Development of TN Statewide Land Use Model Ver. 1

Tennessee Model User Group (TNMUG) Meeting
November 17, 2021

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Project Team

- ## Tennessee Department of Transportation
  - Dr. David Lee (Project Manager)
- ## University of Memphis
  - Sabya Mishra, Mihalis Golias, Ali Riahi Samani
- ## University of Tennessee Knoxville
  - Dr. Jerry Everett
- ## Acknowledgments
  - Chris McPhilamy, Mohammad Molla

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In today's presentation

- Developed Land Use Model's Concept and Results
- On-line Dashboard
- Software Architecture

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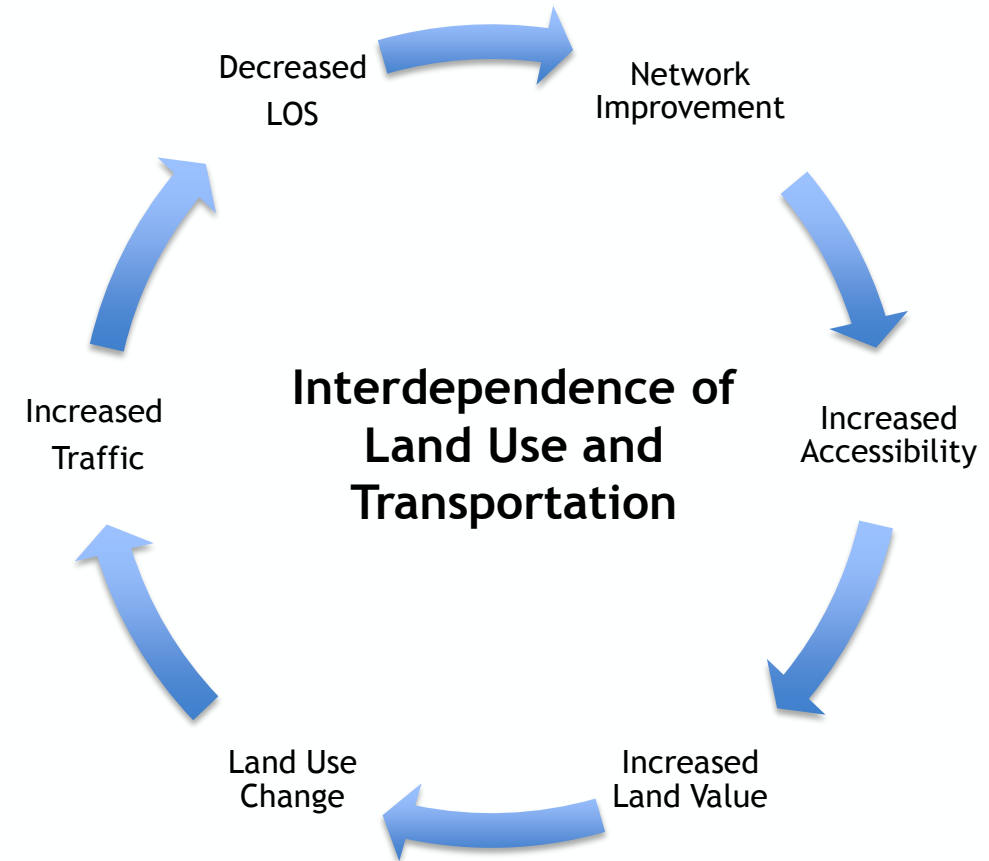
Section 1

THE MODEL CONCEPT

Introduction

Aim:

– to develop a statewide land use forecasting model for TN

– to develop an integrated land use –transport platform for Tennessee Statewide Travel Demand Model (TSTM)

Benefits:

– Increasing the accuracy of future-year land use forecasts

– Assess cumulative and indirect effects of projects.

– Evaluate economic effects of various state and regional policies.

– Obtain land use impact because of travel behavior change

Interdependence of Land Use and Transportation

Decreased LOS → Network Improvement → Increased Accessibility → Increased Land Value → Land Use Change → Increased Traffic → Decreased LOS

Land Use Models' Categories

Land use models can be categorized into

- Macro models
  - Gravity based
- Meso models
  - Logit Based
- Micro models
 - Agent based and Cellular automata models
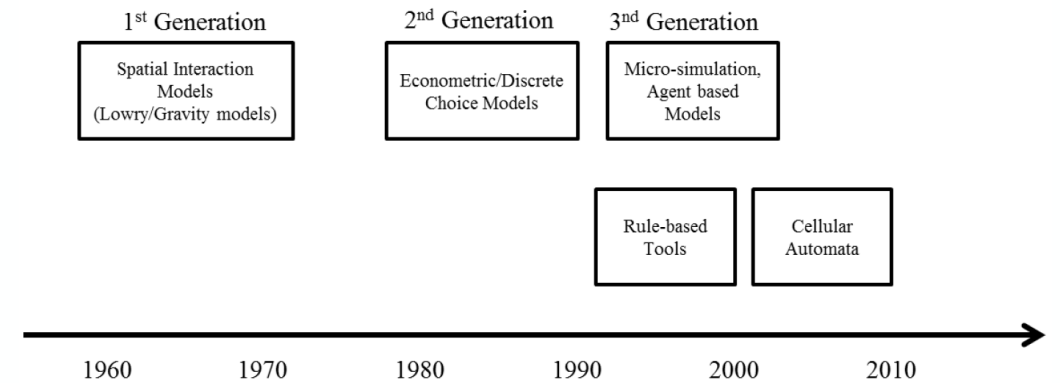
Selecting an approach for developing a land-use model

- Data availability
- Geographic level of zones (parcels, blocks, TAZs, …)
- Number of zones (the scale of study area)
- Future/interval years
- Run-time
- Accuracy

1st Generation	2nd Generation	3nd Generation
Spatial Interaction Models (Lowry/Gravity models)	Econometric/Discrete Choice Models	Micro-simulation, Agent based Models

Rule-based Tools   Cellular Automata

1960   1970   1980   1990   2000   2010

The Developed Land Use Model Structure
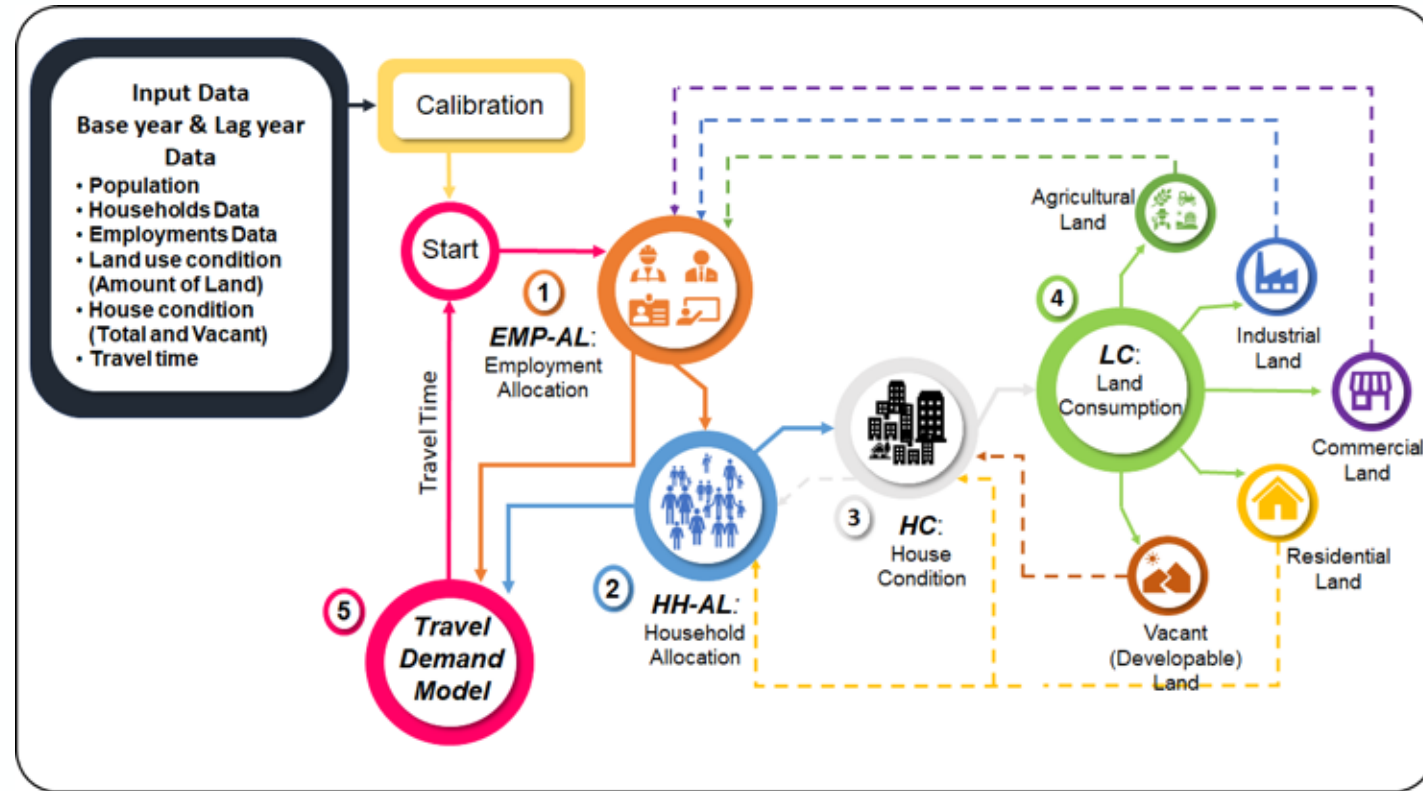
The developed statewide land use model

– An enhanced gravity-based approach

– Operational at TAZ level

– Applicable on large scale cases

– Forecasts S/E & demographic data with 5-year intervals

– Using two years data sets (base and lag year) for calibration

– Forecasting land use conditions and house conditions

– Incorporates, job opportunities, population, house conditions, residential, commercial, industrial, agricultural, and vacant lands in zones.
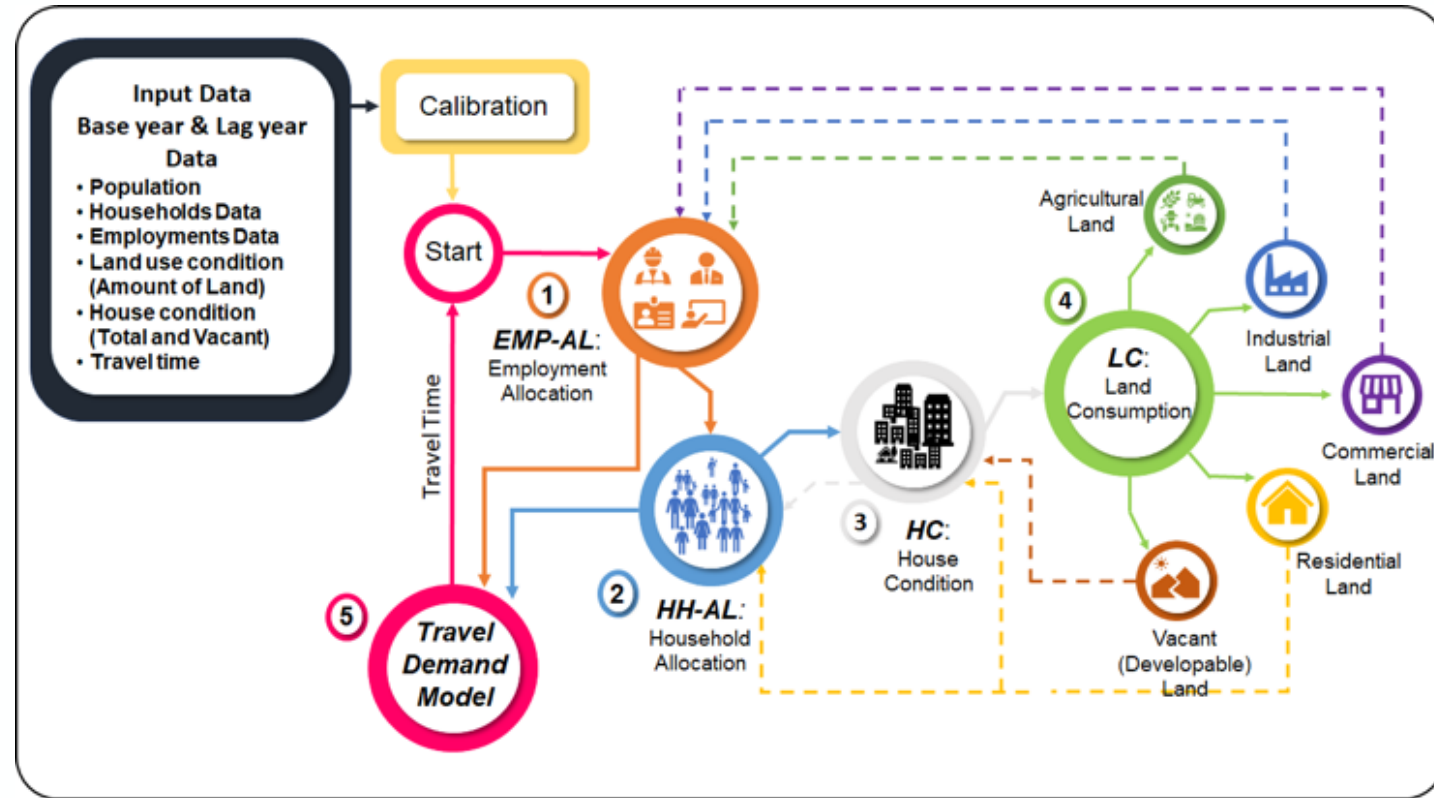
The Developed Land Use Model Structure

The developed statewide land use model

- Input data:

    The input data is collected for two periods (base year e.g., 2010 and lag year e.g., 2005)

- Calibration:

