

Monitoring Informal Settlement Growth on Agricultural Land Using Urban Dynamics Analysis

Implications for Land Management and Future Urban Development

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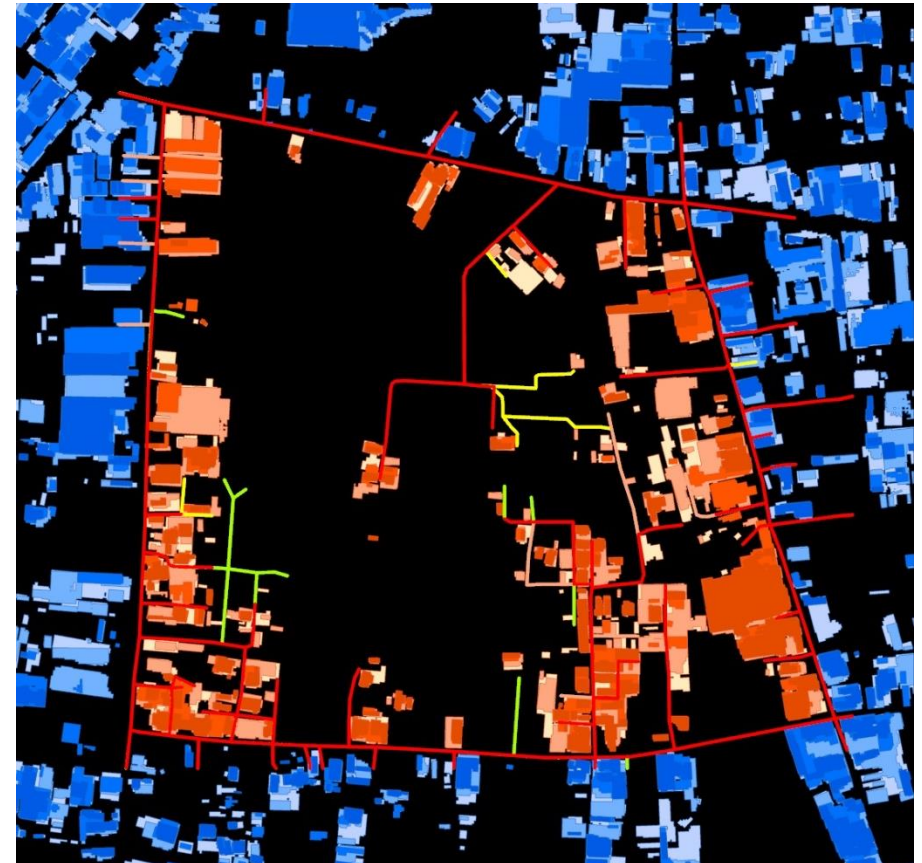
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Land for housing development: challenges from informal settlement growth in peri-urban areas

Housing needs

HCMC's population rose from 3.9 million in 1989 to nearly 9 million in 2019 and 9,7 millions in 2025

Rural and Peri-urban land conversion

Incremental settlement growth can complicate future land assembly and infrastructure provision.

Monitoring capacity

Limited staffing, technical expertise and incomplete records constrain systematic monitoring.

Research opportunity

Accessible imagery and historical networks support early screening and field verification.

