Modelling Land Use Changes under Anthropocene

Urban Expansion and Tea Farm Transformation as Examples

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Motivation & Introduction

This study makes use of Conway's Game of Life to predict and simulate future land use changes, focusing on urban expansion and tea farm transformation. One simulation models urban expansion in Changhua over the next 20 years to explore the optimal location for convenience stores. Another study explores the most suitable development potential for the tea farm industry expansion in the Meishan area under the backdrop of changes in the fog belt, specifically in a scenario where atmospheric temperature rises by two degrees.

Methodology

Cellular Automaton (CA)

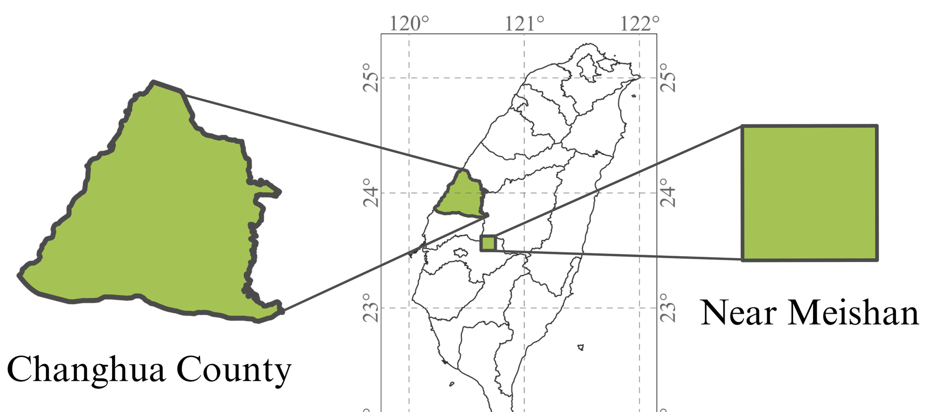
A cell's fate (alive or dead) in Conway's Game of Life is determined by the state of its eight immediate neighbors.

- A live cell with < 2 live neighbors → It dies
- A live cell with > 3 live neighbors → It dies
- A live cell with 2 or 3 live neighbors → It stays alive
- A dead cell with exactly 3 live neighbors → It becomes a live cell

NW	N	NE
W	Cell	E
SW	S	SE

Workflow1

1.1 Data Pre-processing → 1.2 Validation → 1.3 CA Simulation → 1.4 Prediction



Workflow2

2.1 Data Processing (Regrid → Subset) → 2.2 Modeling (Calibration → Simulation)

Data Pre-processing

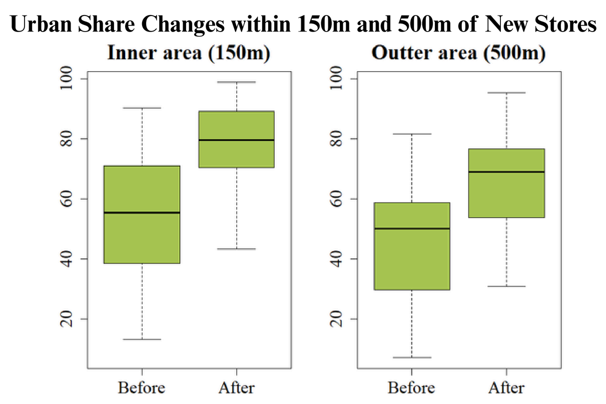
2013 & 2023 Land Use Maps[1]: 6m resolution

Collect data on convenience stores in Changhua and analyze urban expansion around the new store.

Found the growth pattern:

- Within 150 m: urban share rose from ~50% to ~80%.
- Within 500 m: urban share rose from ~50% to ~70%.

These empirical growth rates guided model zonal caps (≤150 m + 30%, 150-500 m + 20%)



Validation

From 2013 land-use, we simulated 10 years with CA and compared the 2023 result with observed data at pixel level. Using **Precision**, **Recall**, and their harmonic mean, **F1-score.** Across all sites, the median F1 is 0.82, indicating good agreement between simulation and reality.

Precision: TP/(TP+FP); Recall: TP/(TP+FN); F1 = 2PR / (P+R); TP (green), FP (blue), and FN (red).