    - Uses the data sets to fit the model and estimate the required parameters (Coefficients)
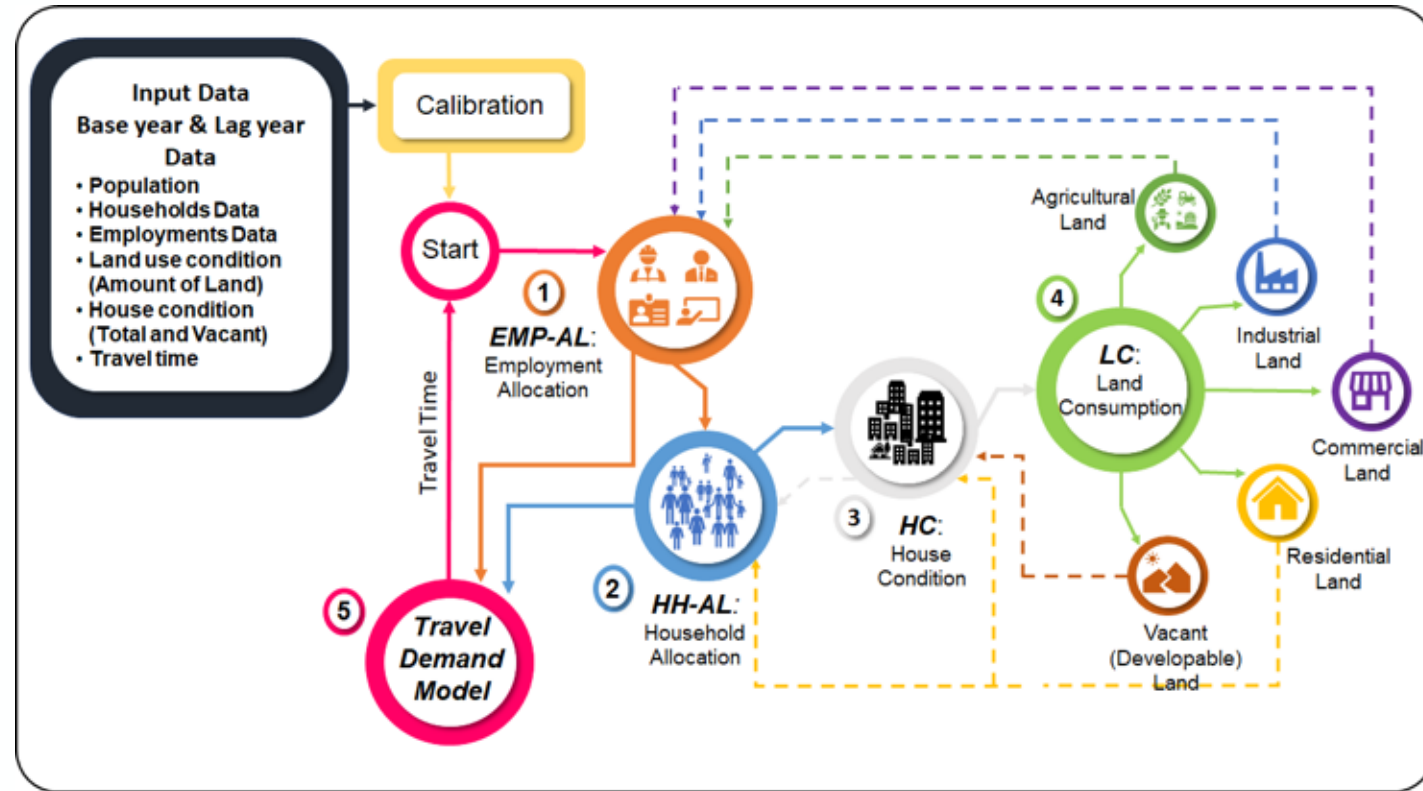   - After calibration, the model is developed for the base year

The Developed Land Use Model Structure

The developed statewide land use model

① EMP-Al (Employment Allocation)

- Allocates the number of employments in each zone based on the population, the attractiveness of zones, and travel costs.
- The attractiveness function is calculated using job opportunities, the amount of commercial, industrial, and agricultural land in a zone
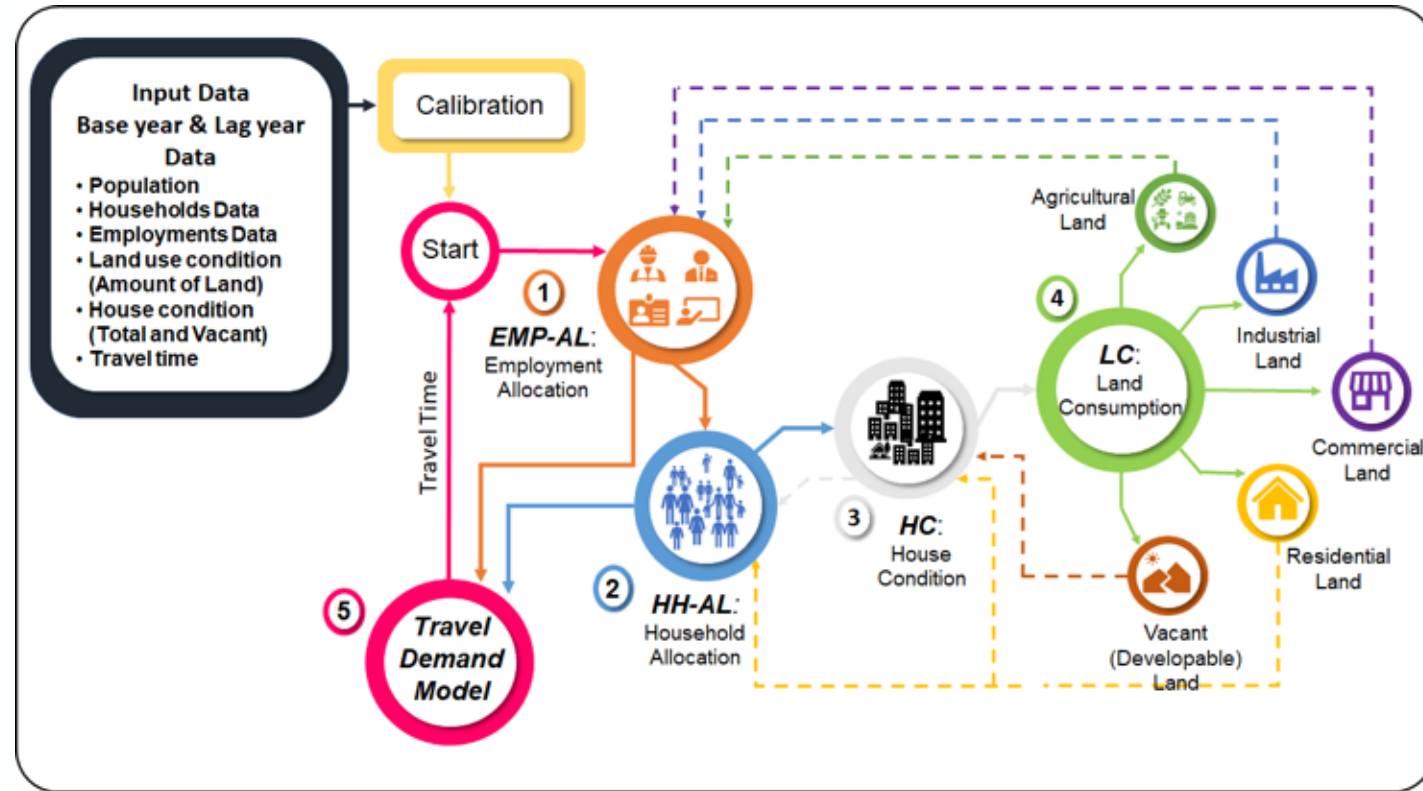
The Developed Land Use Model Structure

The developed statewide land use model

② HH-Al (Households Allocation)

- Allocates the number of households in each zone based on employment, the attractiveness of zones, and travel costs.
- The attractiveness function is calculated using total population, the amount of residential area, total and vacant houses, and total land
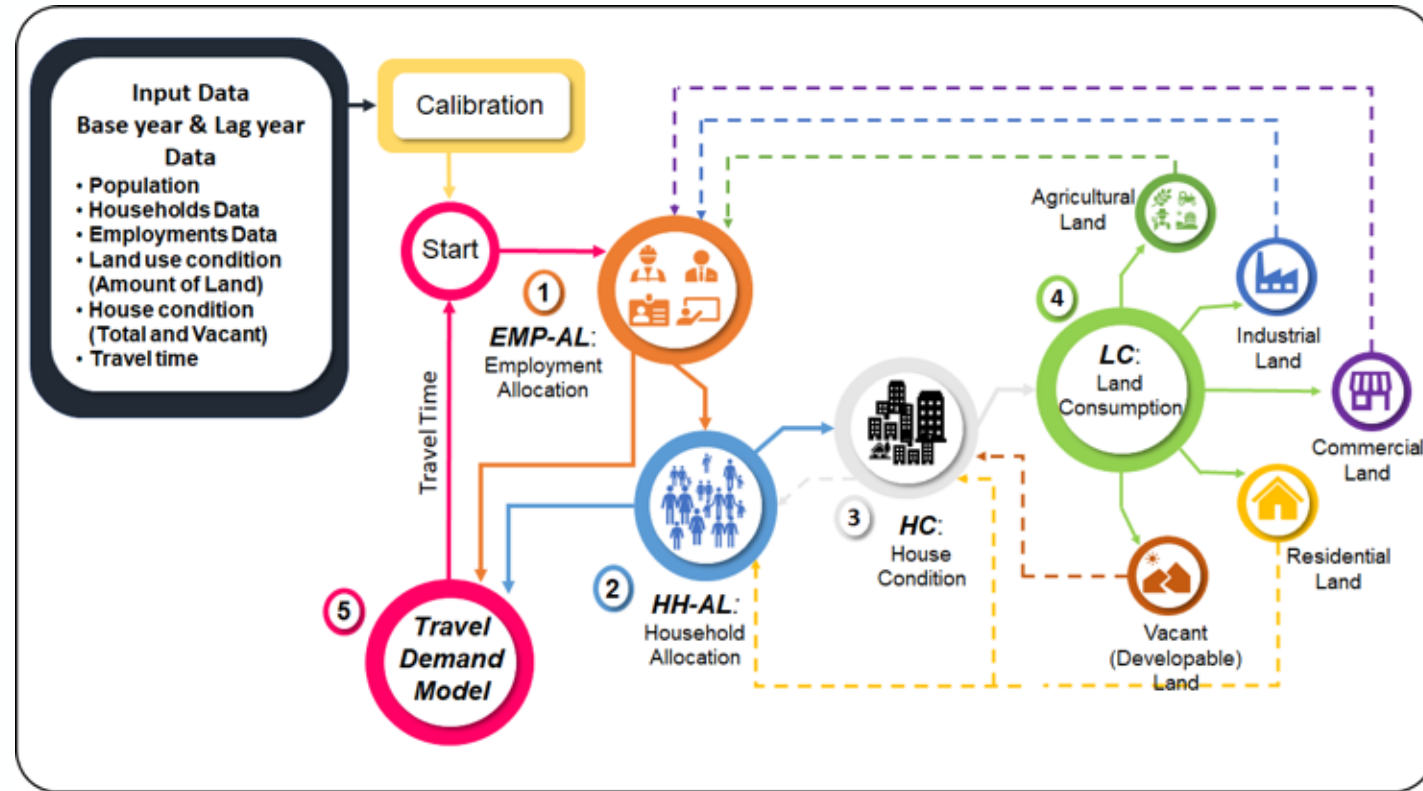
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The Developed Land Use Model Structure

The developed statewide land use model

③ HC (House Condition)

- Updates the total number of houses and the number of vacant houses in each zone
- The total number of houses in the previous year, the amount of vacant land, and the total number of households in that zone.

The Developed Land Use Model Structure

The developed statewide land use model

④ **LC (Land Consumption)**

- Updates the amount of land in different land-use classes to feed the two principal models (HH-AL and EMP-AL) to forecast future years' demographic and socioeconomic conditions.

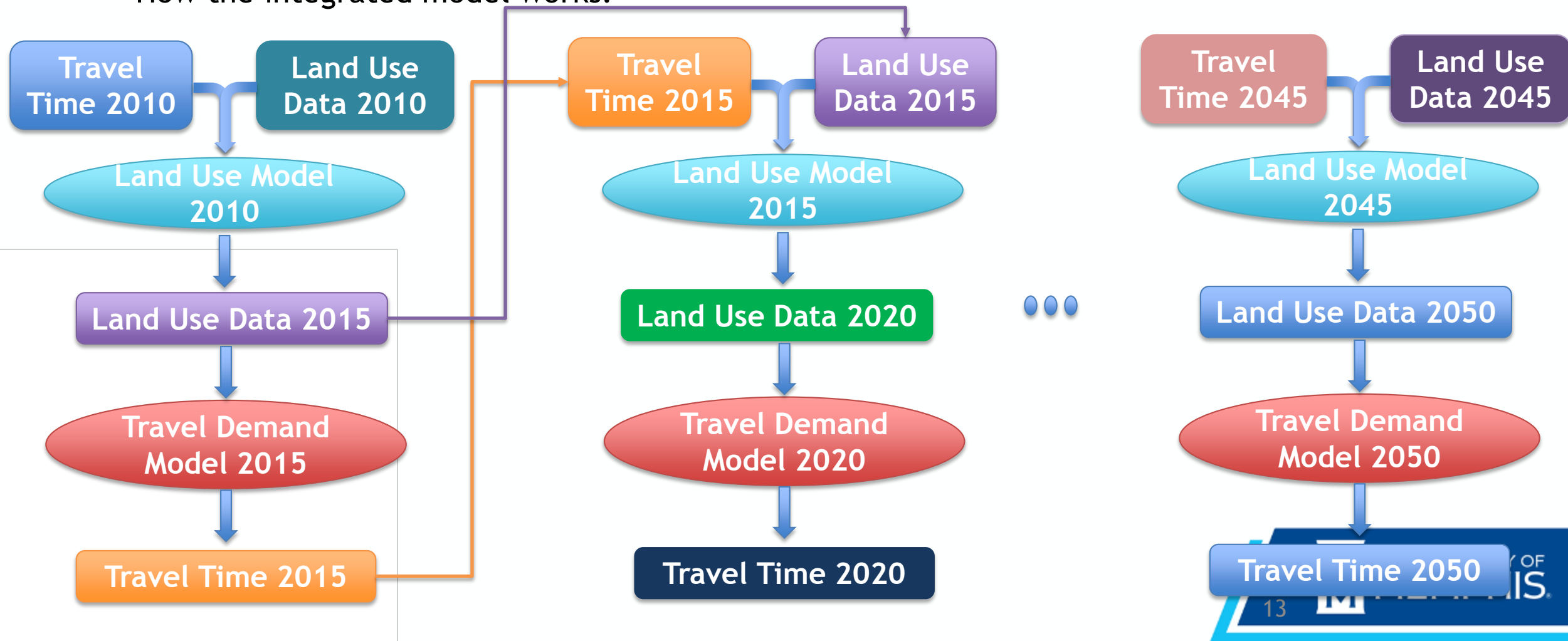- Agricultural, Industrial, Commercial, Residential, and Vacant (Developable)