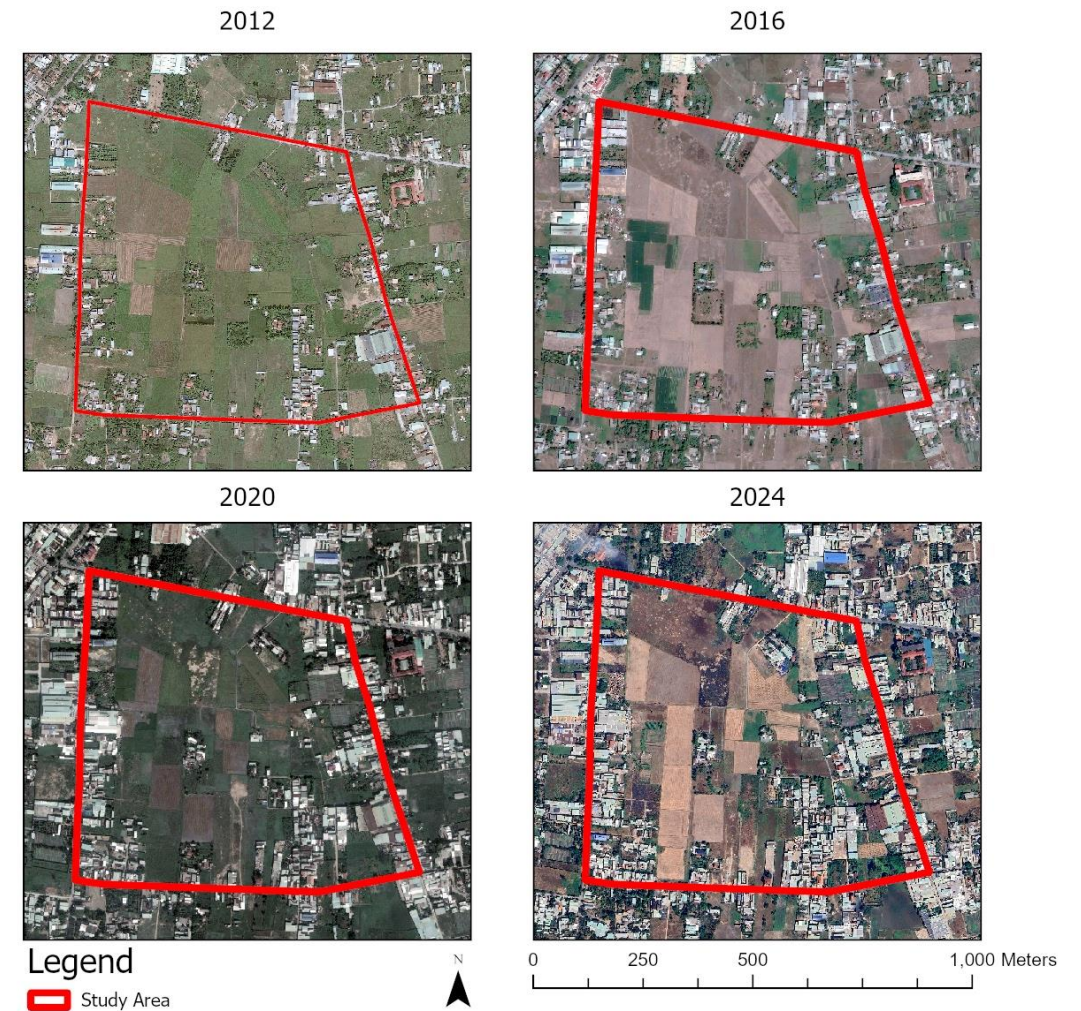


Fig 1. Agricultural land conversion in Tan Vinh Loc between 2012 and 2024

Research questions and contribution

UDA (*notes below*) will be applied in an area in Tan Vinh Loc commune to address the following research questions:

1. How did building patterns and access networks evolve within the agricultural study area in Tan Vinh Loc between 2012 and 2024?
2. How can building extraction, change detection, and network analysis be integrated into a workflow designed to support monitoring by non-specialist local government personnel?
3. How can the resulting spatial evidence support local government monitoring of land conversion?

Notes: **Urban Dynamics Analysis (UDA)** is an ArcGIS Pro add-in developed to support monitoring informal settlement developments. It combines building extraction, change detection and circulation network analysis in an ArcGIS Pro add-in designed for non-specialist users.

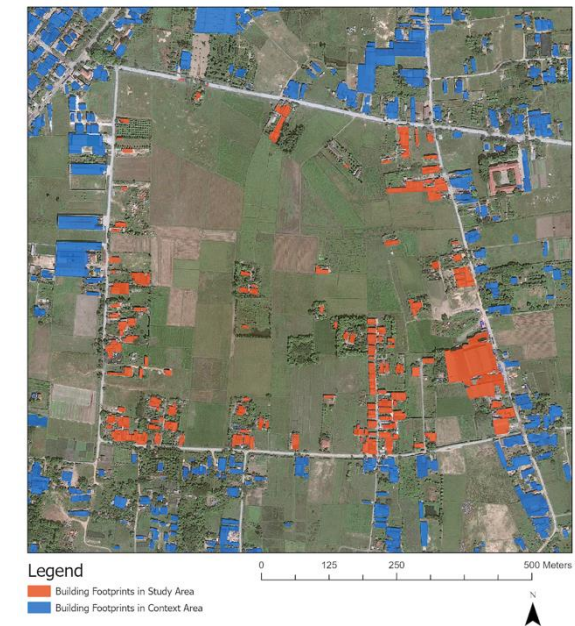
Study area



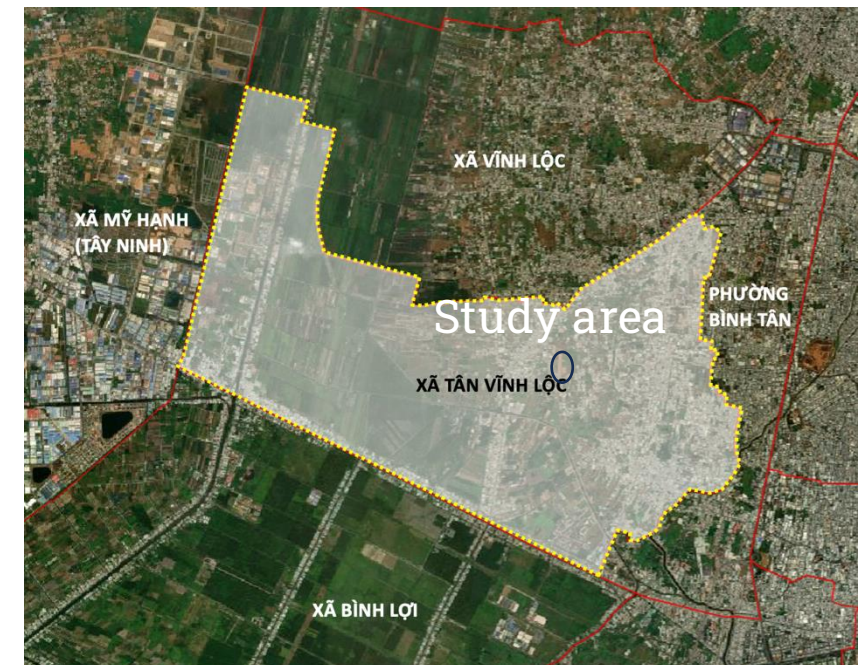
Fig 2. Research area

An area within Tan Vinh Loc commune Ho Chi Minh City
Approximately 45 ha in former Binh Chanh District.