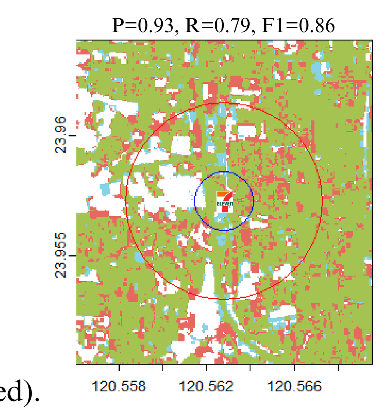


Figure 1. Validation 2013→2023

CA Simulation

Starting from 2023 land-use, a 20-step CA projects urban growth to 2043. Each year uses Conway's CA for candidate cells, distance-weighted probabilities, and zonal caps (150 m + 30%, 500 m + 20%).

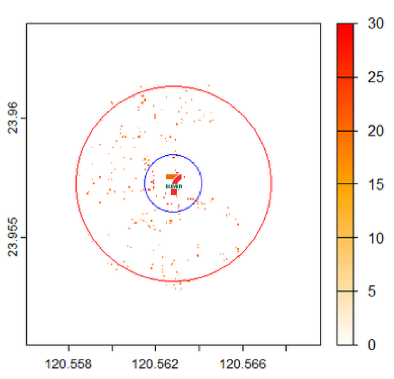
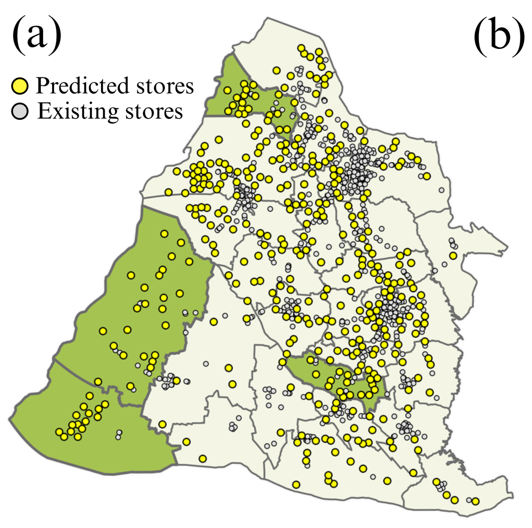


Figure 2. Projected urban growth 2023→2043

Prediction

Using road-network intersections as candidate sites, simulated 20-year urban growth to identify where new stores may promote expansion. For each township, the number of predicted new stores was compared to existing ones, and the ratio (new/existing) was used to rank areas by future accessibility improvement.

(a)



(b)

District	Existing stores	Predicted stores	Ratio	County Avg. (Stores)
Dacheng	3	15	5	29.85
Xianxi	7	20	2.86	29.85
Tianwei	8	16	2	29.85
Fangyuan	13	24	1.85	29.85
⋮				

Figure 3. (a) Predicted new store sites from network-based (b) Township-level ratios of new vs. existing stores

Data Processing

- 2018 & 2021 Land Use Maps[1]: 6m resolution
- Fog Frequency Maps[2] and Yearly Rainfall Maps[3] (2018): Derived from 2km maps, regridded to 6m resolution, and then clipped to the study area.
- Climate Data: Simulated fog data under climate change scenarios (2018 + 2°C increase in temperature).

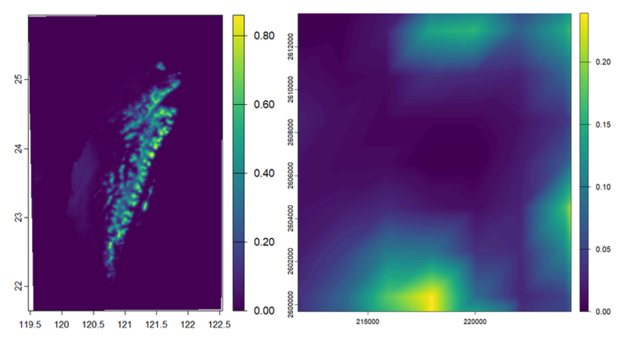


Figure 4. Fog Occurrence. Regridding 2km data to 6m for the study area.

Modeling

$$\text{Suitability Score} = \begin{array}{l}(\text{influence}\times[(\text{rain weight}\times\text{Normalized Rainfall})+\\ ((1-\text{rain weight})\times\text{Normalized Fog})])+\\ ((1-\text{influence})\times\text{Random Noise})\end{array}$$

Using 2018 fog and rainfall data to find good-fit parameters for a model calibrated from 2018 to 2021. The good-fit parameters are then applied to the simulation formula, with 2018 as the starting point. The input is changed to fog data under a climate change scenario (2018 + 2°C increase in temperature), while the 2018 rainfall data is kept as a control variable.