⑤ **Travel Demand Model**

Updating the travel time (cost) between zones
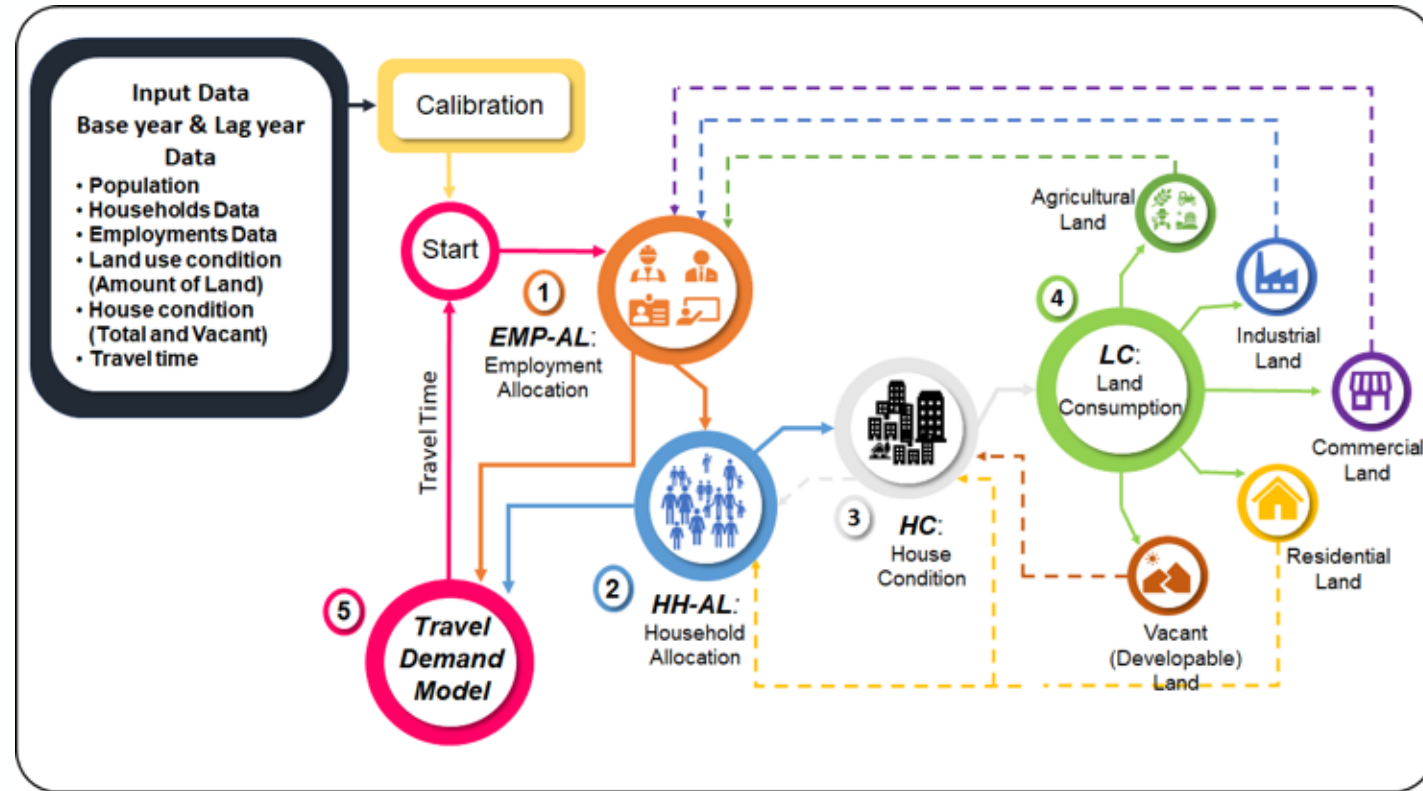
Integrated Land Use and Travel Demand

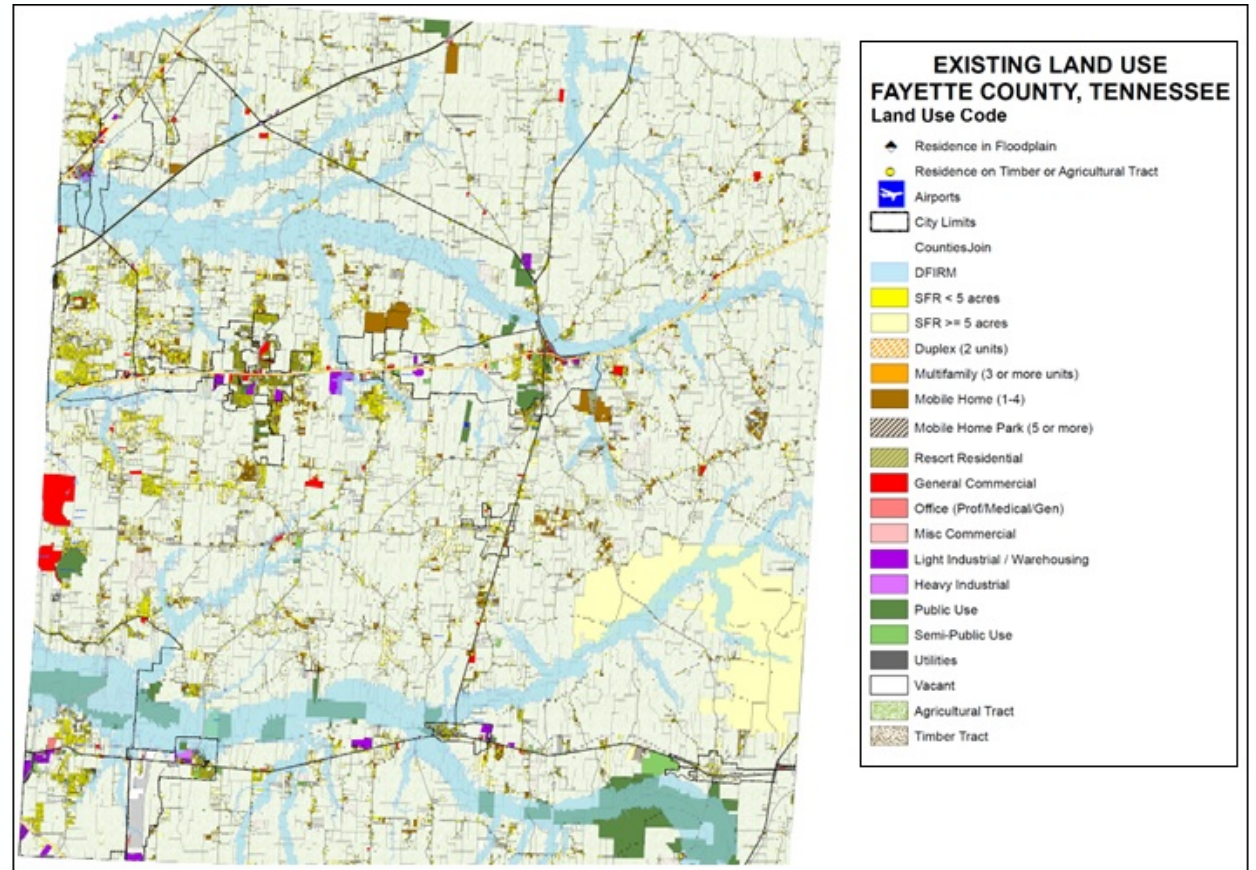- How the integrated model works:

Data collection

- Household categories
  - Total population
  - Households
  - Household's size
  - Group Quarter
  - Households with seniors
  - ...
- Employment categories
  - 20 NAICS Categories
- House conditions
  - Total houses
  - Occupied houses
  - Vacant houses

- Land use condition (from parcel data)
  - Residential
  - Commercial
  - Industrial
  - Agricultural
  - Developable (Vacant)

The State of Tennessee with 95 Counties and 3293 TAZs
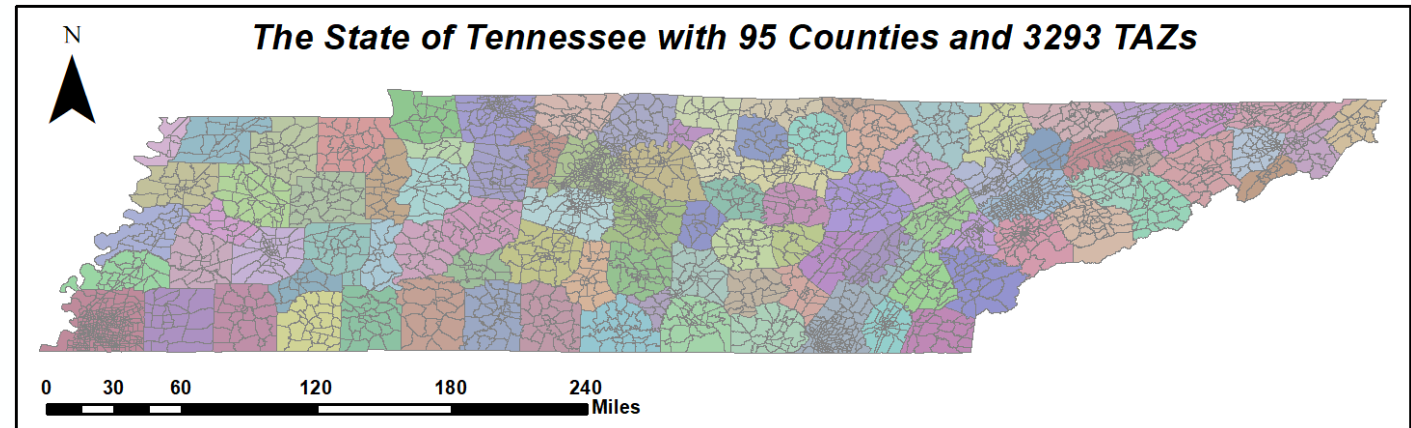
Data Collection (Parcel Data)

Parcel data refers to a combination of both spatial and nonspatial attribute files, presenting land ownership in a local jurisdiction

- Land properties (lands uses)
- Year of built
- Status of the land (vacant/occupied)
- Land's price
- Land's owner
- The date of last transition
- …

EXISTING LAND USE
FAYETTE COUNTY, TENNESSEE
Land Use Code

- Residence in Floodplain
- Residence on Timber or Agricultural Tract
- Airports
- City Limits
- CountiesJoin
- DFIRM
- SFR < 5 acres
- SFR >= 5 acres
- Duplex (2 units)
- Multifamily (3 or more units)
- Mobile Home (1-4)
- Mobile Home Park (5 or more)
- Resort Residential
- General Commercial
- Office (Prof/Medical/Gen)
- Misc Commercial
- Light Industrial / Warehousing
- Heavy Industrial
- Public Use
- Semi-Public Use
- Utilities
- Vacant
- Agricultural Tract
- Timber Tract

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Data Collection (Parcel Data)

The content, currency, structure, and coverage of parcel data sets vary significantly across jurisdictions and regions.

- **Some of the challenges include:**
  1. An understanding of data availability and completeness
  2. The willingness of local governments to provide data
  3. The varying content, format, and structure of data among counties
  4. Conflicts between parcels and TAZs (one parcel might drop between multiple TAZs)

TAZ Boarder
Parcel Boarder
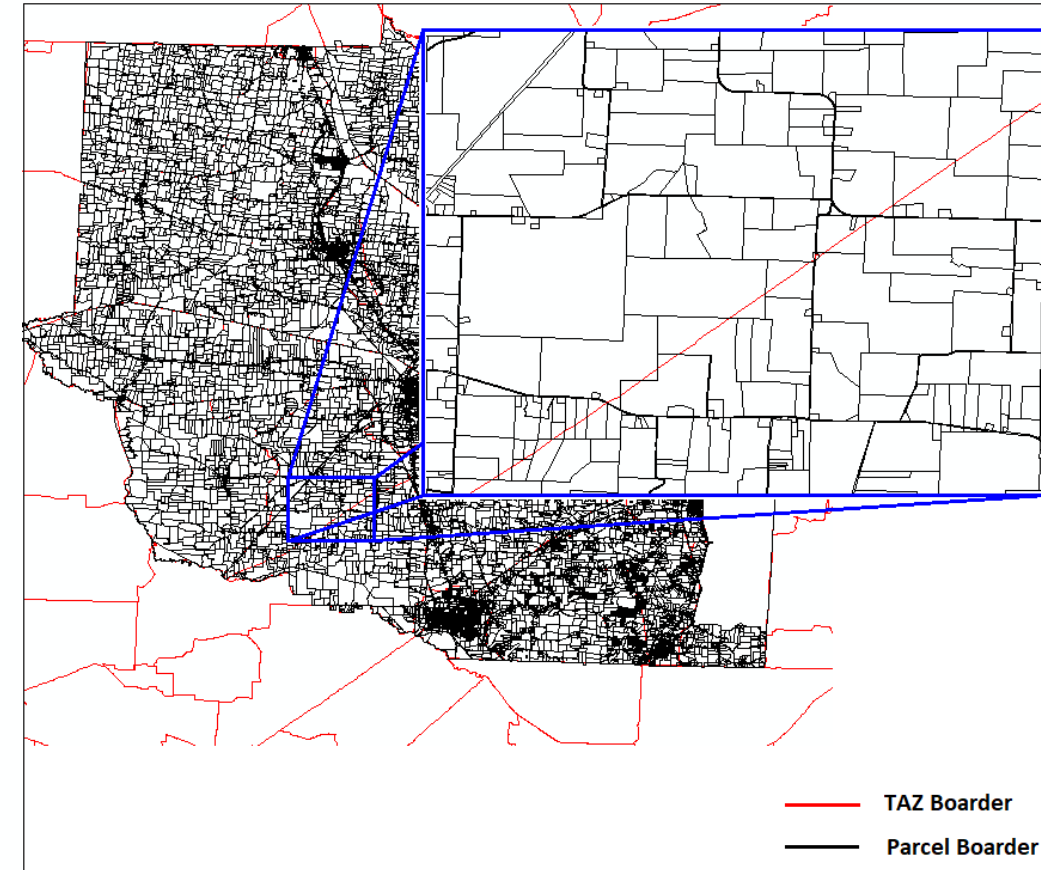
Implementation of the land use model

The result of developing model for the year 2010 (Base year)

Land use filed	R^2	MAPE (%)	PGP
Total Population	0.957	11.29	0.967
Total Households	0.965	15.41	0.967
HH with 1 Person	0.968	14.61	0.958
HH with 2 Persons	0.955	11.21	0.96
⋮			
HH with 7 or more	0.903	38.42	0.857
Total Employment	0.946	281.69	0.901
Emp in NAICS 11	0.926	91.52	0.802
Emp in NAICS 21	0.891	103.89	0.743
⋮			
Emp in NAICS 92	0.974	162.35	0.688
Residential Land	0.997	3.32	0.993
Commercial Land	0.959	11.17	0.957
Industrial Land	0.817	66.12	0.926
Agricultural Land	0.999	19.28	0.994
Vacant Land	0.926	25.64	0.896

The result of developing (calibrating) the model for the base year (2010)

Three measures are provided to show the accuracy and the goodness of the fit of the model
- R-squared (R^2)
- Mean Absolute Percentage Error (MAPE)
- Percentage of Good Prediction (PGP)

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Model Development (2010)