Up to 2025, the study area is not effectively covered by urban
and rural plans



Study area surrounded by context area



Integrated analytical workflow

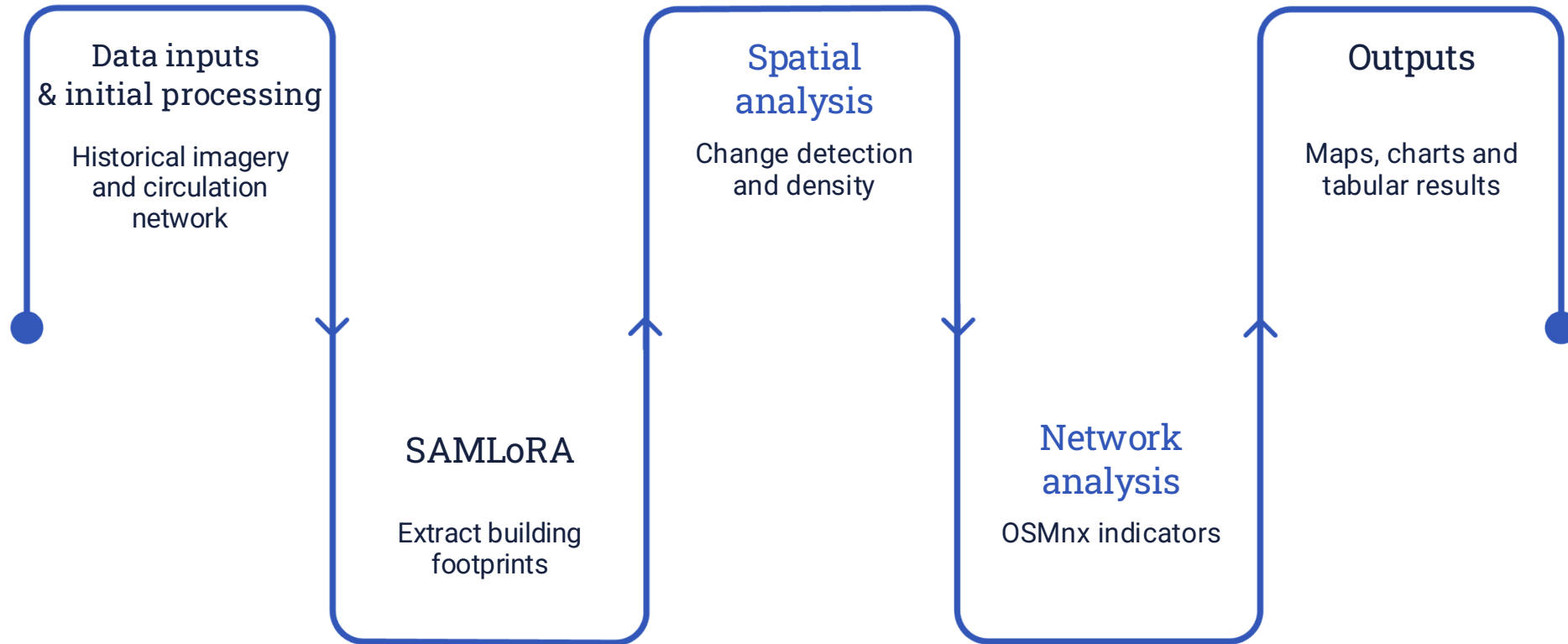


Fig 3. Analytical workflow

Compare the Study Area (SA) with the surrounding Context Area (CA) within the full Analysis Area (AA – 100ha). Examine intensification, network connectedness and the spatial relationship between buildings and routes.

SAMLoRA: Segment Anything Model (SAM) with set of trainable layers called Low-Rank Adaption (LoRA)

