From Aerial Imagery to Official Statistics: Integrating Registry Data in Operational Deep Learning for Fine-Grained Built-Up Area Mapping in the Netherlands

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BACKGROUND

- Reliable land use information is essential for spatial planning, infrastructure monitoring, and environmental reporting.
- In the Netherlands, this is provided by the *Bestand Bodemgebruik (BBG)* dataset.
- BBG integrates registry data, topographic information, and aerial imagery, but its production remains **partly manual and resource-intensive**.
- Earth Observation (EO) and deep learning offer opportunities to **automate and scale land-use mapping workflows**.

OBJECTIVES

- Develop an operational deep learning framework to classify 14 built-up land use classes using high-resolution aerial imagery.
- Evaluate the added value of integrating registry-derived attributes to improve classification of functionally distinct but visually ambiguous classes.
- Produce parcel-linked raster predictions aggregated to official statistical reporting units for BBG production.

KEY TAKEAWAY

RGB-Only Pipeline	Multimodal Fusion Pipeline
64.3%	**65.8%**
Macro-averaged F1 score	Macro-averaged F1 score

Fusion improves transport classes (rail, metro/tram, main roads); RGB-only suffices for visually distinct land uses.

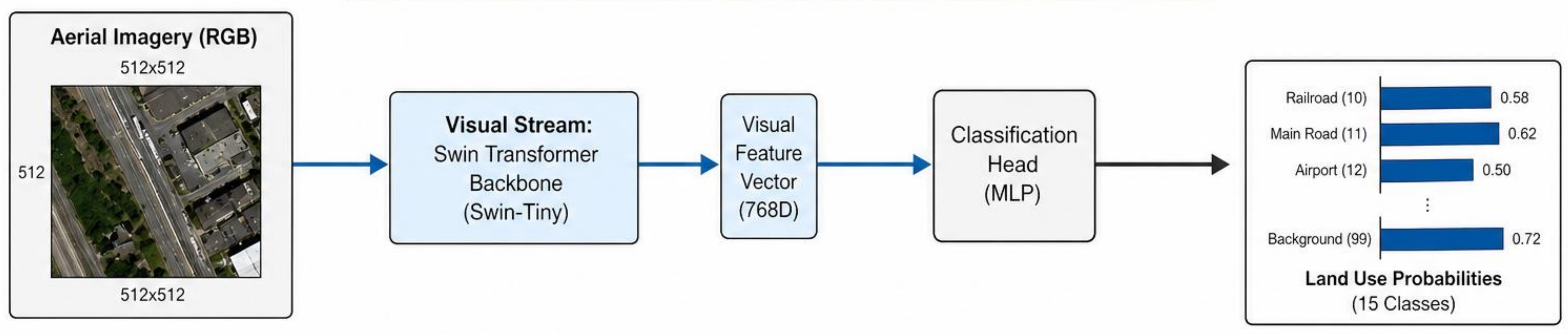
DATA

- **Study Area**

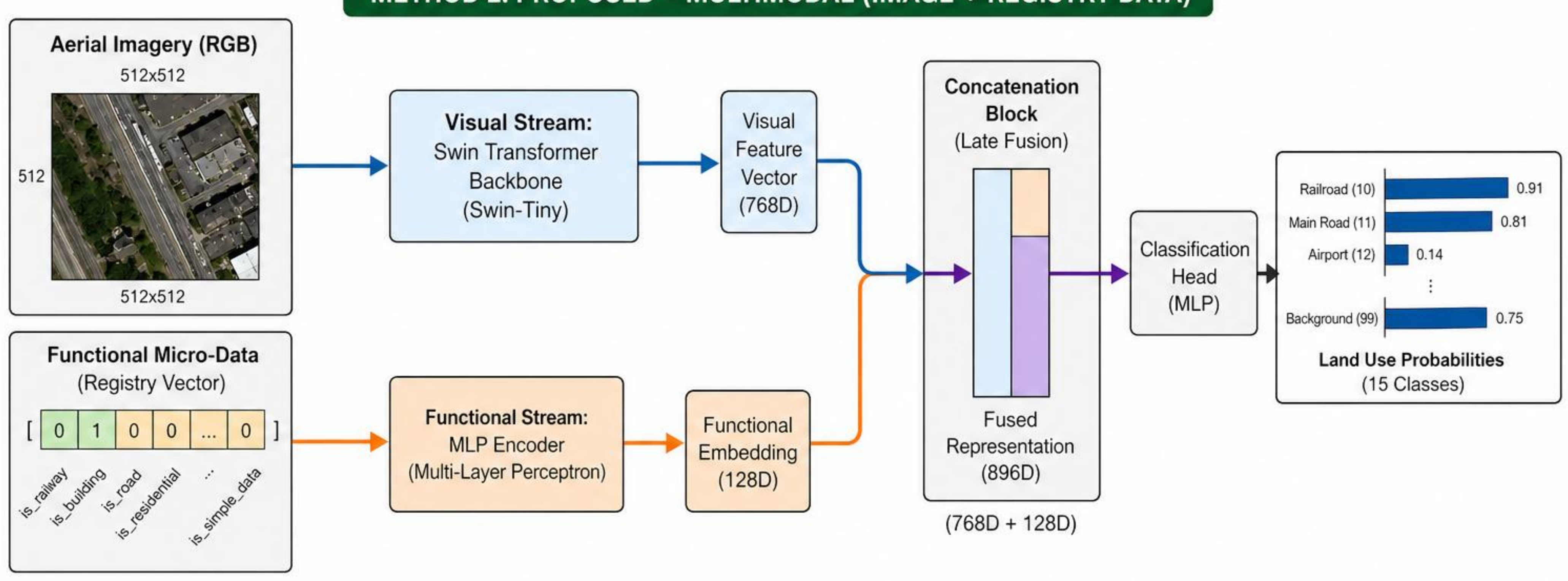
The Netherlands (BBG 2020)

- **Land Use Labels:** CBS – BBG (14 built-up classes + background)
- **Aerial Imagery:** PDOK RGB orthophotos (25 cm resolution)
- **Registry Data (fusion):** BAG, BRT, NWB, BGT, ProRail
- **Dataset**
  - ~39,000 image patches Nationwide coverage
- **Split**
  - Train: 72% | Val: 14% | Test: 13%
  - Geographically separated

METHOD 1: BASELINE – SWIN-TINY ONLY (IMAGE-ONLY)