Estimated Total Population

Observed Total Population

Total Population, Year 2010

| 0 - 1000 | 1001 - 2000 | 2001 - 3000 | 3001 - 5000 | +5000 |

0 30 60 120 180 240 Miles
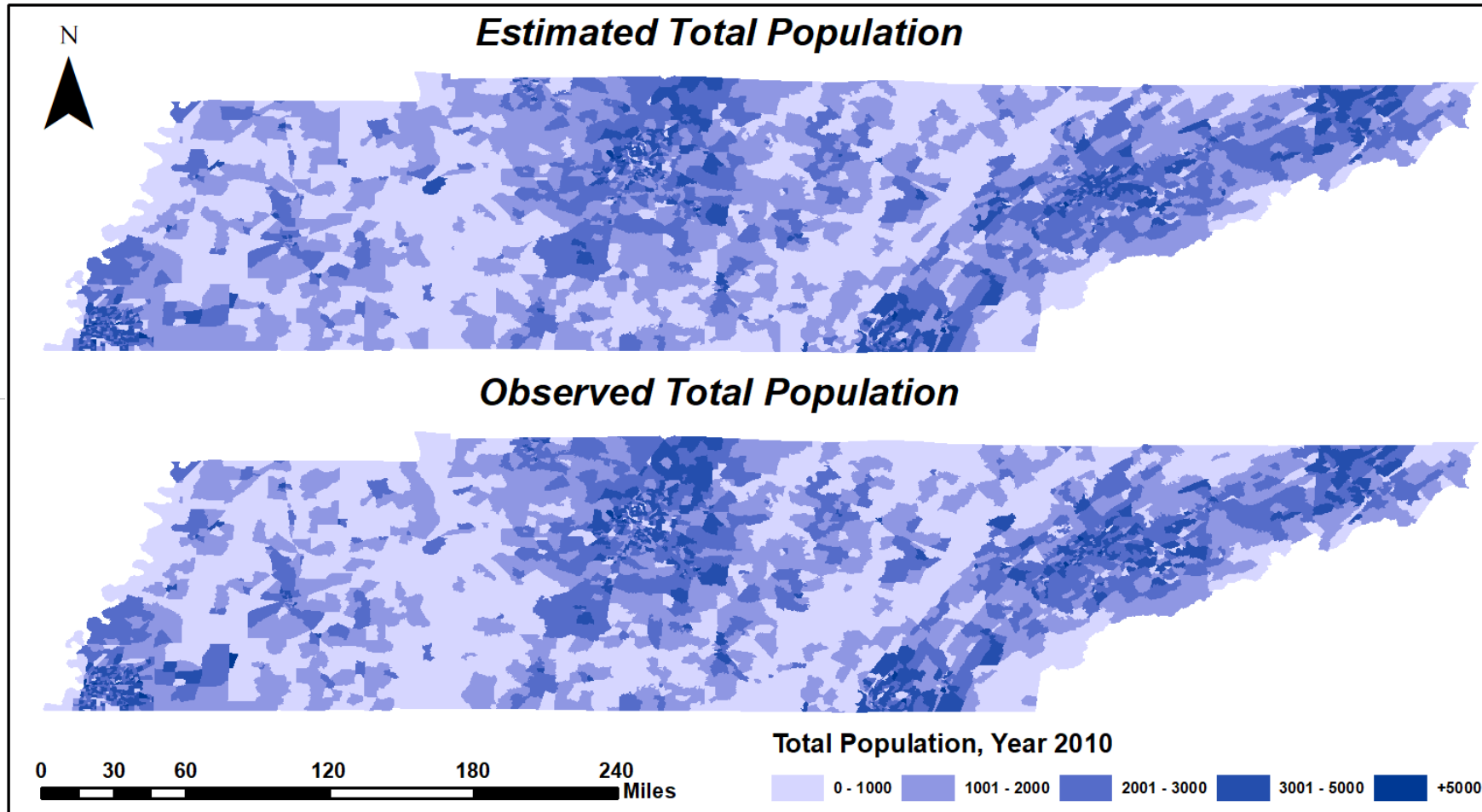
Similarities between observed and predicted value for total population for the base year (2010)

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Model Development (2010)

Estimated Total Households

Observed Total Households

Total Households, Year 2010

0 - 500 | 501 - 1000 | 1001 - 1500 | 1501 - 2000 | +2000

0 30 60 120 180 240 Miles
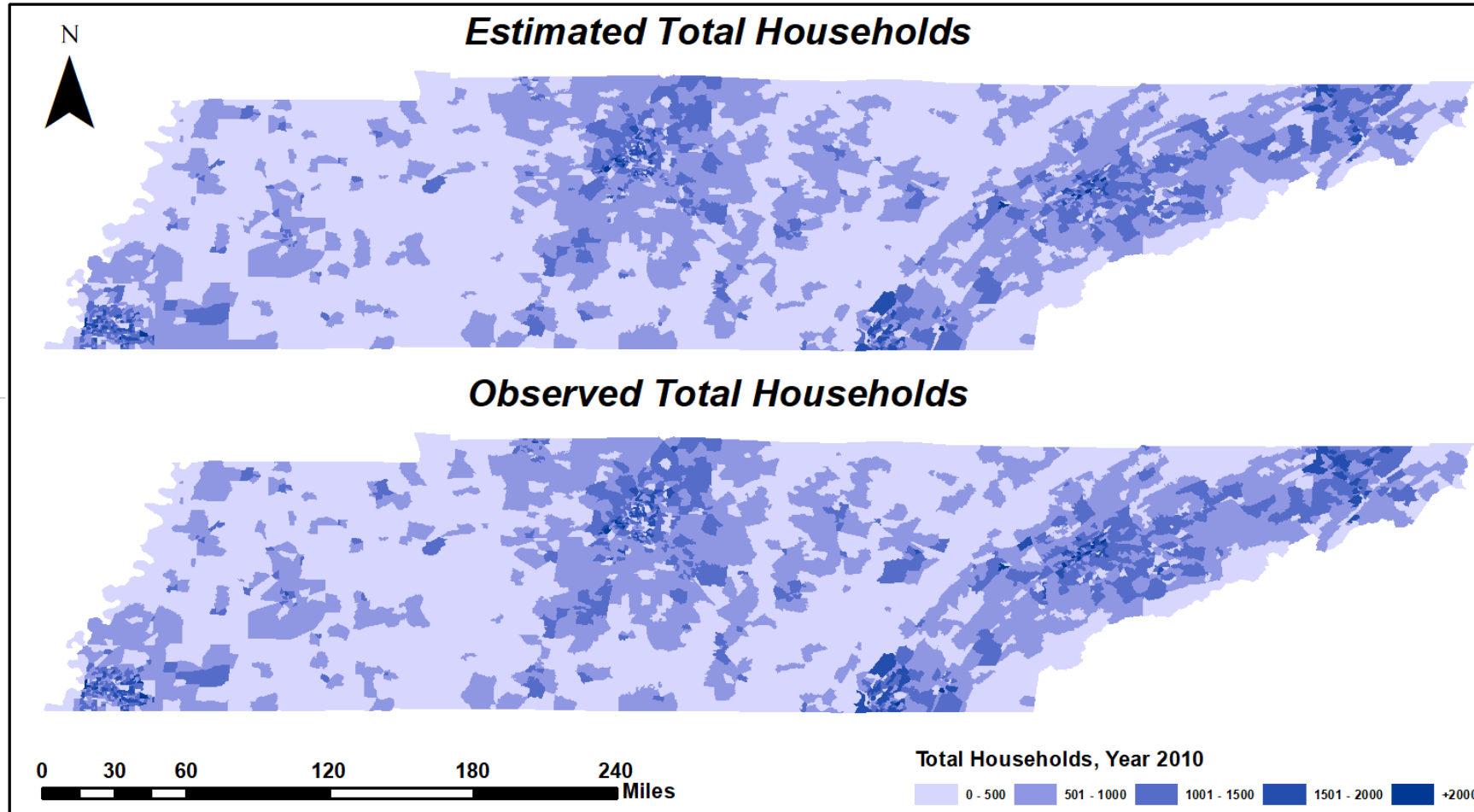
Similarities between observed and predicted value for total households for the base year (2010)

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Model Development (2010)

Estimated Total Employment

Observed Total Employment

Total Employment, Year 2010

0 - 250 | 251 - 500 | 501 - 1000 | 1001 - 2000 | +2000

0 30 60 120 180 240 Miles
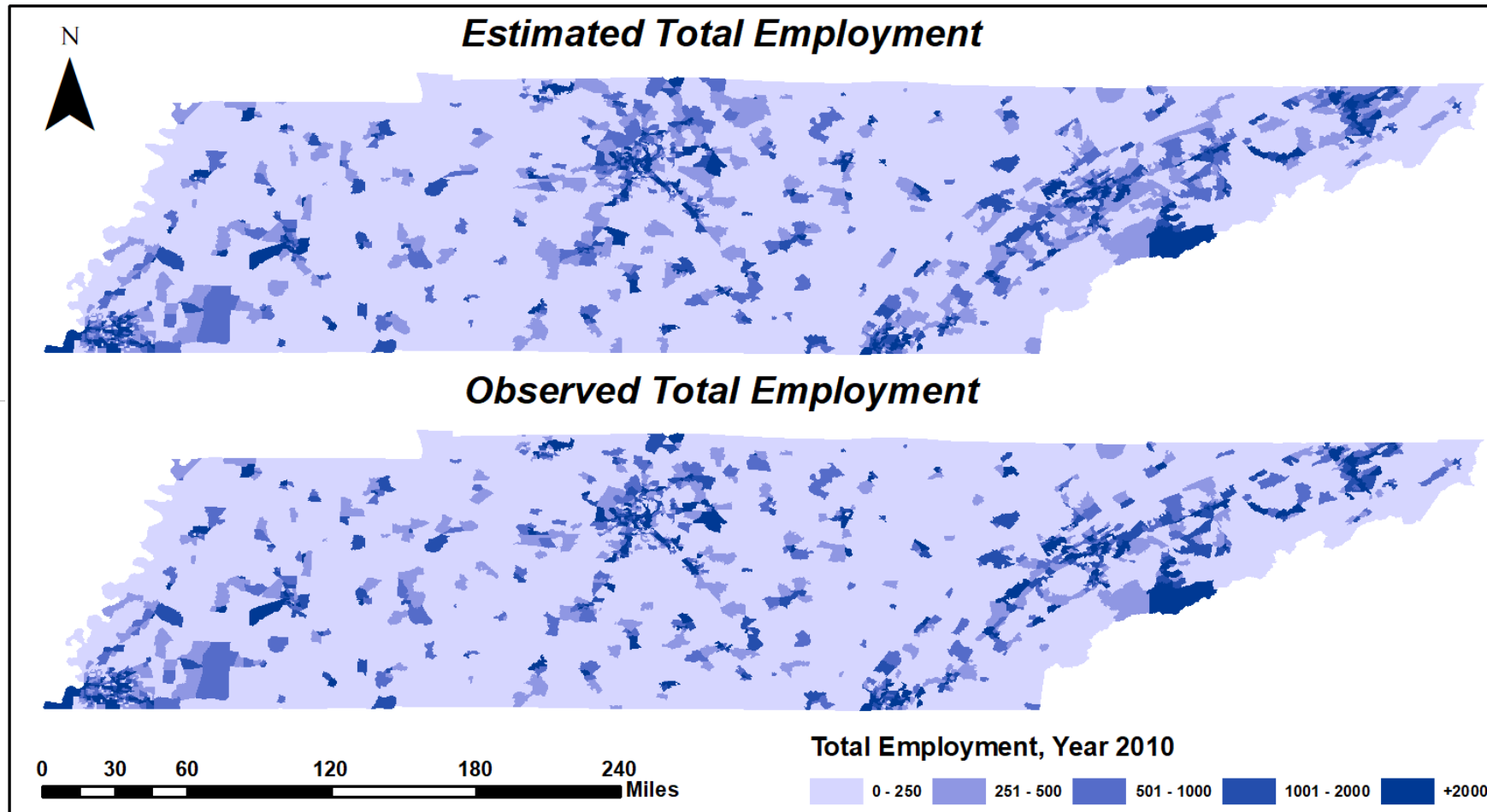
Similarities between observed and predicted value for total employments for the base year (2010)

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Model Development (2010)

Estimated Employment in NAICS 44-45

Observed Employment in NAICS 44-45

Employment in NAICS 44-45, Year 2010

0 - 100   101 - 200   201 - 400   401 - 800   +800
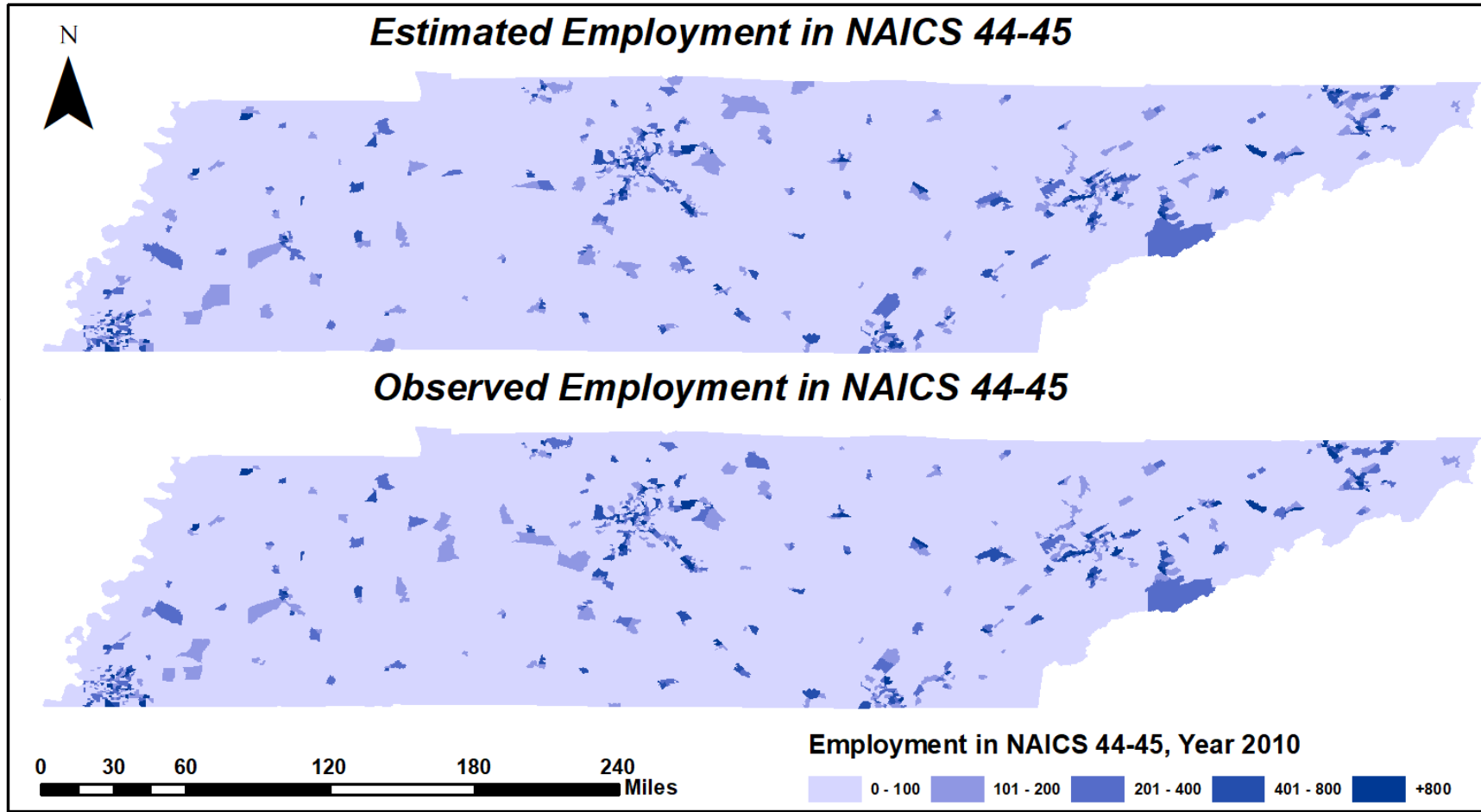
Similarities between observed and predicted value for employments in NAICS 44-45 (the retail trade sector) for the base year (2010)

Model Validation

- The accuracy of the model backcasting

  - Backcasting: using the model with inputs from a five-year lag period and comparing the observed and estimated values.

