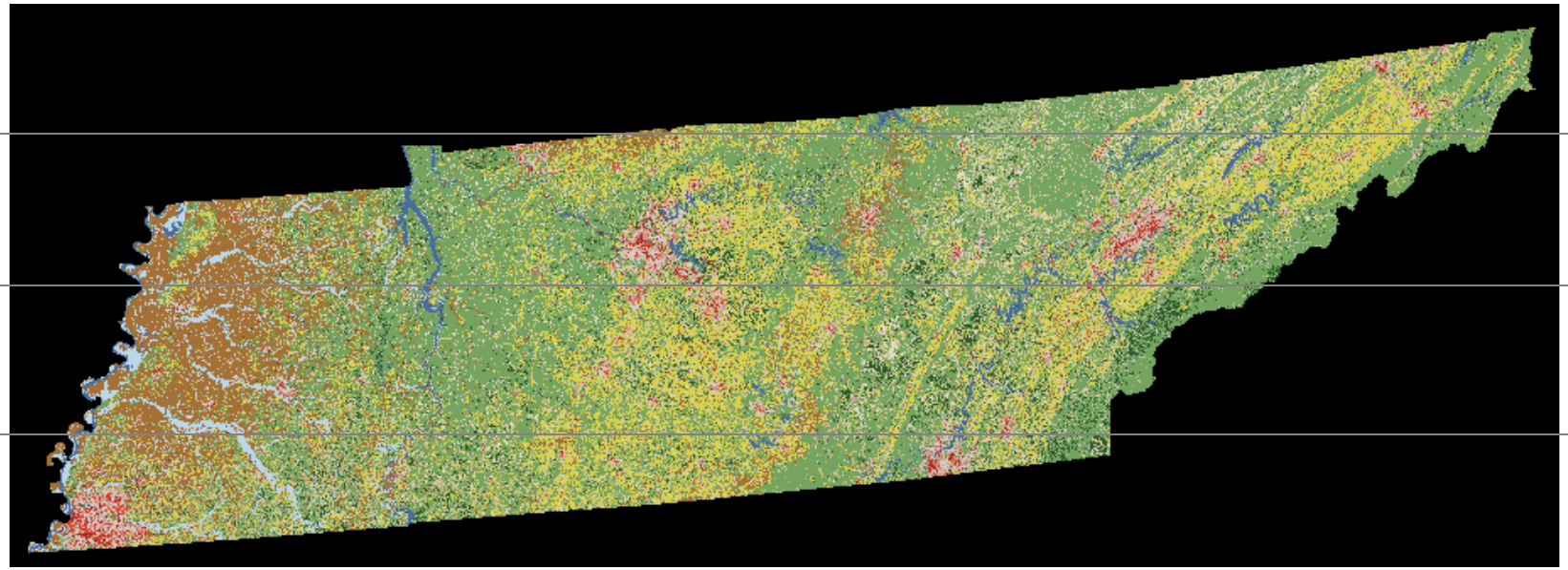
Work Distribution

1

2

3

4



Dasymetric Mapping (Weighting Method)

- Step 1: Assign weights to each grid according to its land type.

- Step 2: Distribute the total population in a block group into grids according to their weights.

Dasymetric Mapping (Weighting Method)

- Count the number of 30m*30m grids by land type and block group ID.