The selected two Kappa scores both achieved with influence of 0.75 and threshold of 0.9:

	Rain Weight	Kappa	Tea Plantation Growth without Climate Change	Tea Plantation Growth with Climate Change
A.	0.5	0.898	16	6
B.	0.75	0.898	5	3

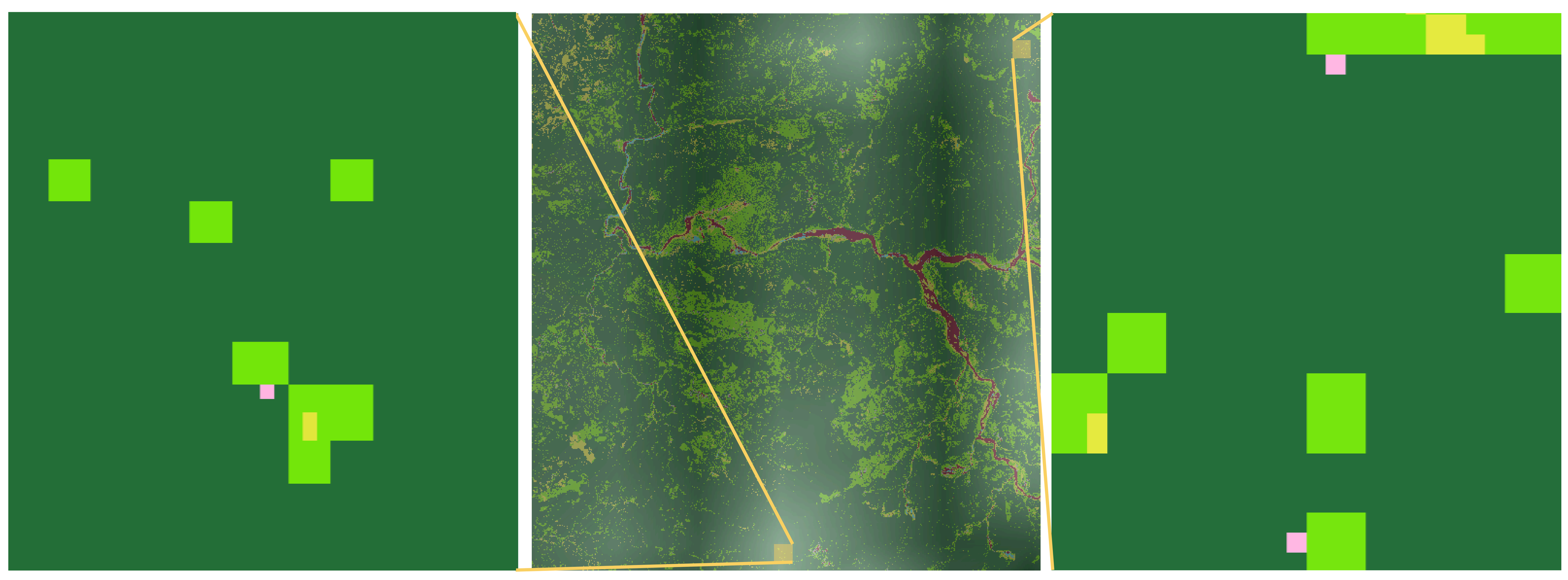


Figure 5. Simulated results of potential tea farm locations, with Group B serving as a representative example under a 2°C temperature increased climate change scenario.

Acknowledgement & Reference

The data utilized in this study were provided by the lab of Prof. Y.-Y. Chen and I.-C. Tsai at the RCEC. The climate simulation grid data, including fog ratio (.nc files) for two climate experiment scenarios (WC15LU and PGW15LU), and annual land use data (.tif files), were obtained directly from our research lab. Additionally, monthly rainfall data in NetCDF format (2km resolution) were sourced from the TCCIP TReAD V1 archive. We thank Prof. Y.Y. Chen for providing access to these valuable datasets and computational resources for this work.

[1] Lin et al. Environ Monit Assess. 2024; [2] Chen et al. JGR-Atmos. 2025; [3] TCCIP TreAd Dataset v1. 2021.

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