UDA system architecture

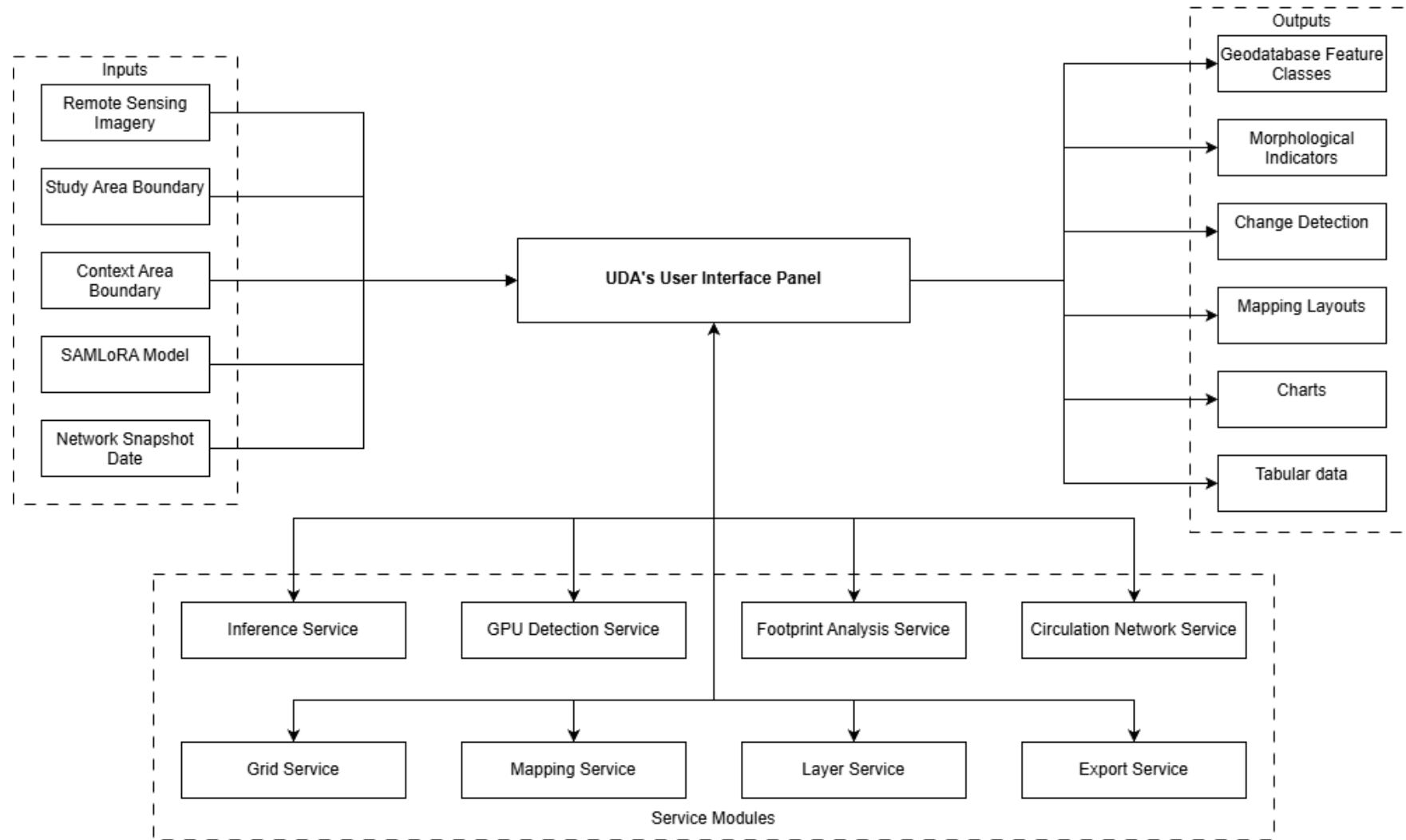


Fig 4. System architecture of UDA

Input data: remote sensing imagery

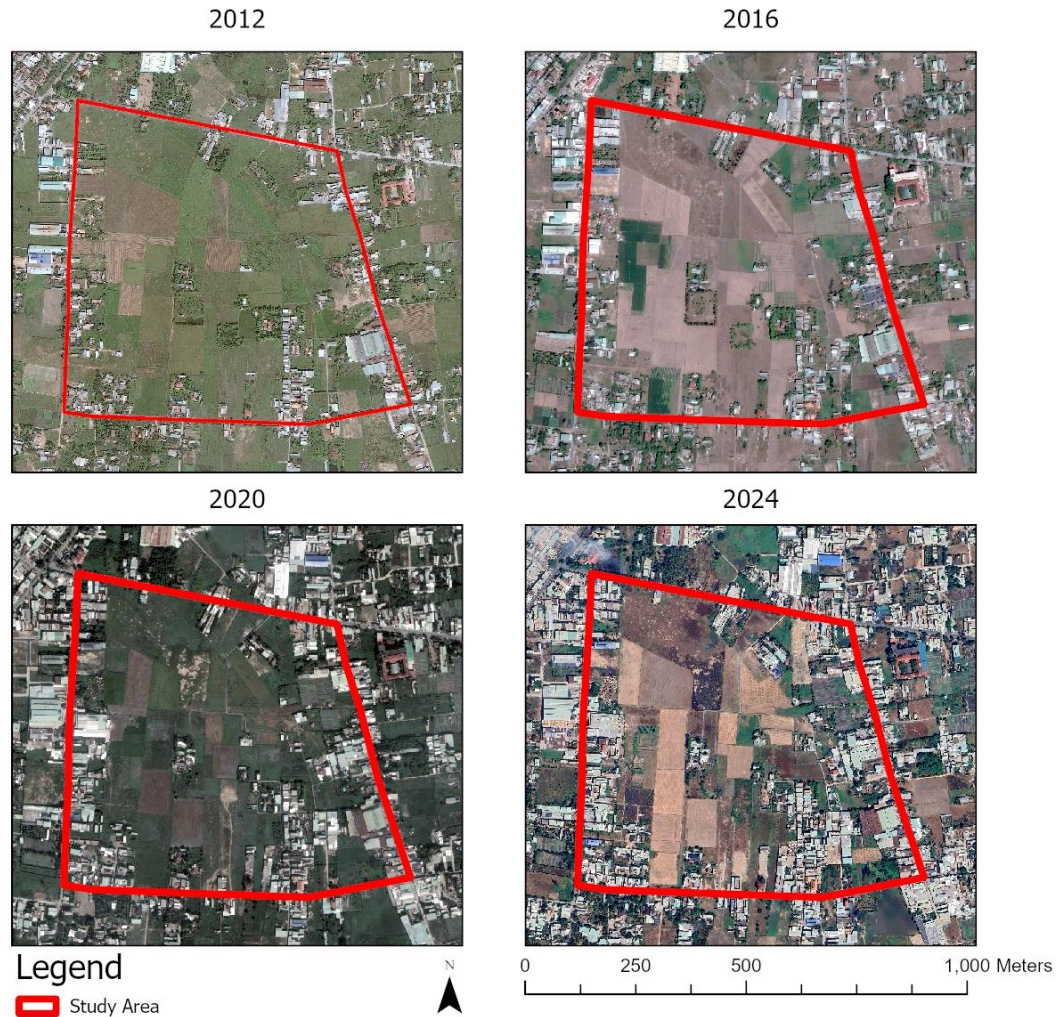


Fig 5. Google Earth remote sensing images of the study area in 2012, 2016, 2020, and 2024

Four observation dates

Dec 1, 2012

Feb 27, 2016

Dec 28, 2020

Feb 28, 2024

Data source: Google Earth

Input data: circulation data (road and alleyway network)

The ohsome API (HeiGIT, n.d.) retrieves historical OSM circulation network for the four observation dates. Early snapshots contain missing roads, particularly in 2012 and 2016. Network preparation addresses missing routes and features outside the study boundary before analysis.