  - The backcasting approach was implemented for the year 2005

  - The data for year 2000 was collected

  - Testing the model accuracy in a disaggregated environment

    - 10 household categories

    - 21 employment categories

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Model Backcasting Validation

The accuracy of the model in backcasting the year 2005

Land use filed	R^2	MAPE (%)	PGP
Total Population	0.95	7.76	0.969
Total Households	0.956	9.15	0.97
HH with 1 Person	0.967	14.6	0.955
HH with 2 Persons	0.951	14.22	0.962
⋮			
HH with 7 or more	0.905	29.41	0.863
Total Employment	0.956	199.9	0.904
Emp in NAICS 11	0.893	72.73	0.771
Emp in NAICS 21	0.848	77.01	0.709
⋮			
Emp in NAICS 92	0.842	80.51	0.741
Residential Land	0.997	3.32	0.974
Commercial Land	0.974	13.53	0.962
Industrial Land	0.890	75.28	0.83
Agricultural Land	0.998	21.27	0.999
Vacant Land	0.933	29.31	0.926

- The developed model shows acceptable accuracy in all categories and in a disaggregated environment

- Based on the studies R-squared and PGP greater than 0.66 represents acceptable accuracy.

- Model shows high accuracy in predicting households and land use conditions
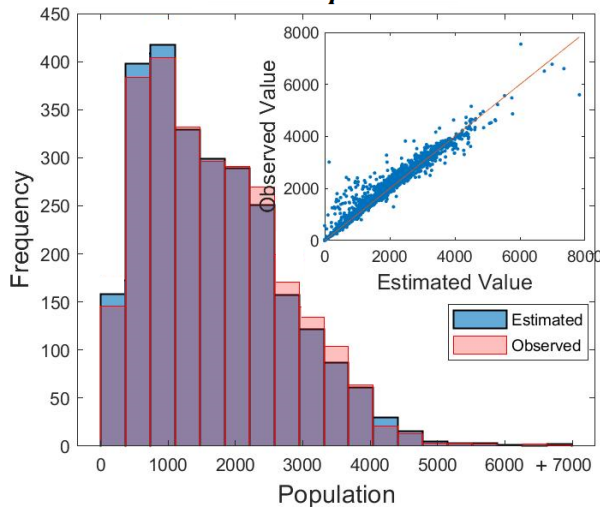
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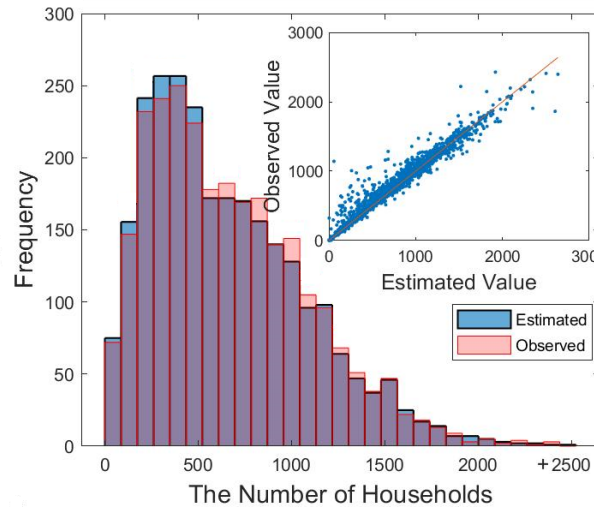
Model Backcasting Validation
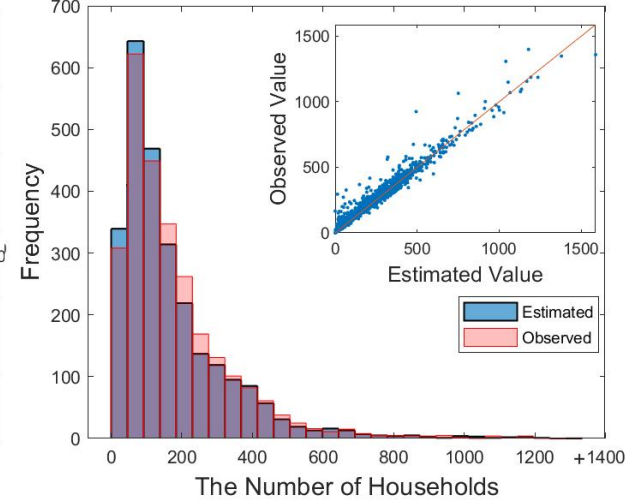
Histogram and Correlation Plot of estimated and observed households 2005
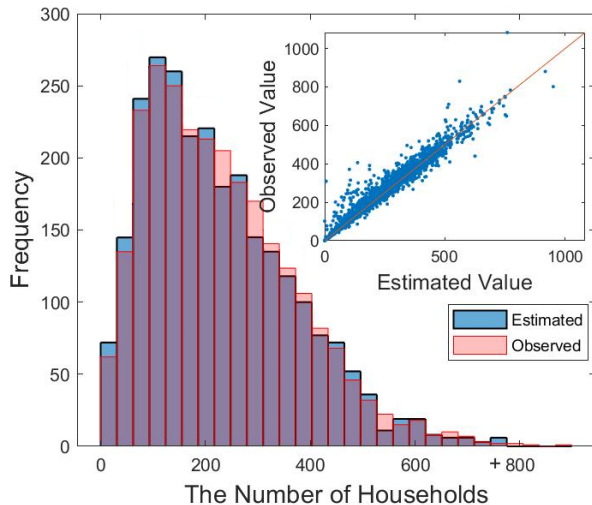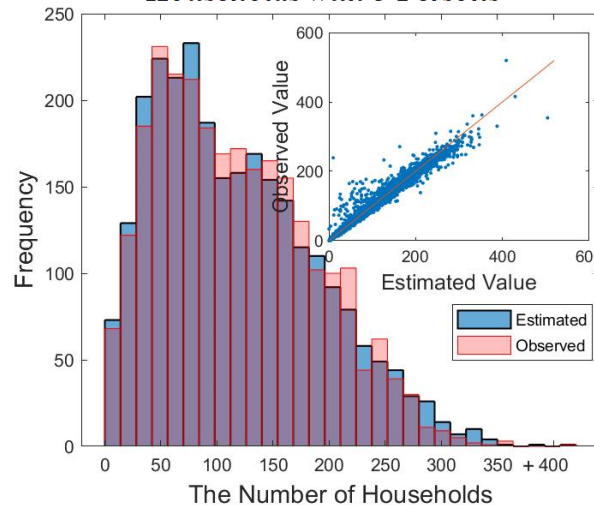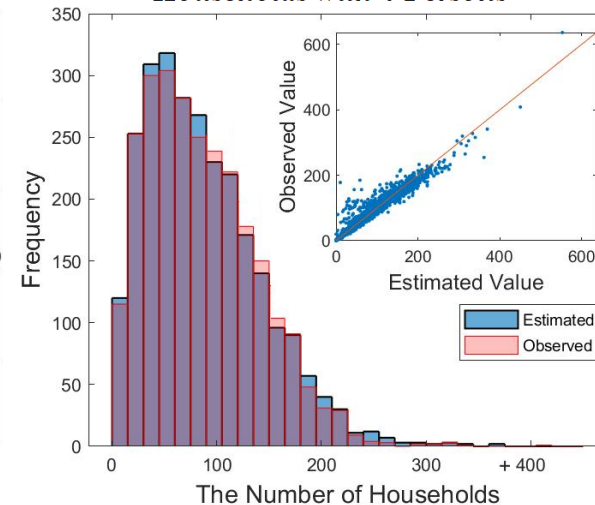
Model Backcasting Validation
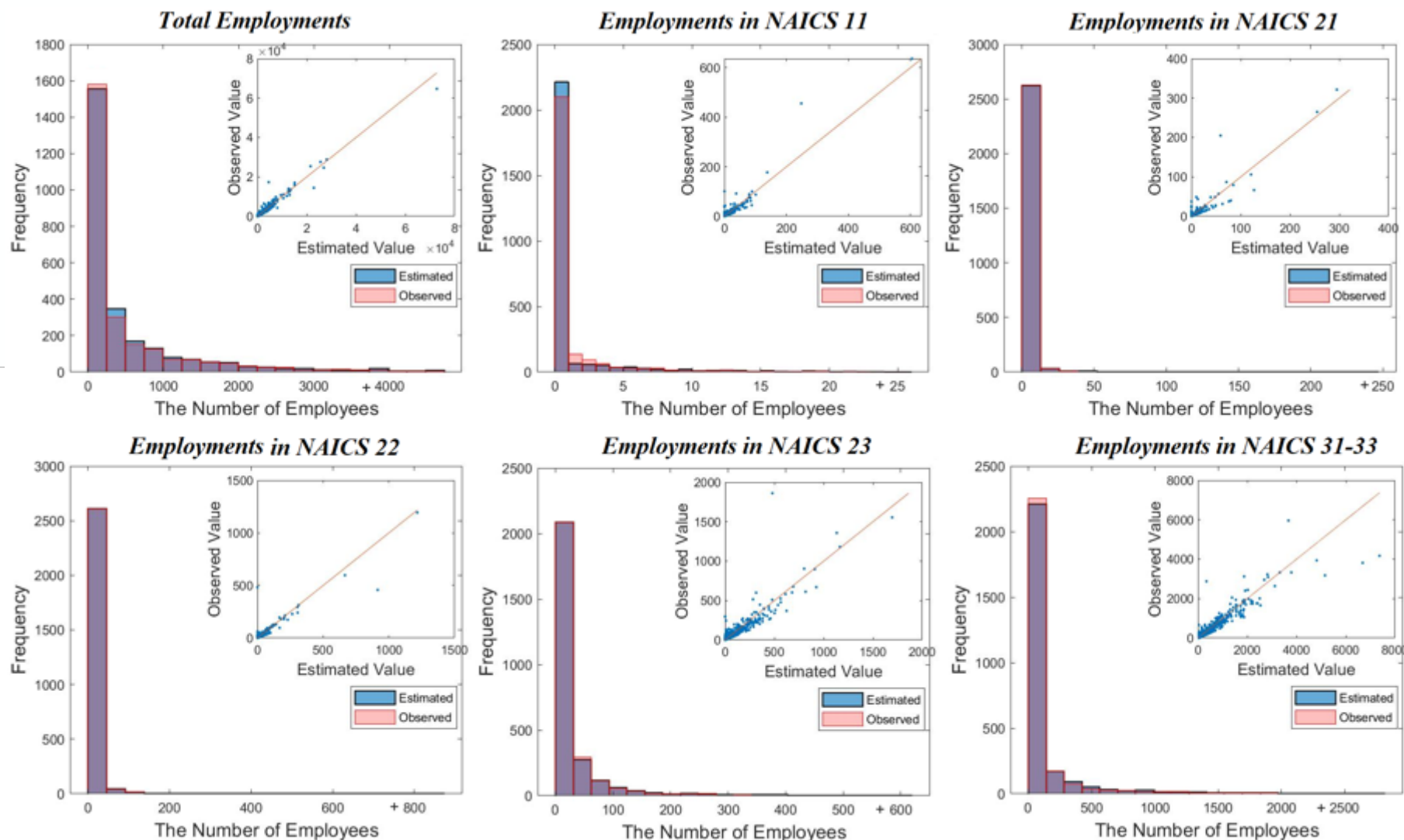
Histogram and Correlation Plot of estimated and observed for total employments, employment in NAICS 11, 21, 22, 23, and 31-33 in the year 2005
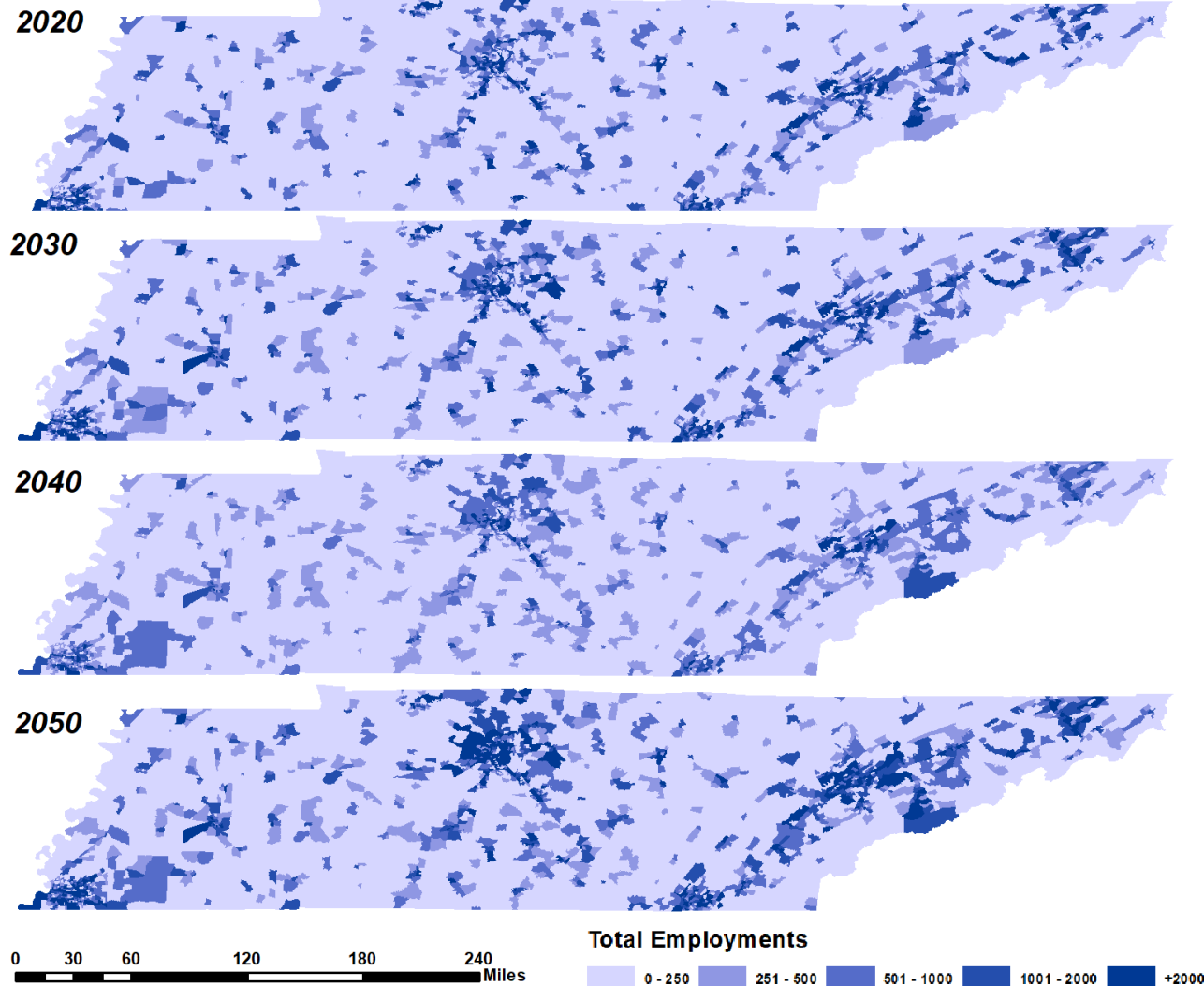
Model Backcasting Validation
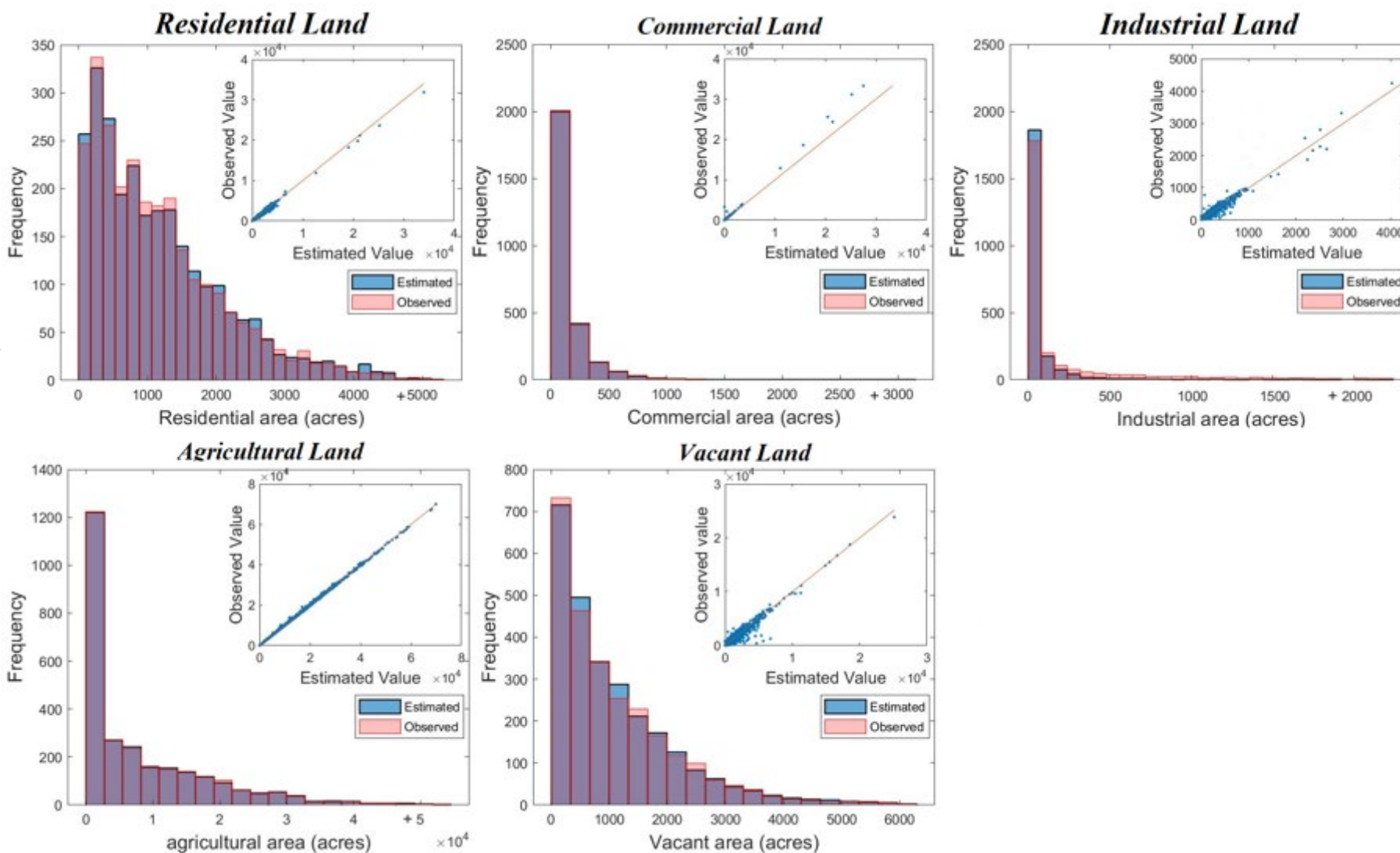
Histogram and Correlation Plot of estimated and observed for land use condition in five categories in the year 2005