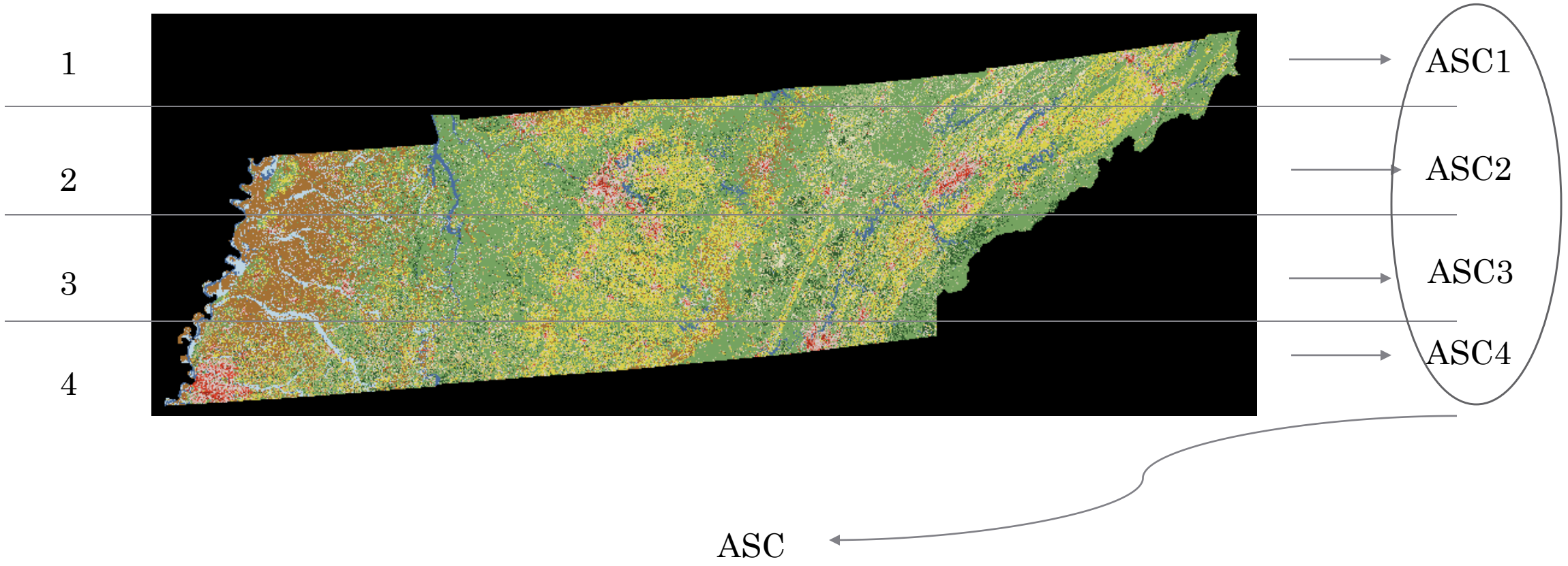
NLCD data

Block group boundary file

	1	**2**	**3**	**4**	**5**	**…**
water	156	356	343	142	67	…
forest	235	546	647	243	134	…
Agriculture land	134	134	643	245	135	…
Resident area	341	124	213	434	486	…
grassland	714	643	234	134	366	…
…	…	…	…	…	…	…

ASC

Cont.



Weights

$$P_s = \alpha + \left(\sum_{c=1}^{C} \beta_c A_{sc} \right) + \varepsilon_s$$

$$E(P_S|A_S) = \exp(\alpha + \beta A_S)$$

Possible regression models to get the population estimate in each 30m*30m grid

Problem: Coefficients can be negative, but the population density cannot be negative!

Cont.

- In general, alpha and beta tells us the population density on a grid given its land type.

water	water	forest	forest	forest
water	water	forest	forest	forest
Low pop	High pop	High pop	Low pop	forest
Low pop	High pop	High pop	Low pop	forest
Low pop	High pop	High pop	High pop	Low pop

0	0	1	1	1
0	0	1	1	1
30	50	50	30	1
30	50	50	30	1
30	50	50	50	30

Calculation

- However, population in a grid is not only determined by its land type, it is also related to the total population of its block group.

- We need to adjust according to the total population in a block group.(ACS)

- Population in a grid is equal to the total population of the block group that it belongs to times the weight of this grid divided by the total sum of weights in this block group.

- The only unknown parameter: total weights of the block group, if it is known, we can do this process in parallel easily.

Total Weights

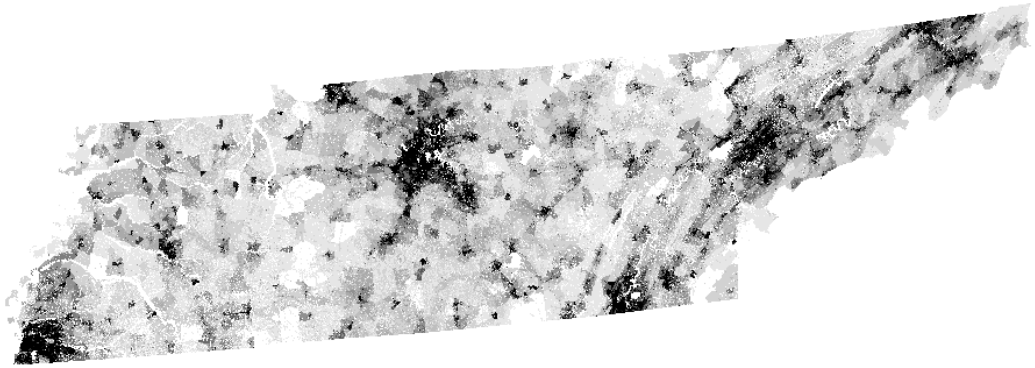
- Will not cost a lot of time, because useful information is already stored.