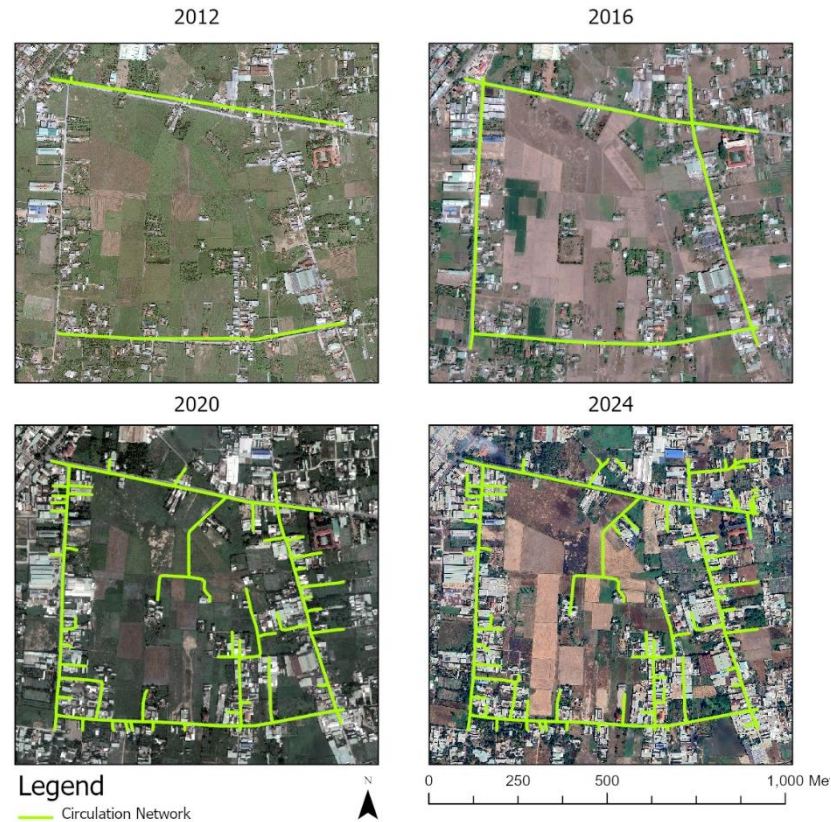


Fig 6. Downloaded OSM networks

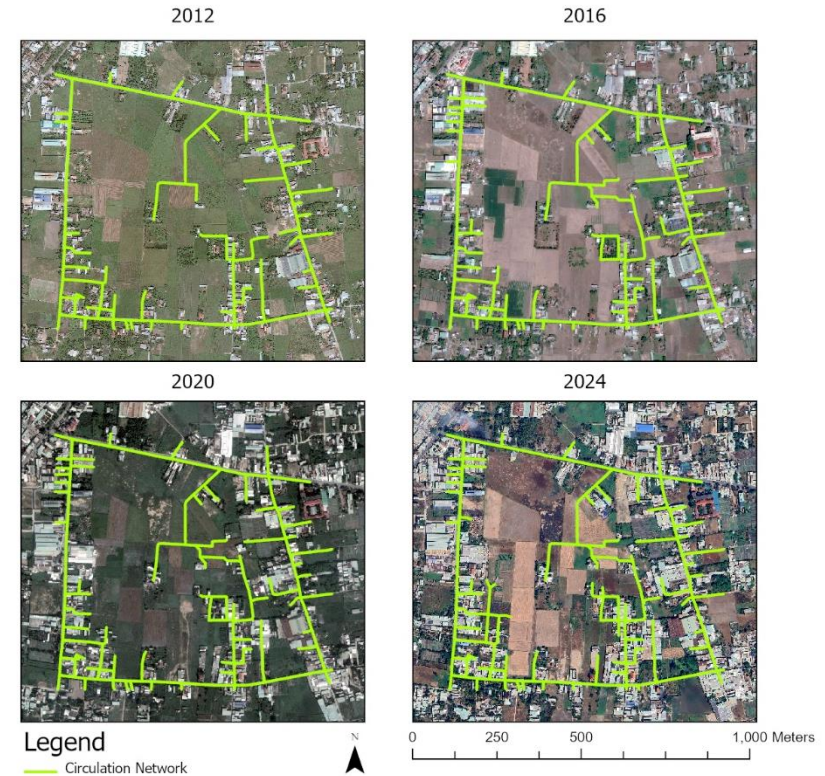
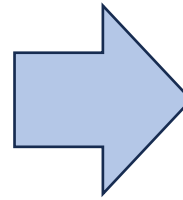


Fig 7. Processed networks

Semantic segmentation model: fine-tuned SAMLoRA

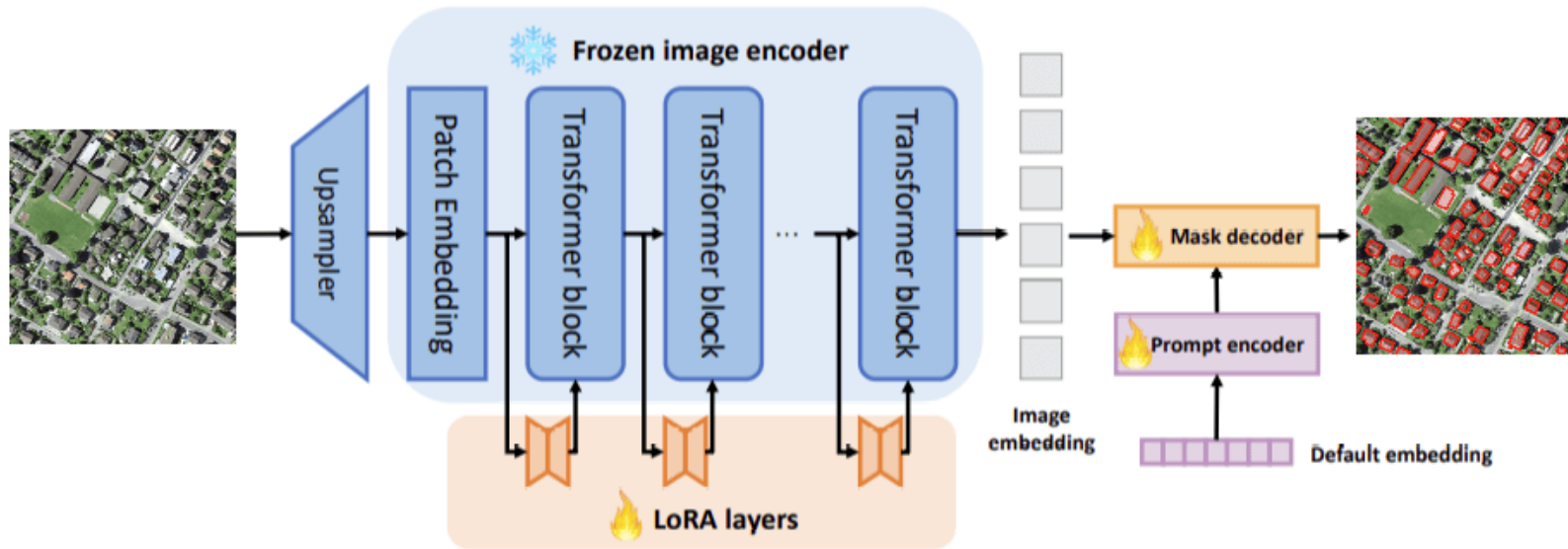


Fig 8. SAMLoRA architecture (Hooey & Tuteja, 2024)

Initial model: Building Footprint Extraction-India.