Forecasted Values for Future Years
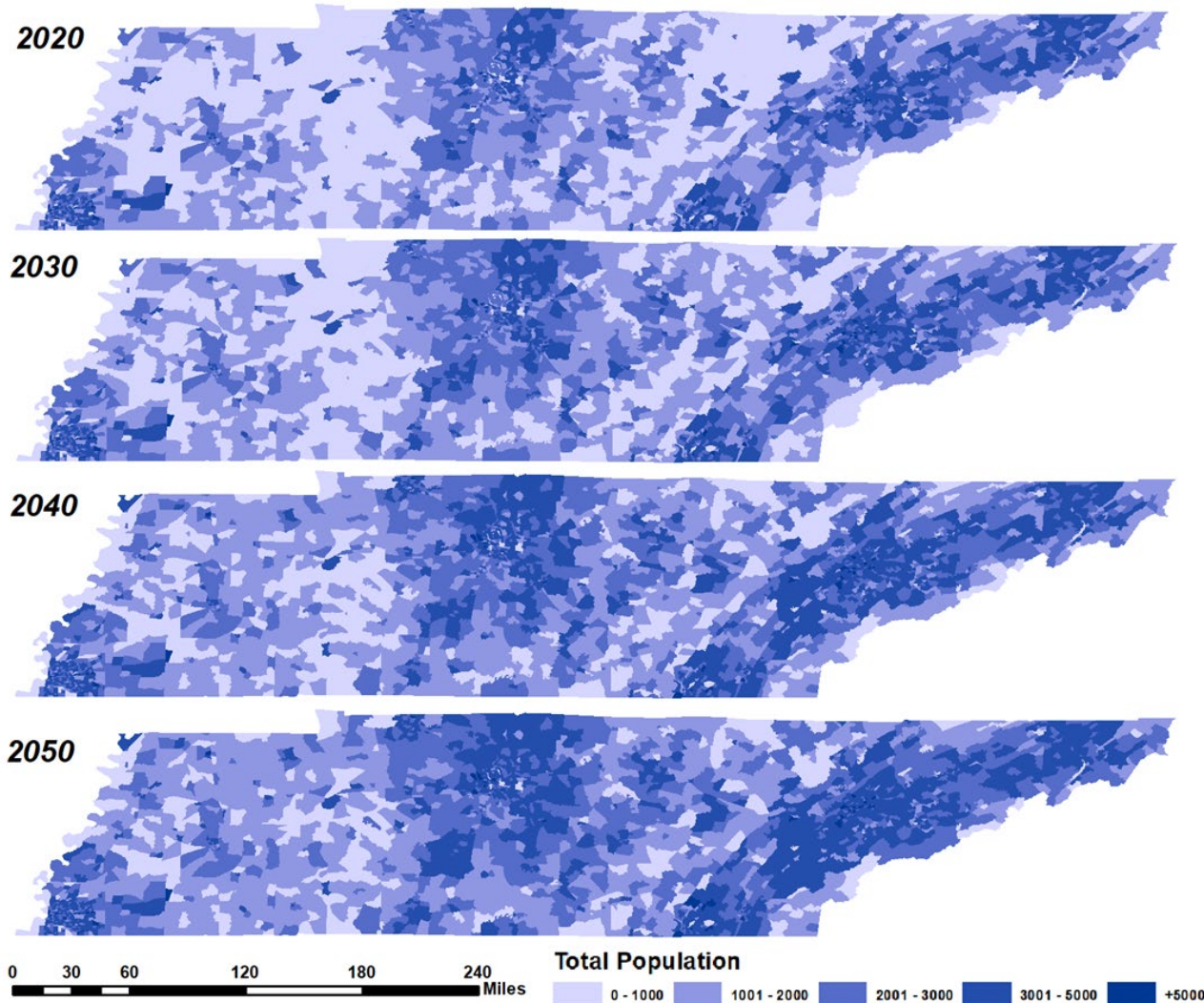
The forecasted total population form year 2020 to 2050

Forecasted Values for Future Years

2020

2030

2040

2050

Total Employments

0 - 250   251 - 500   501 - 1000   1001 - 2000   +2000

0 30 60 120 180 240 Miles

- The forecasted total employment form year 2020 to 2050

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Section 2

THE ON-LINE DASHBOARD

Online Dashboard

Online dashboard address: https://arcg.is/0fTO0H
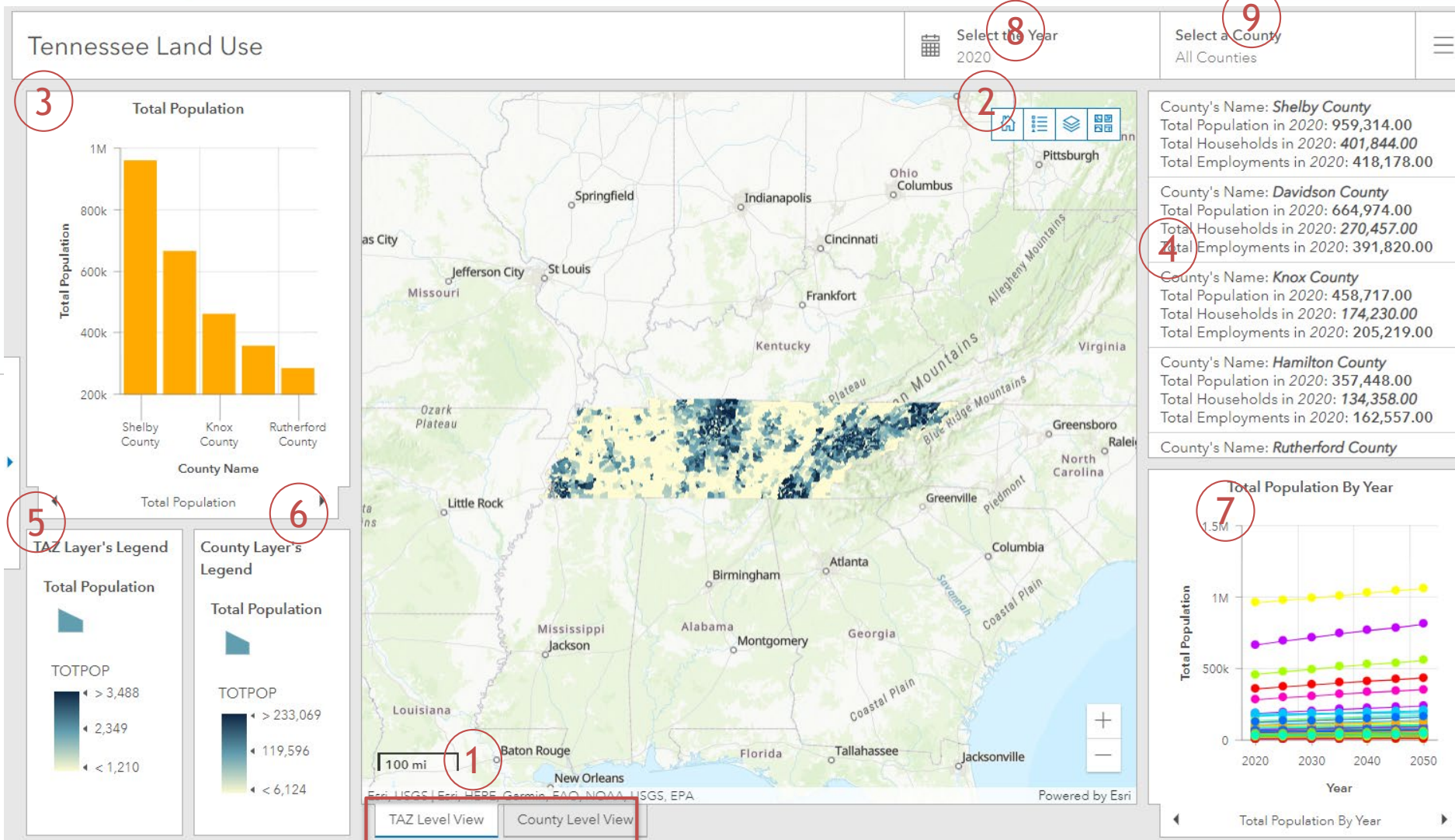
Online Dashboard Sections:
1. Navigation Tab
   - Transmitting between geographic levels
2. Maps' extensions:
   - Base map switcher
   - Layer switcher
   - Legend
   - General view
3. Demographic and employments in county level
4. Counties' quick info
5. TAZ level map legend
6. County level map legend
7. Demographic and employments in counties level per year
8. Year selection
9. County selection