ASC → 40 water, 500 high pop, 300 low pop

Alpha, beta → Weight for water:0
Weight for high pop: 50
Weight for low pop: 30

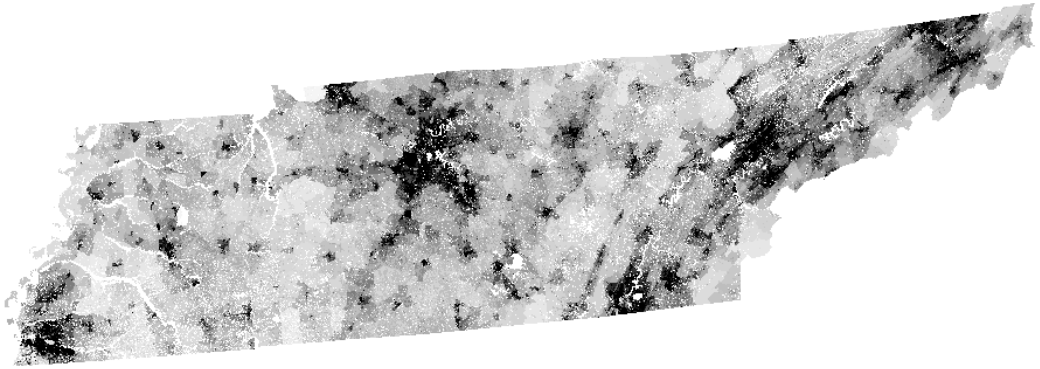
Total weights for this block group is: 40*0+500*50+300*30

Result

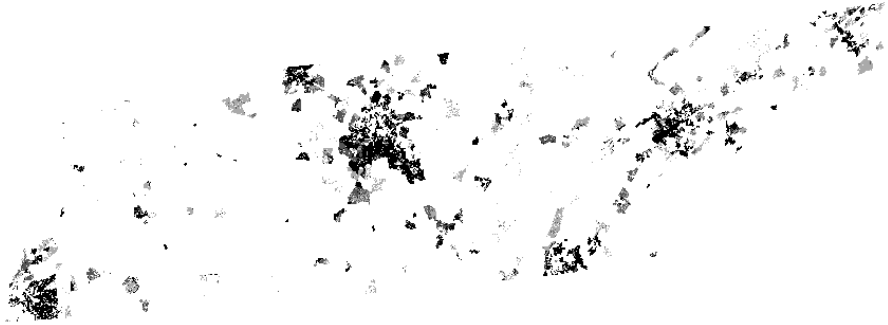


Total population

Asian population



White population



Black population

Future Work

- Larger study area
- More population groups

Easy (Our algorithm is scalable)

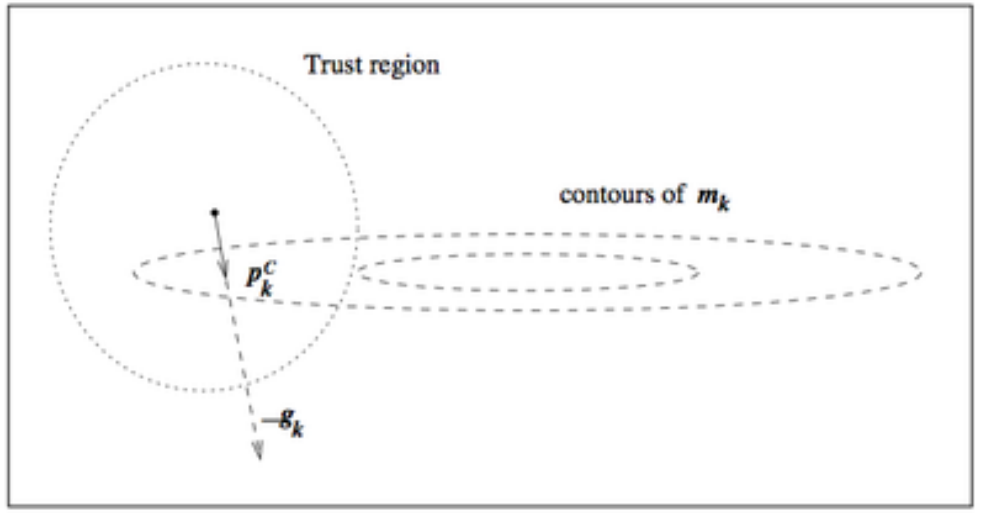
- More complicated algorithms
- Some improvements

