Geospatial Database Design

Case Study: Urban Agriculture in Glasgow

1. Introduction

Glasgow possesses significant potential resources in the form of Vacant and Derelict Land (VDL). Converting these areas into urban agriculture projects could address food insecurity, spatial inequality, and land revitalization(Russell, Li and Wang, 2023). This report outlines the design of an efficient geospatial database to manage the transformation of VDL into community gardens, track resident participation, and ensure logical spatial constraints. The geodatabase integrates spatial and non-spatial data to support decision-making and sustainable management.

The primary objectives of this geodatabase include:

1) Land Conversion Tracking: Document VDL suitability, status, and conversion processes.
2) Resource Optimization: Manage community garden facilities, irrigation systems, and administrative organizations.
3) Resident Participation Analysis: Link tenant data with crop records to promote equitable allocation.
4) Spatial Data Governance: Enforce topology rules to ensure data integrity and support spatial optimization

2. Geodatabase Design

1) Workflow (Figure.1, Page 2):

The design process starts with analysing requirements and identifying potential data sources, followed by conceptual modelling using an Entity-Relationship Diagram (ERD). Then, the logical schema is developed with clear definitions for data types, attribute domains, and spatial topology rules. Finally, the physical implementation in ArcGIS Pro includes creating feature classes, adding data and testing to make sure the validation is satisfied.

2) Core Entities and Attributes:

The geodatabase consists of three primary entities:

i. VDL Parcels (Polygon): Stores information on land ownership, suitability, and conversion status.
ii. Community Gardens (Polygon): Tracks established gardens, including facilities, irrigation availability, and management details.
iii. Residents (Point): Captures participant information, including plot assignments and cultivated crop types.

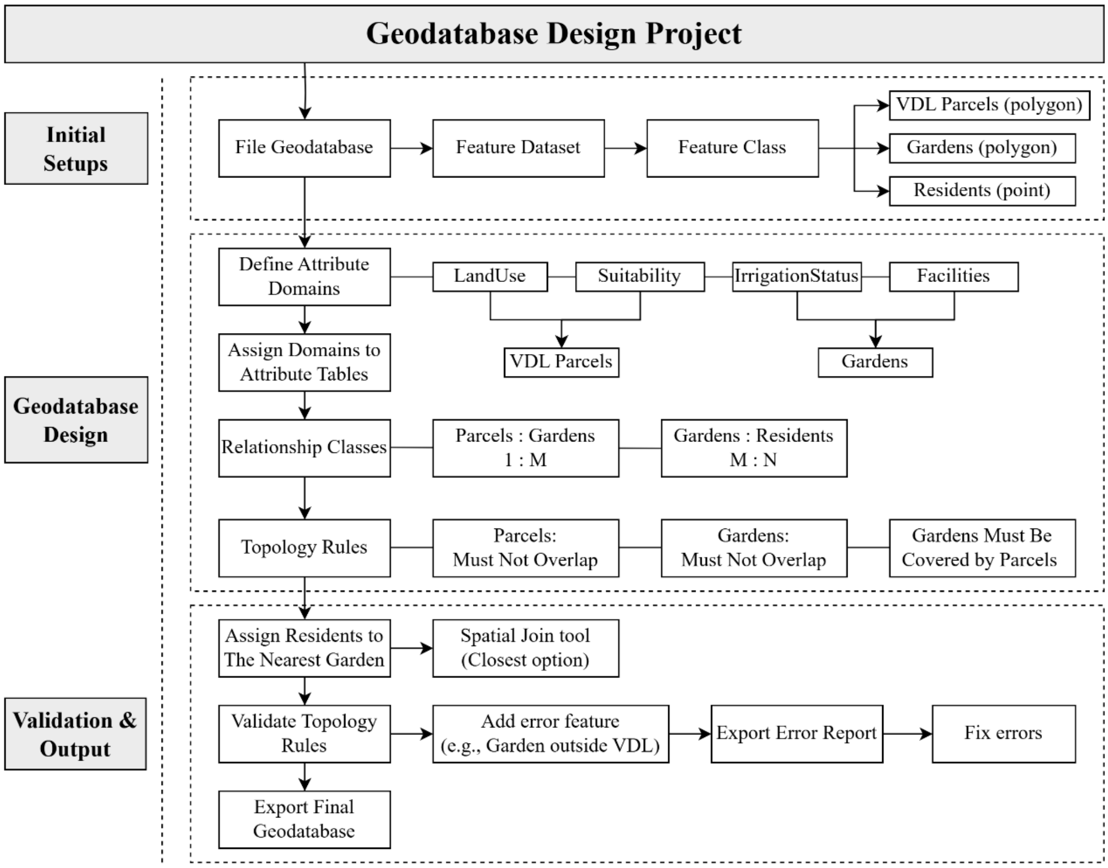


Figure 1 Workflow Plot on Geodatabase Design

Entity-Relationship Diagram (Figure 2) illustrates relationships between the core entities:

i. VDL Parcels to Gardens: A one-to-many (1:M) relationship via Parcel_ID, ensuring each garden is associated with a specific VDL parcel.
ii. Gardens to Residents: A many-to-many (M:N) relationship managed through an intermediate table (Garden_Residents) that links Garden_ID and Resident_ID.

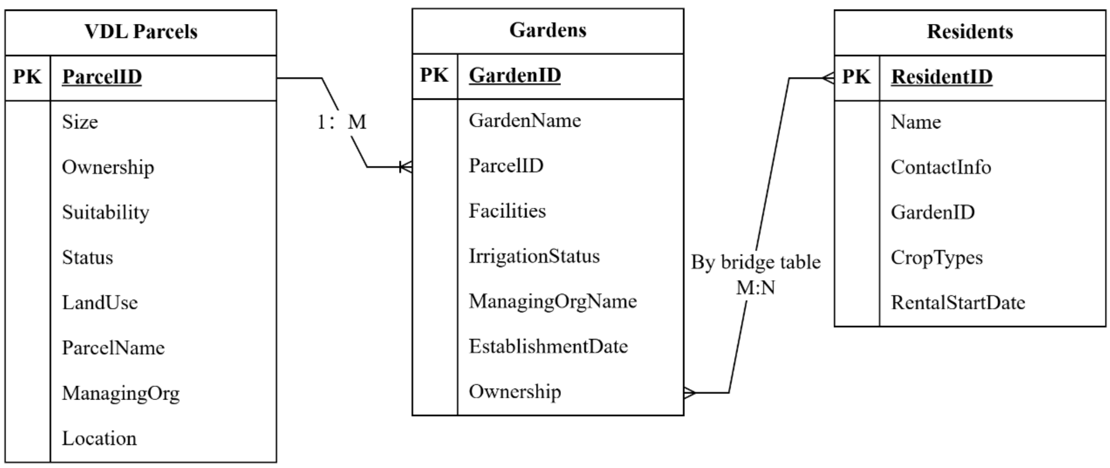
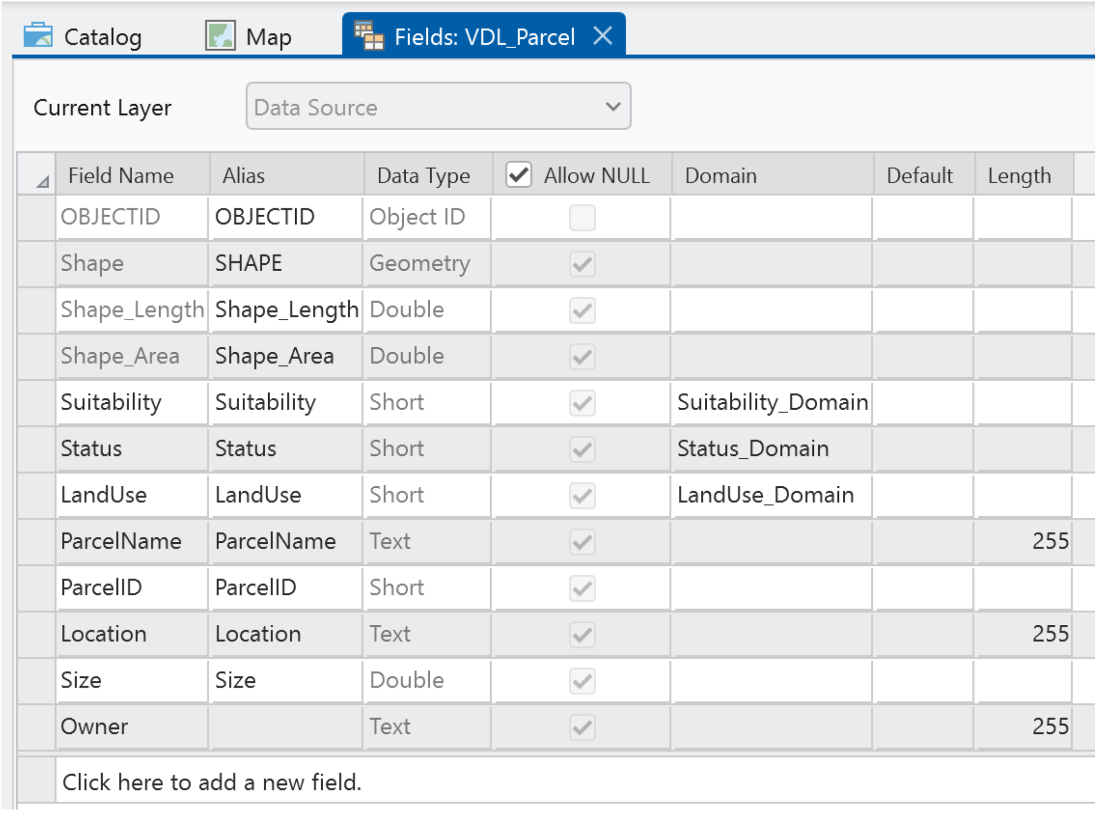