Online Dashboard
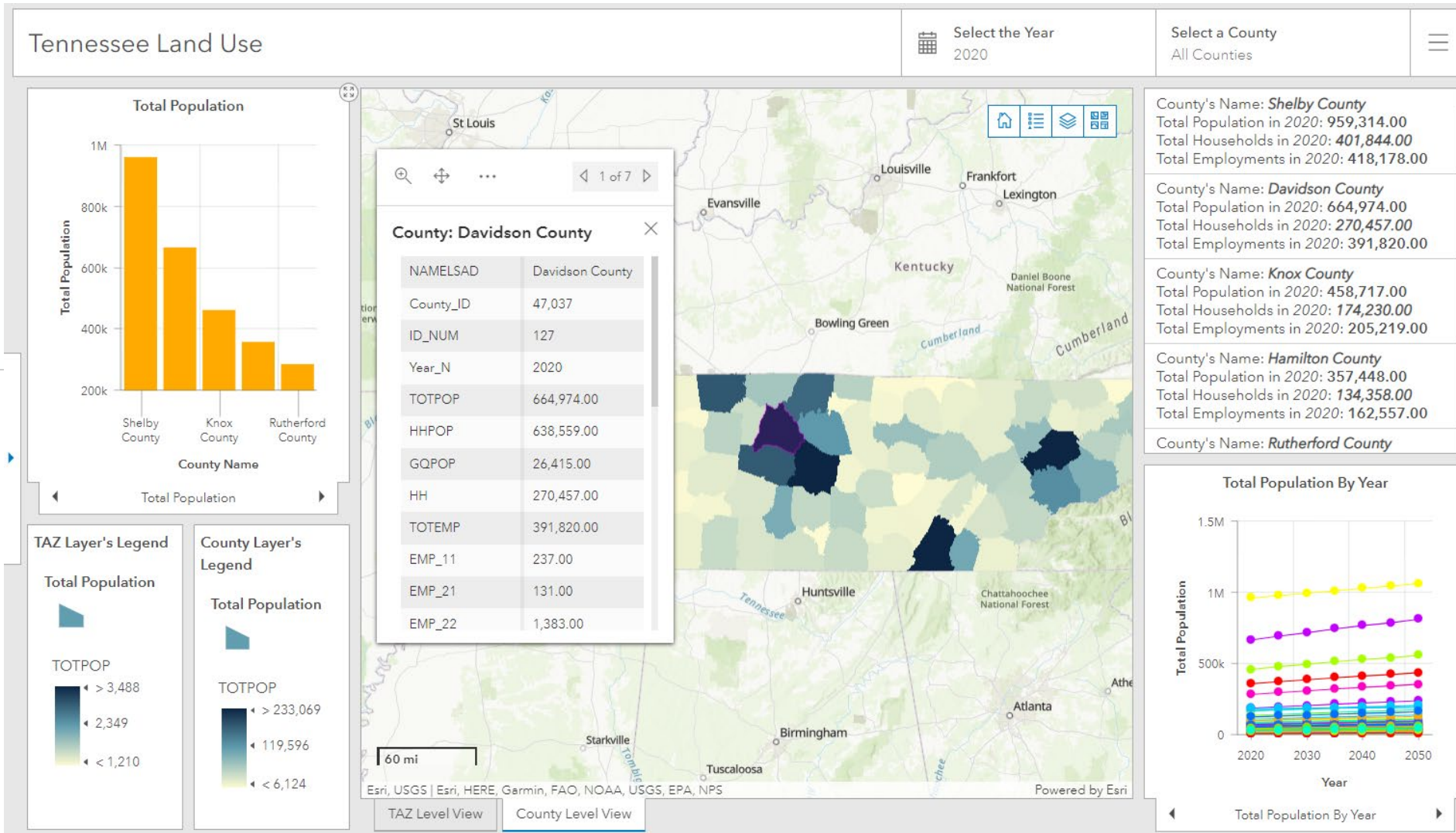
Presenting results in two geographic levels:
- County Level
- TAZ level

By clicking on each TAZ/County the information of the selected TAZ/ County will pop up

Online Dashboard
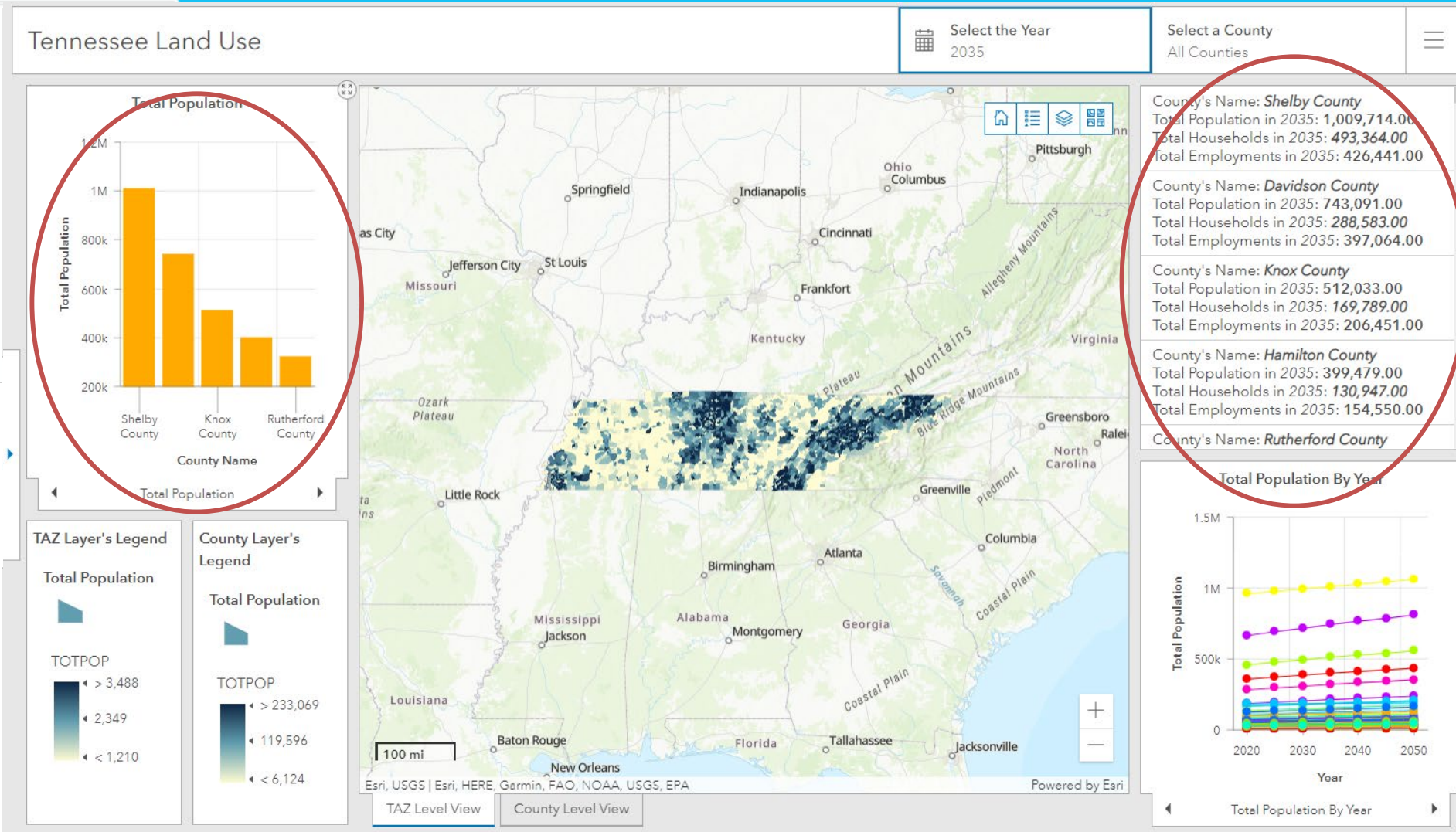
Forecasting Years:
- 2020
- 2025
- 2030
- 2035
- 2045
- 2050

It is possible to update the data and present new information (e.g., new year, new category)

Online Dashboard

Online dashboard address: https://arcg.is/0fTO0H

County-base category
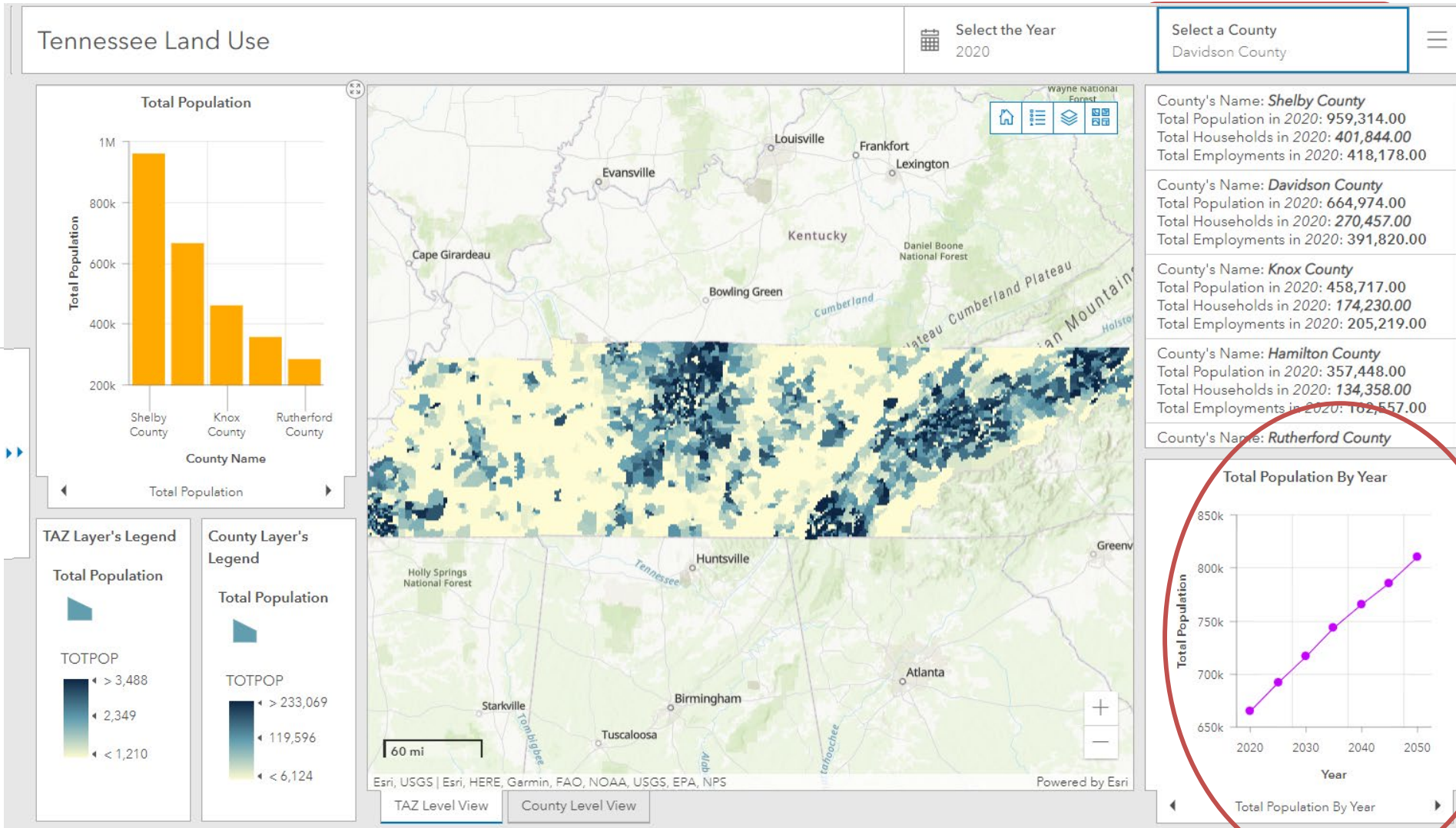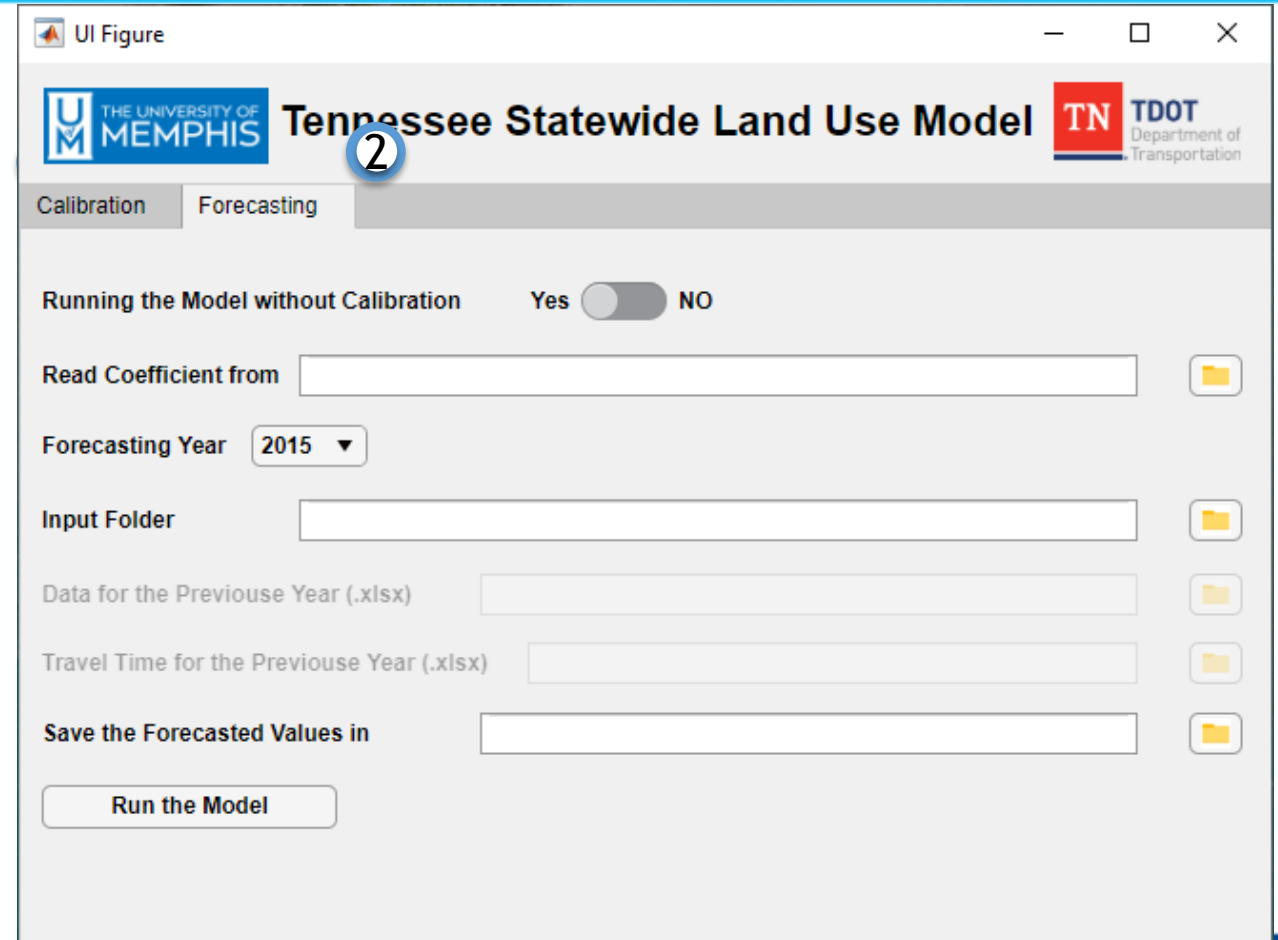
Selected county demographic and socio-economic info by year