Local fine-tuning uses 185 chips from the 2024 Google Earth mosaic.

- Training: 130 chips (70%).
- Validation: 55 chips (30%).

Building footprint indicators:

- Building footprint area within the analysis area (BFA)
- Building footprint area within the study area (BFS)
- Building footprint area within the context area (BFC)
- Building density of the analysis area (BDA)
- Building density of the study area (BDS)
- Building density of the context area (BDC)
- Annual building density change in the study area (BDCS)
- Annual building density change in the context area (BDCC)

Network analysis: OSMnx

OSMnx is an open-source tool that integrates OSM data acquisition with street network analysis and visualization. It provides an easy, consistent, scalable, and automatable method to analyze street networks in any area in the world

Circulation network indicators:

- Nodes
- Edges
- Average node degree
- Intersection
- Clean intersection
- Street segment
- Node density (per sq km)
- Intersection density (per sq km)
- Clean intersection density (per sq km)
- Edge length (m)
- Average edge length (m)
- Edge density (m/sq km)
- Street length (m)
- Average street length (m)
- Street density (m/sq km)
- Average streets-per-node

User interface: five sequential tabs

1. Study Area Setup

Define input datasets.

2. Download Historical OSM Data

Select observation dates and retrieve network data.

3. Building Footprint Extraction

Configure imagery and execute model inference.

4. Analysis Tools

Calculate building and network indicators.

5. Results

Review charts and export tabular results.

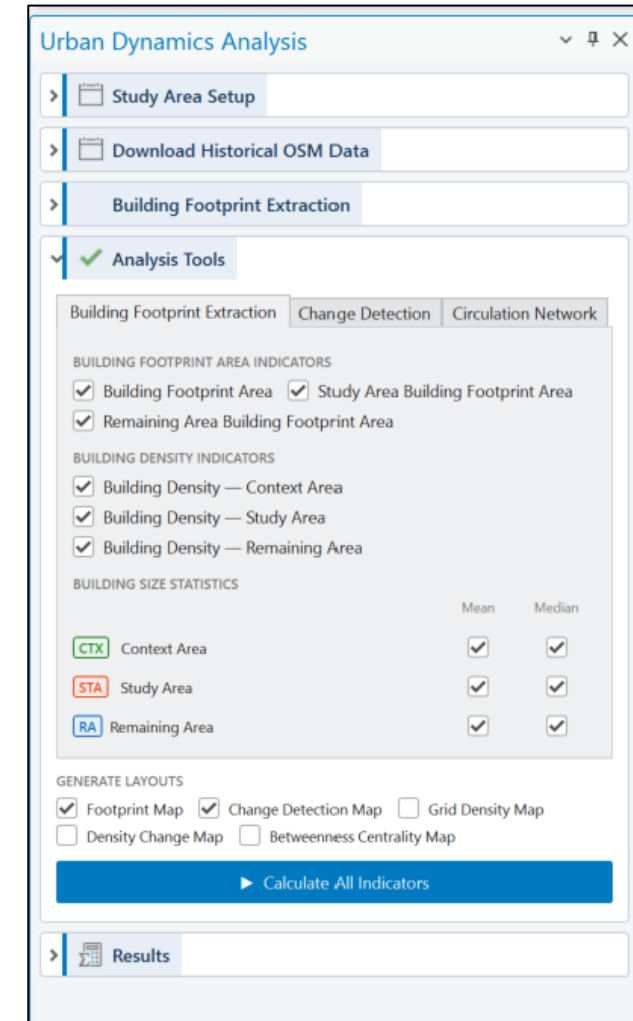
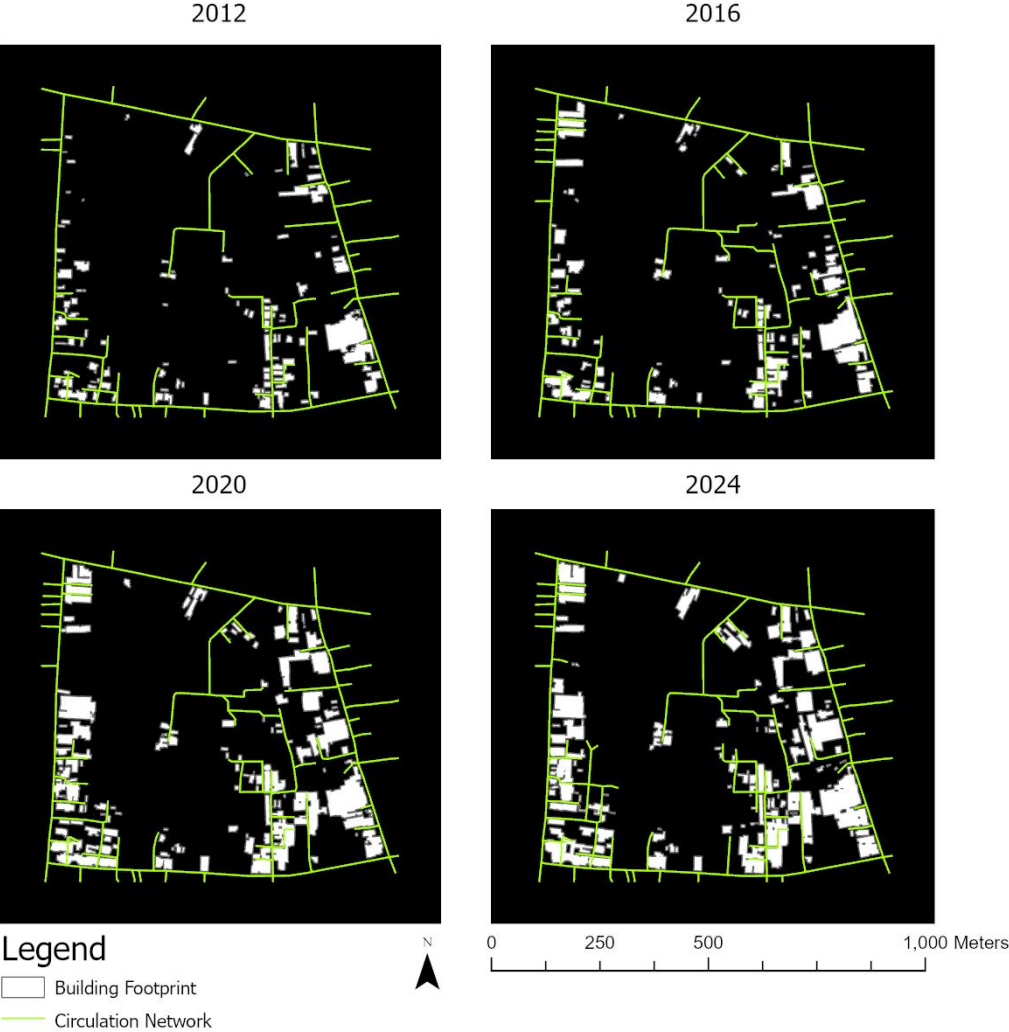