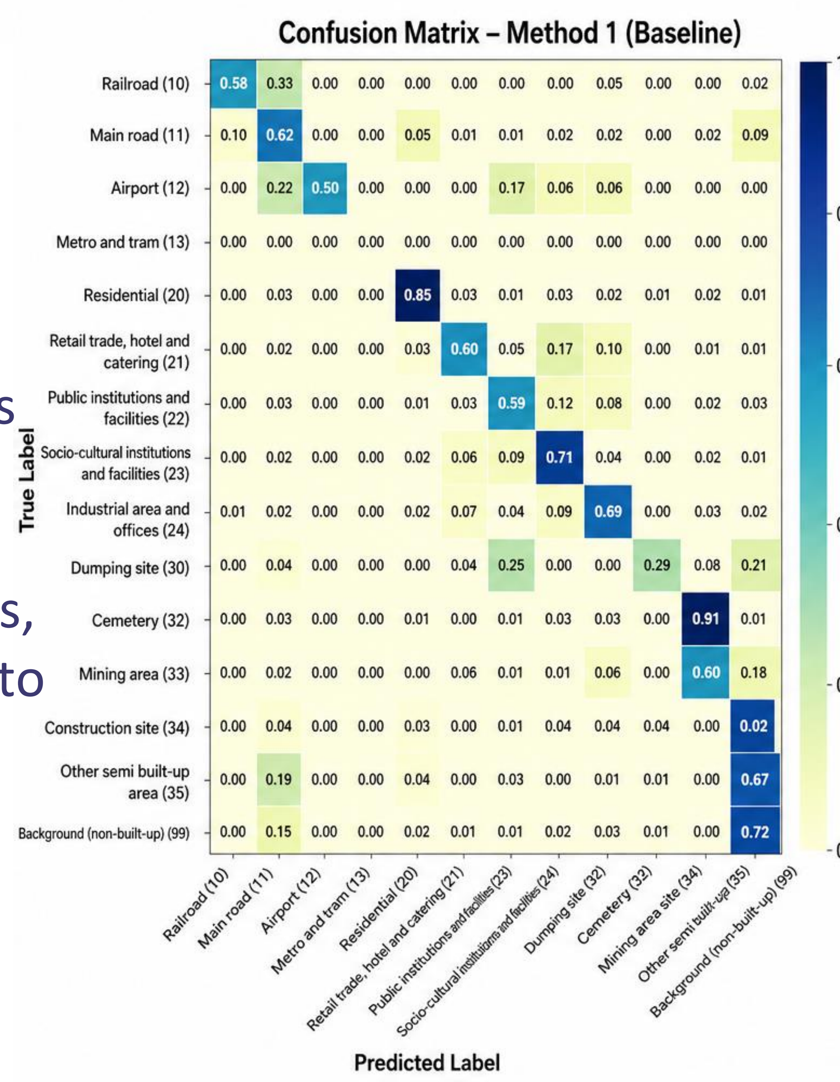


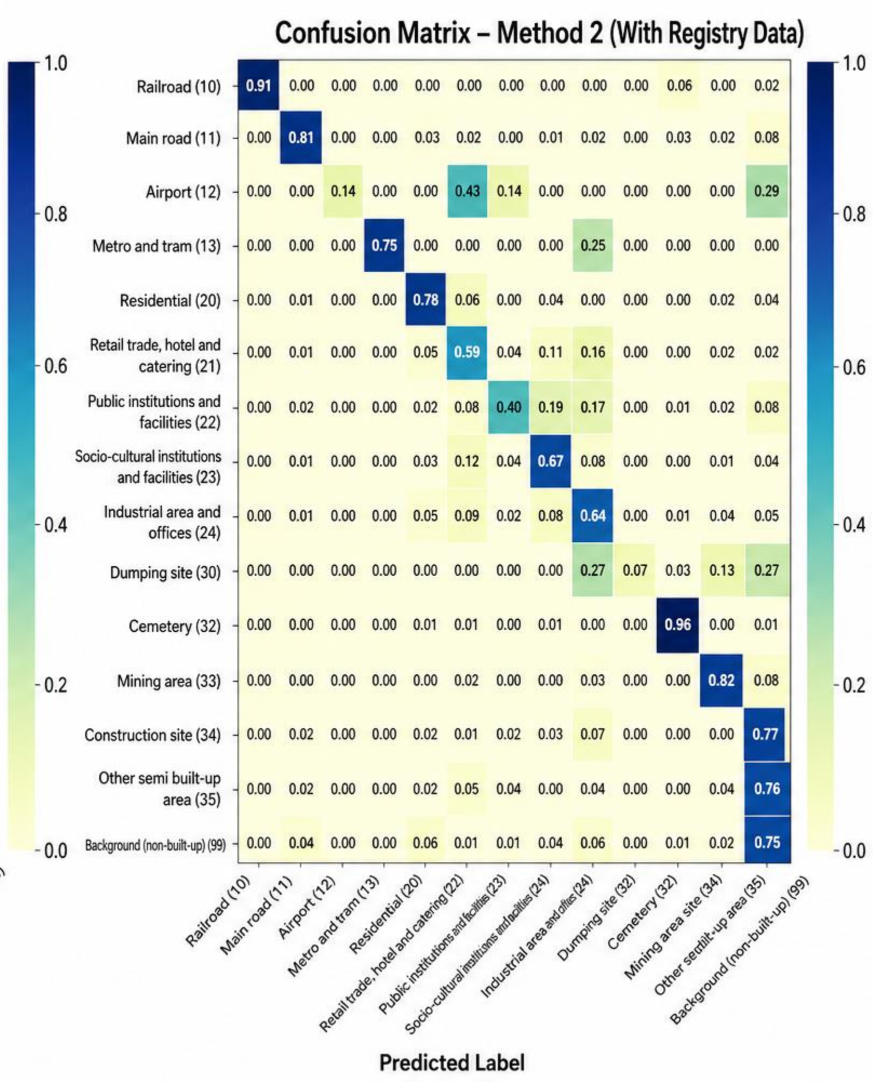
METHOD 2: PROPOSED – MULTIMODAL (IMAGE + REGISTRY DATA)