Section 3

DEVELOPED SOFTWARE

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Software Demonstration

- The Software's GUI has two tabs:
  1. Calibration
  2. Forecasting
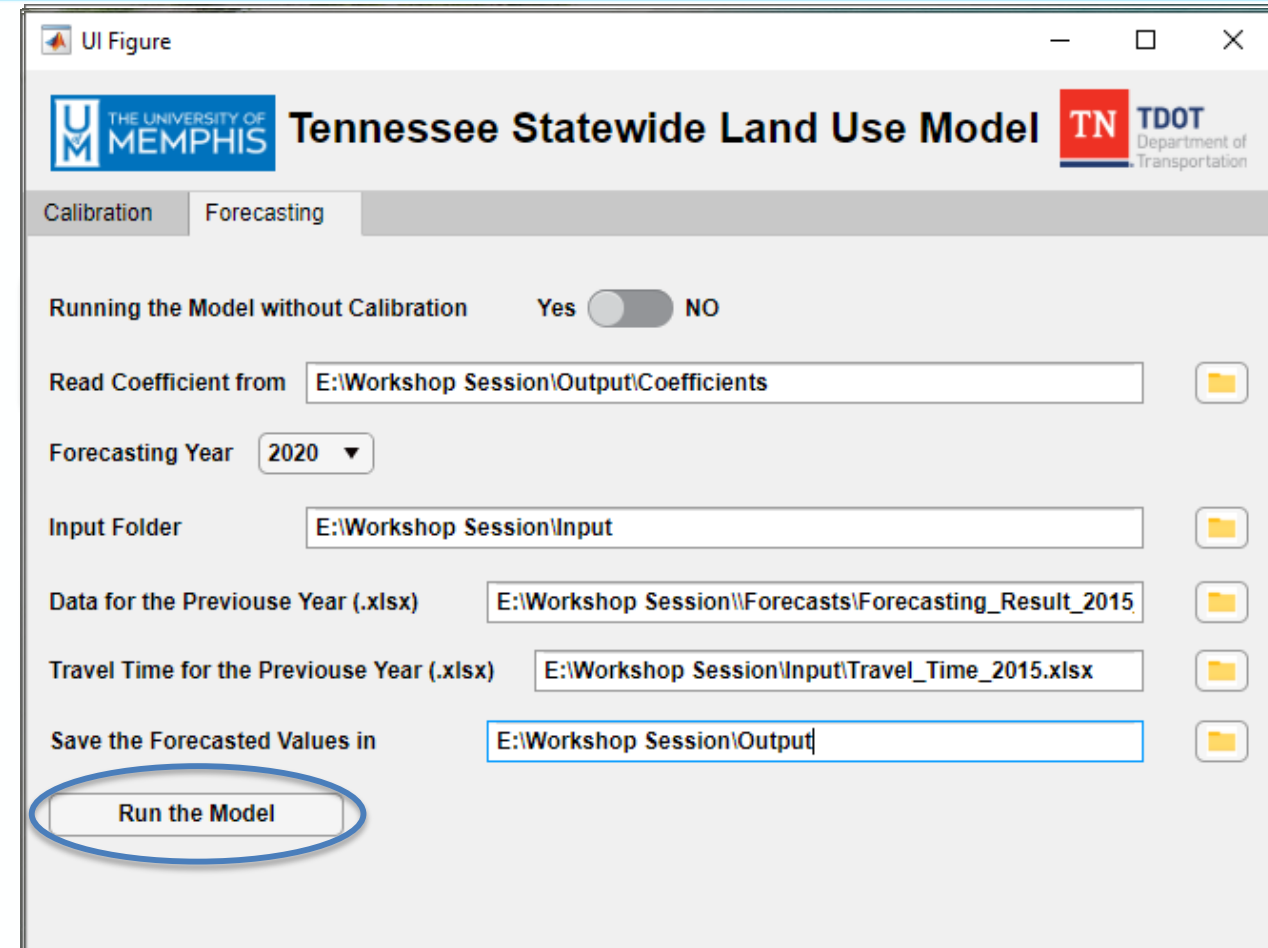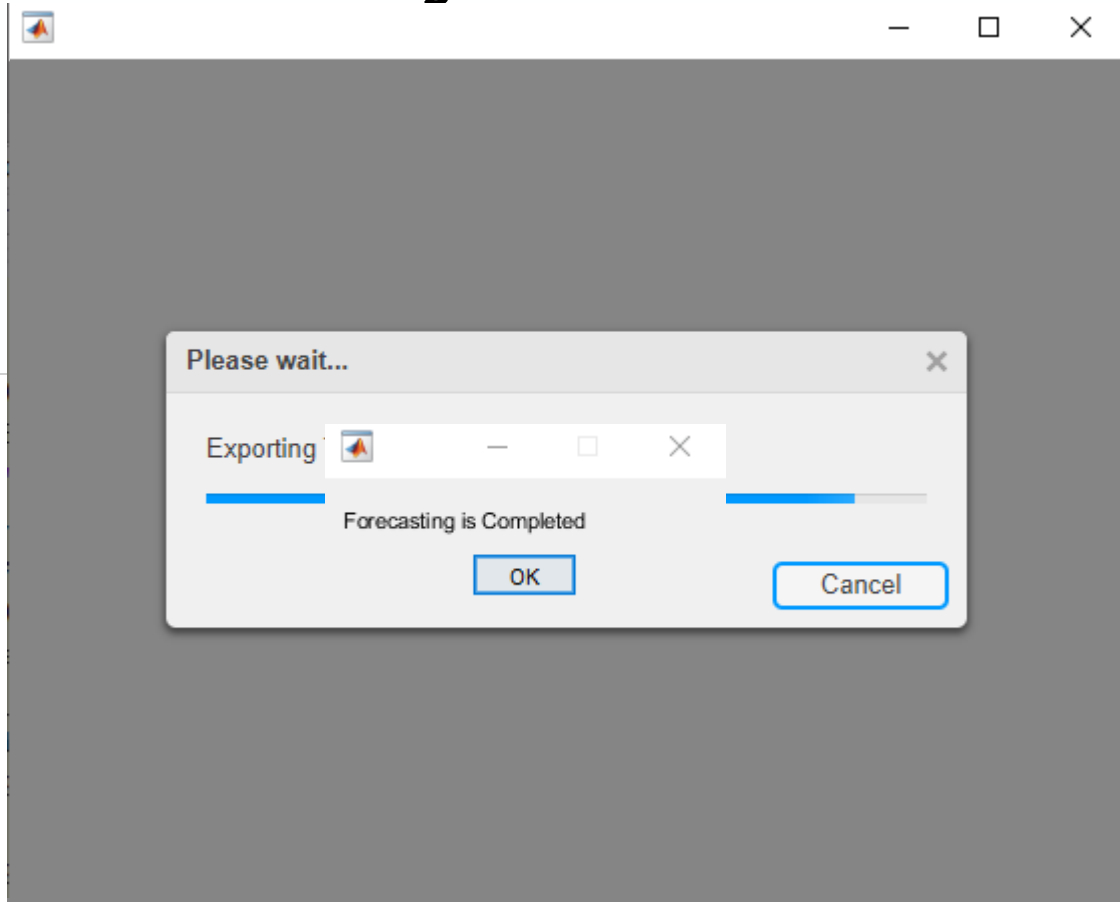- These two tabs work separately and can be executed independently.

Software Demonstration

- **Calibration**
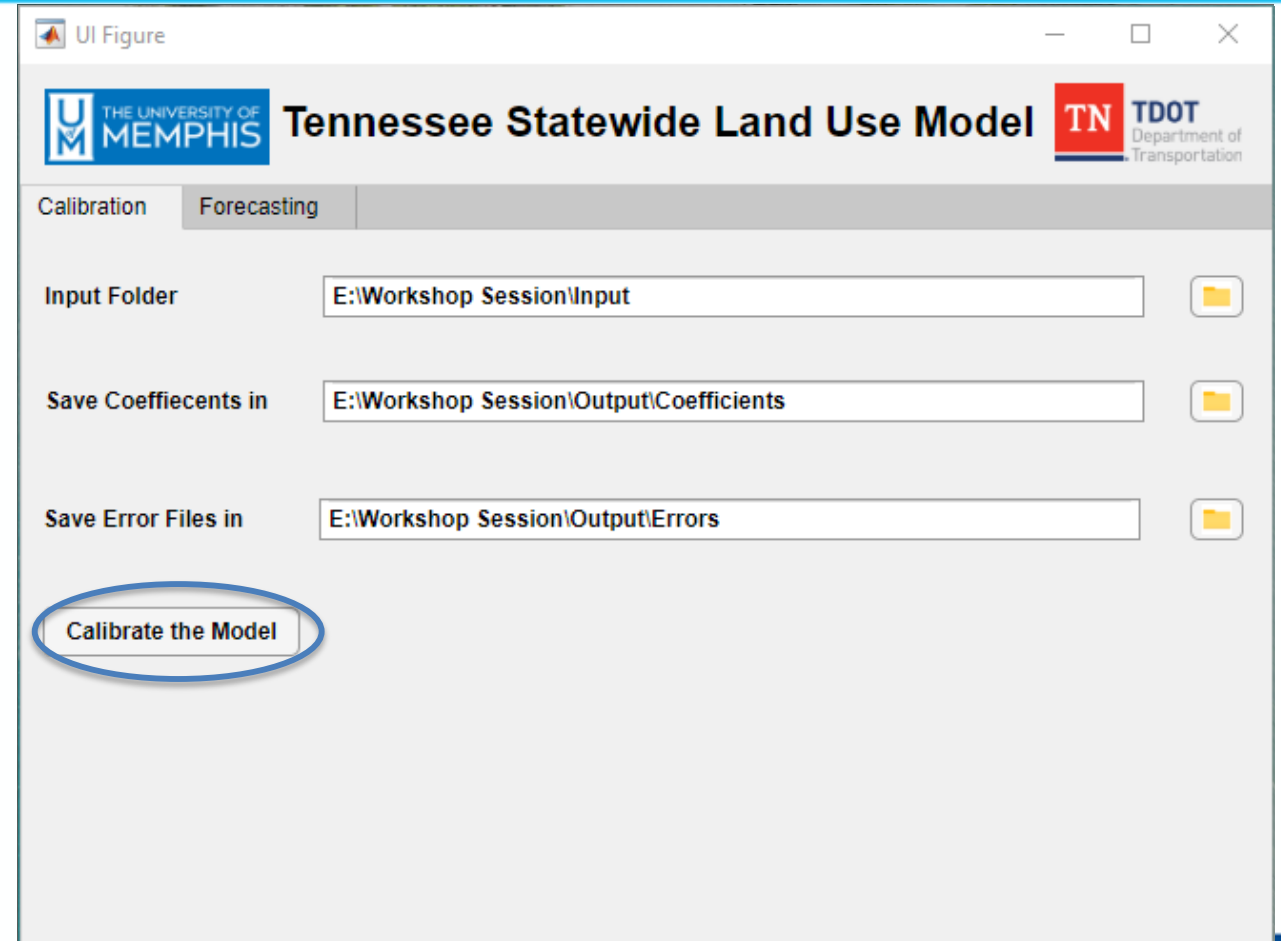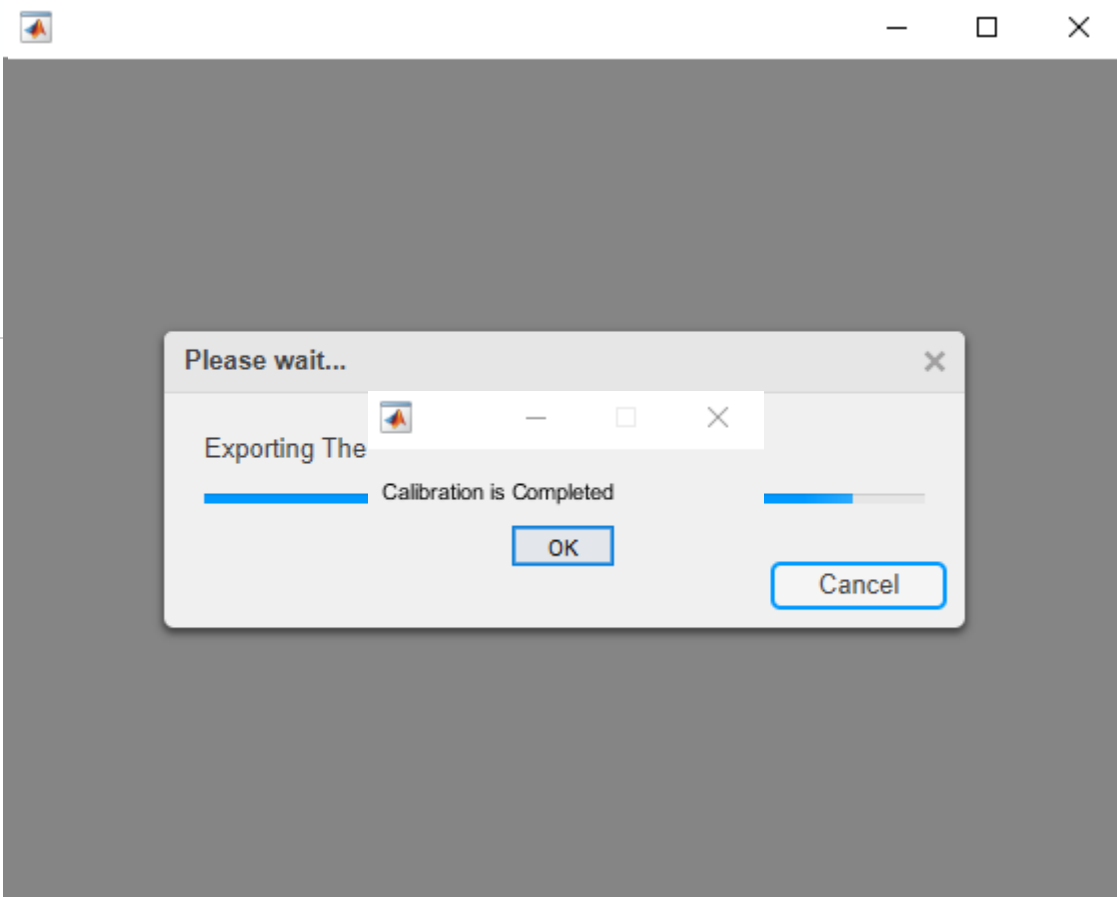
Software Demonstration

- **Forecasting**

Discussion

Thank you for your time

Q/A?

Contact:

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