Fig 9. UDA user interface

SAMLoRA model validation



93.27%

Reported overall pixel accuracy

0.8827

Precision

0.9905

Recall

Fig 10. Buildings and circulation networks, 2012–2024.

Building growth and densification, 2012–2024

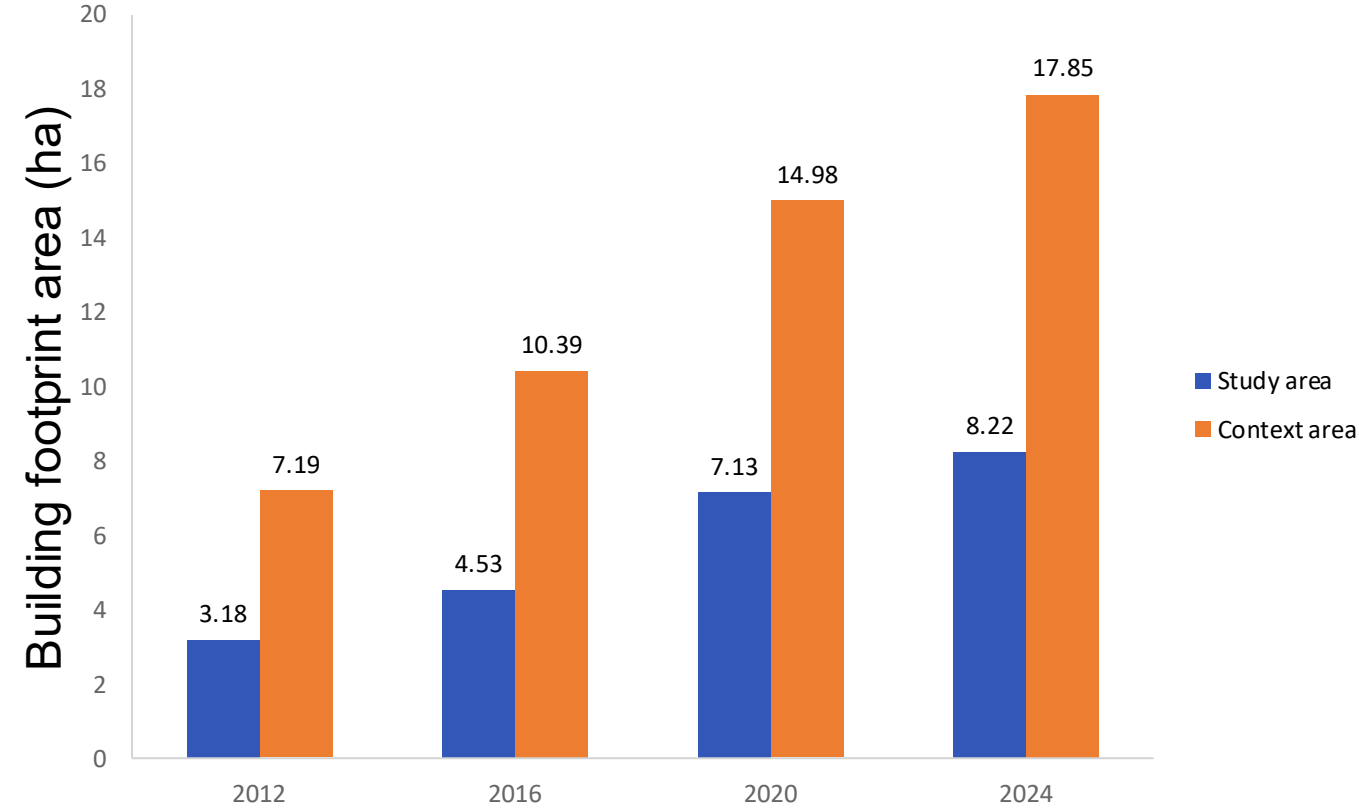


Fig 11. Building footprint area within the study area.

Study-area growth

Building footprint area increased from 3.18 to 8.22 ha, approximately 158%.

The largest increase occurred during 2016–2020.

Coverage densification

Study area: 7.4% to 19.0%.

Context area: 12.9% to 32.0%.