PMEDM Method

$$\max \; -\sum_{it} \frac{n}{N}\frac{w_{it}}{d_{it}} \log\left(\frac{w_{it}}{d_{it}}\right) - \sum_{k} \frac{e_k^2}{2\sigma_k^2}$$

subject to the relaxed pycnophylactic constraints

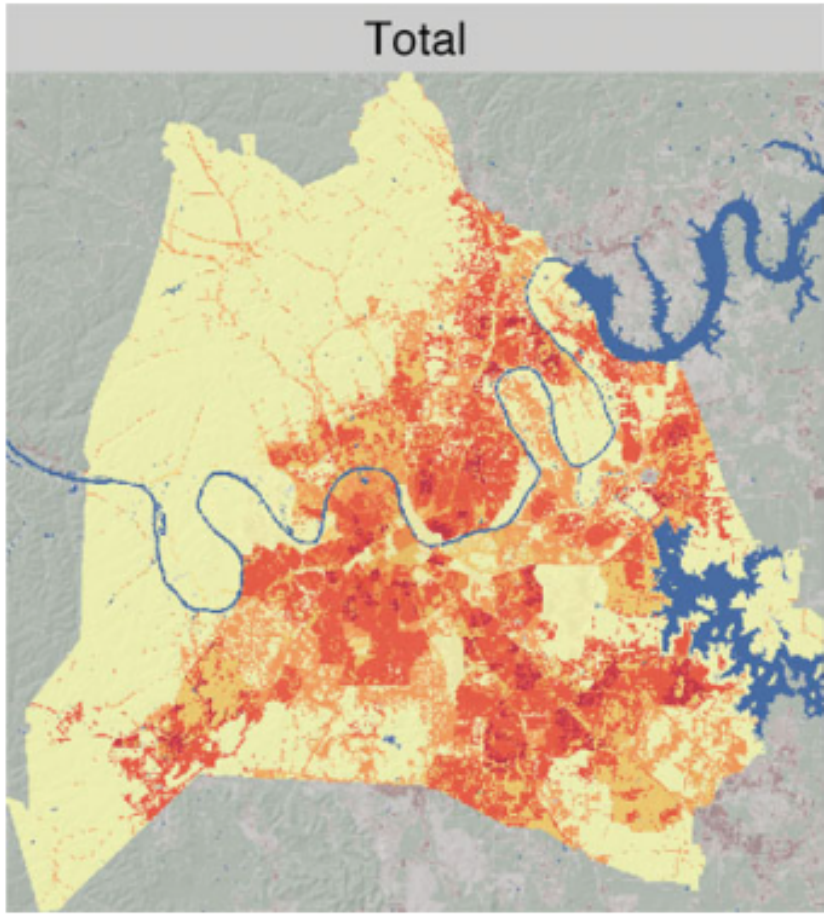
$$\sum_{it \in k} w_{it} = \widehat{\text{Pop}}_k + e_k \text{ for each constraint } k.$$