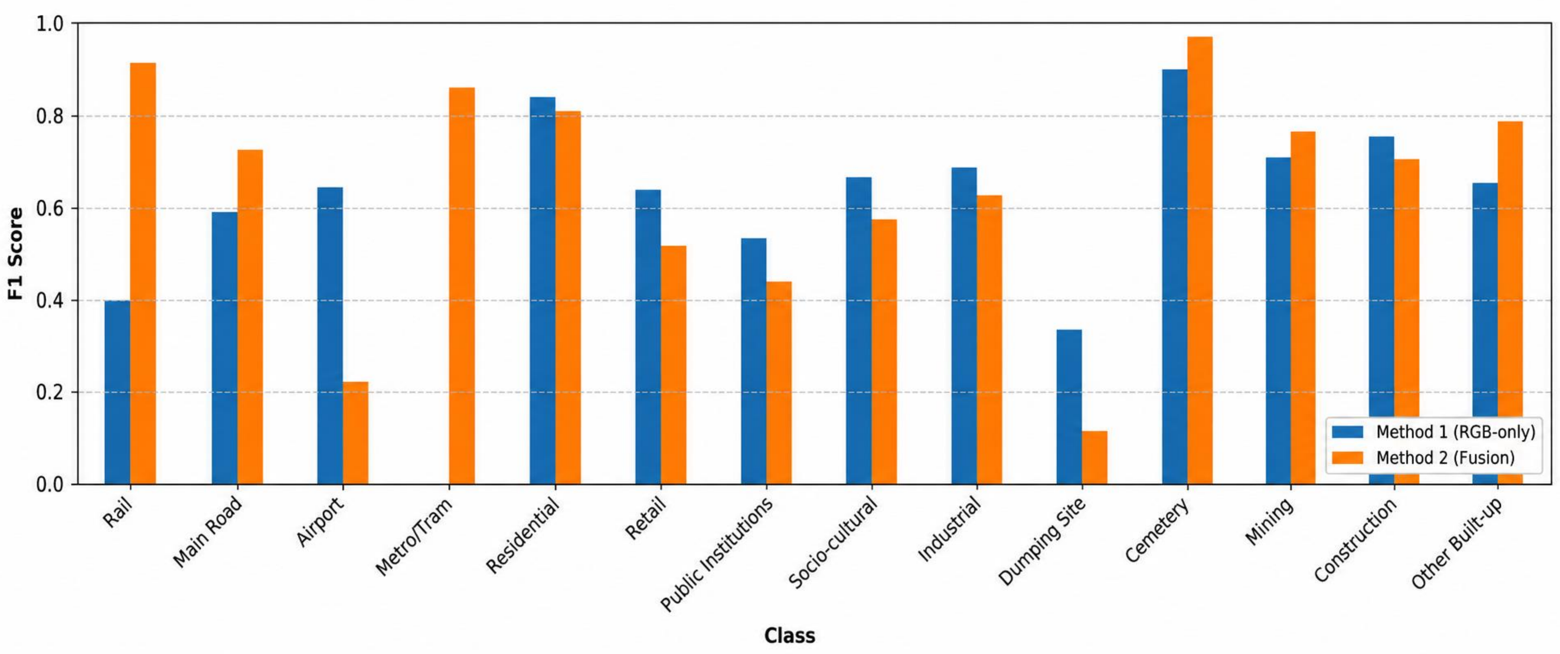


INSIGHTS

- Stronger diagonal in Method 2 indicates higher class-wise accuracy than RGB-only.
- Misclassification drops sharply in transport classes (rail, metro/tram, main roads).
- Rare classes (dumping sites, airport) stay unstable due to limited samples.







PER-CLASS F1

- Largest fusion gains: rail, metro/tram, main road (transport classes).
- RGB already strong for residential, cemetery, construction — little to add from fusion.
- Dumping sites and airport stay low for both methods (rare-class instability).

CONCLUSION

- Scalable deep learning framework enables parcel-level land-use mapping for national statistics (BBG).
- For BBG production: registry fusion is most worthwhile where visual cues alone fall short, i.e. transport classes.
- Headline F1 gain looks small (+1.5 pts), but per-class gains for transport classes justify the added pipeline complexity.
- Recommendation: hybrid deployment — RGB-only by default, registry fusion selectively for transport classes.

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