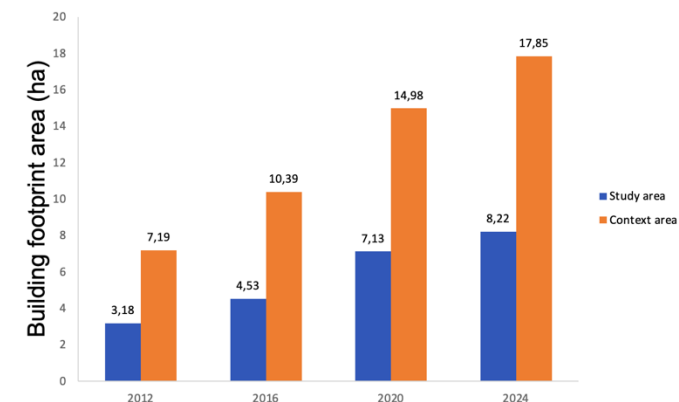
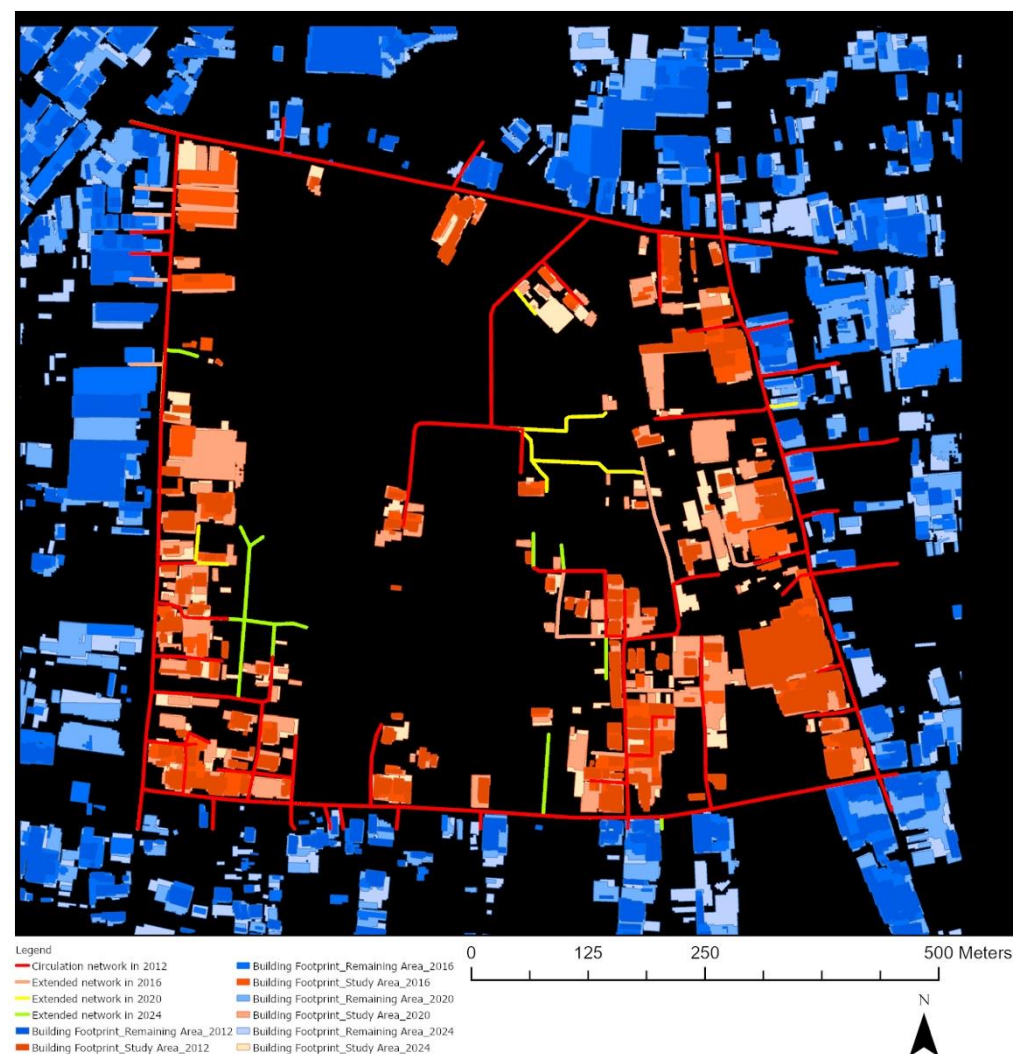
The densification within study area was relatively equal to the context area

Circulation network development

Indicator	2012	2016	2020	2024
Nodes	84	101	110	124
Edges	150	178	194	238
Average node degree	3.57	3.52	3.53	3.84
Intersection	39	43	46	60
Clean intersection	34	34	37	50
Street segment	75	89	97	119
Node density (per sq km)	194.28	233.60	254.41	286.79
Intersection density (per sq km)	90.20	99.45	106.39	138.77
Clean intersection density (per sq km)	78.64	78.64	85.57	115.64
Edge length (m)	10,499.19	11,905.25	12,694.44	13,709.19
Average edge length (m)	69.99	66.88	65.44	57.60
Edge density (m/sq km)	24,282.89	27,534.89	29,360.15	31,707.09
Street length (m)	5,249.59	5,952.63	6,347.22	6,854.59
Average street length (m)	69.99	66.88	65.44	57.60
Street density (m/sq km)	12,141.44	13,767.44	14,680.07	15,853.54
Average streets-per-node	1.79	1.76	1.76	1.92

Table 1. Circulation network indicators during research period

Building change and network co-evolution



2012–2016

Footprint area increased 42%, with growth around existing routes.

2016–2020

Fastest footprint growth: 58%. New clusters and access routes emerged.

2020–2024

Footprint growth slowed to 15%, while network connectedness increased.

Fig 12. Morphogenetic process during 2012-2024

Implications for land and housing policy

Early screening for effective management

Identify emerging building clusters and access routes, then prioritise field verification (for urban management related-tasks)

Future planning options

Use UDA outputs to assess where historical settlement development may inform planning, land compensation, land assembly and infrastructure provision.

Integrated evidences to inform decision-making

Combine UDA outputs with official planning documents, construction permit records and statutory plans before intervention.

Near real-time monitoring of urban development

The model can be applied for similar cases and tasks, providing a near real-time monitoring of land use and construction status, enabling the digitization of urban management and governance

Thank you

Urban Dynamics Analysis (UDA)

An integrated ArcGIS Pro workflow for monitoring urban change

Download: <https://arcg.is/z90e0>

Contact: vckien.arc@gmail.com