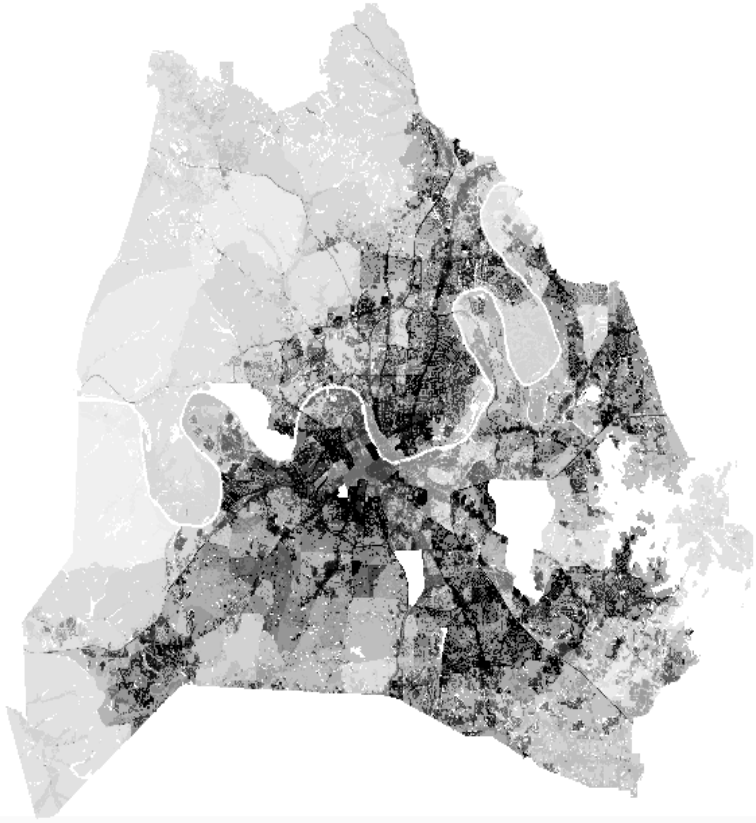
Advantages

- Fast
- More accurate
- Errors can be estimated

Comparison



PMEDM



Weighting Method(Parallel)

Reasons for the difference

- Different coloring method (Not important)

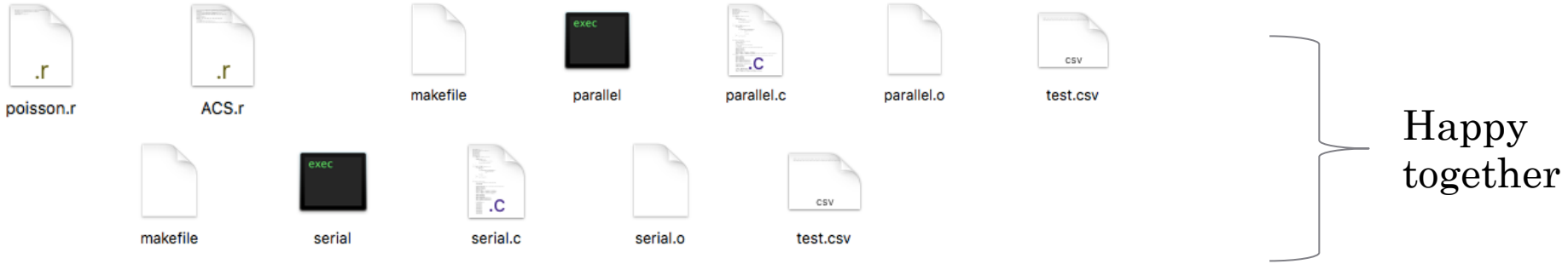
- My code is performed on the whole Tennessee, thus there may be area with fewer population

Some areas are grey rather than white

- Dr. Nagle's algorithm is more accurate

Some Possible Improvements

- Incorporate R codes and C++ codes
  - Extracting from American Community Service Tables
  - Regression part to determine coefficients
  - (Using Rcpp possibly)



- Try to get positive regression coefficients
  - Constrained regression?
  - Clever subsetting of data?
  - Aggregation of negative land use classes with other, non negative classes?
  - …

References

- Langford, M. (2006). Obtaining population estimates in non-census reporting zones: An evaluation of the 3-class dasymetric method. Computers, Environment and Urban Systems, 30(2), 161-180.
- Jeremy Mennis and Torrin Hultgren, Intelligent Dasymetric Mapping and Its Application to Areal Interpolation Cartography and Geographic Information Science, Vol. 33, No. 3, 2006, pp. 179-194
- Nicholas N. Nagle , Barbara P. Buttenfield , Stefan Leyk & Seth Spielman (2014) Dasymetric Modeling and Uncertainty, Annals of the Association of American Geographers, 104:1, 80-95, DOI: 10.1080/00045608.2013.843439
- Dependence-Preserving Approach to Synthesizing Household Characteristics
- Numerical Optimization Chp4.1-4.2

Acknowledgements

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