Figure 2 Entity-Relationship Diagram

Feature Class Field Design: The following table outlines the field design for each feature class (example of VDL parcels field in Figure 3):

Type\Feature Class	VDL Parcels (polygon)	Garden (polygon)	Residents (point)
Primary key	Parcel_ID	Garden_ID	Resident_ID
Foreign key		Parcel_ID	AssignedGarden_ID
With domain	LandUse, Suitability and Status	Facilities and IrrigationStatus	\
Text	Parcel name, Ownership and Location	Garden Name, ManagementOrg	Resident Name, ContactInfo and Crop Types
Date	\	EstablishmentDate	RentalStartDate

Table 1　Feature Class Field Attributes



Field Name	Alias	Data Type	Allow NULL	Domain	Default	Length
OBJECTID	OBJECTID	Object ID				
Shape	SHAPE	Geometry	✓			
Shape_Length	Shape_Length	Double	✓			
Shape_Area	Shape_Area	Double	✓			
Suitability	Suitability	Short	✓	Suitability_Domain		
Status	Status	Short	✓	Status_Domain		
LandUse	LandUse	Short	✓	LandUse_Domain		
ParcelName	ParcelName	Text	✓			255
ParcelID	ParcelID	Short	✓			
Location	Location	Text	✓			255
Size	Size	Double	✓			
Owner		Text	✓			255

Click here to add a new field.

Figure 3 Field Design of VDL Parcels

3) Spatial Topology Rules:

To ensure logical consistency, the following topology rules are defined (Figure 4):

i. VDL Parcels Must Not Overlap： Prevents overlapping parcels.

ii. Gardens Must Not Overlap: Ensures non-overlapping garden boundaries.

iii. Gardens Must Be Covered By VDL Parcels: Guarantees gardens are strictly within VDL boundaries.

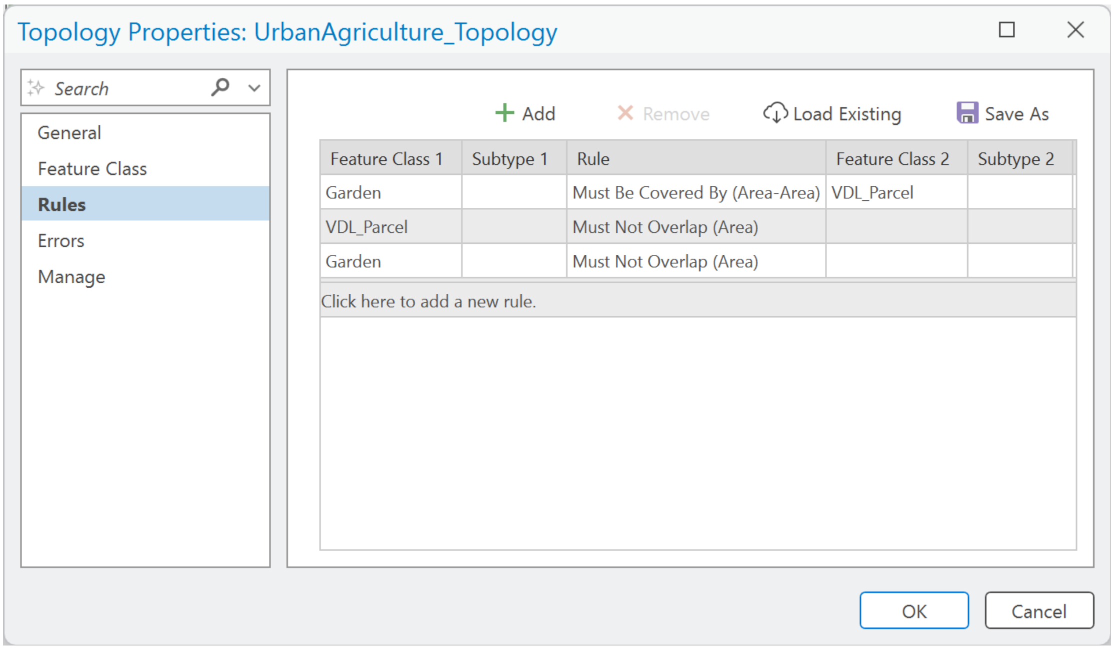


Figure 4 Topology Setting

4) Attribute Domains:

To maintain data integrity, predefined attribute domains are applied:

Domain Definition		
Name	Value	Entity
LandUse_Domain	Vacant, Industrial, Green, Rental	VDL_Parcels
Suitability_Domain	Suitable, Suitable after development, Unsuitable	VDL_Parcels
Status_Domain	Occupied, Unoccupied	VDL_Parcels
IrrigationStatus_Domain	Having Irrigation Facilities, Not having Irrigation Facilities	Gardens

Table 2 Domain Settings

5) Data Population and Validation:

i. Fictitious Data Insertion:

1. VDL Parcels: 5 records with area, suitability, and ownership details.
2. Gardens: 10 records (including 1 invalid garden outside VDL for testing).
3. Residents: 13 records assigned to gardens with crop types.

ii. Resident Allocation:

The Spatial Join tool in ArcGIS Pro with the "Closest" match option was used to allocate residents to the nearest garden. This method was chosen for its simplicity, although further enhancements could consider social and community factors.

iii. Topology Validation:

1. A test case was introduced by deliberately placing a garden outside VDL boundaries (Figure 4).

2. Topology validation was run within ArcGIS Pro. Error reports were generated and analyzed to identify inconsistencies.
3. Invalid features were manually corrected, ensuring compliance with spatial rules.

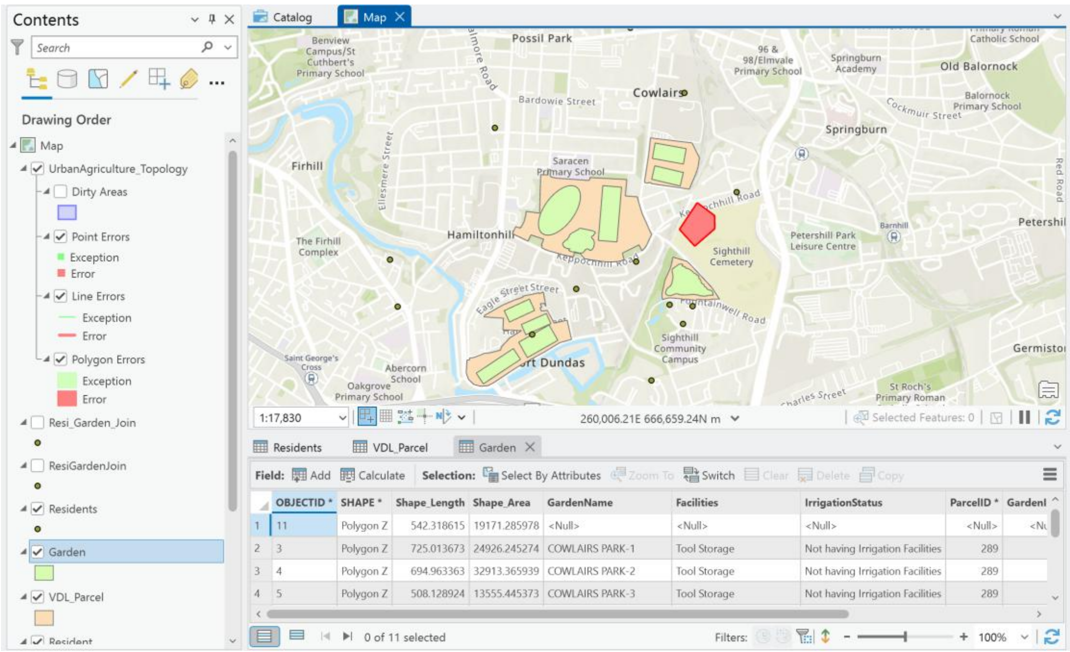


Figure 5 Topology Validation Test

6) Schema Report: A schema report was generated in ArcGIS Pro, detailing all feature classes, fields, domains, and topology rules implemented within the geodatabase. Here is an example map (Figure 6) that shows the geodatabase with fictitious data.

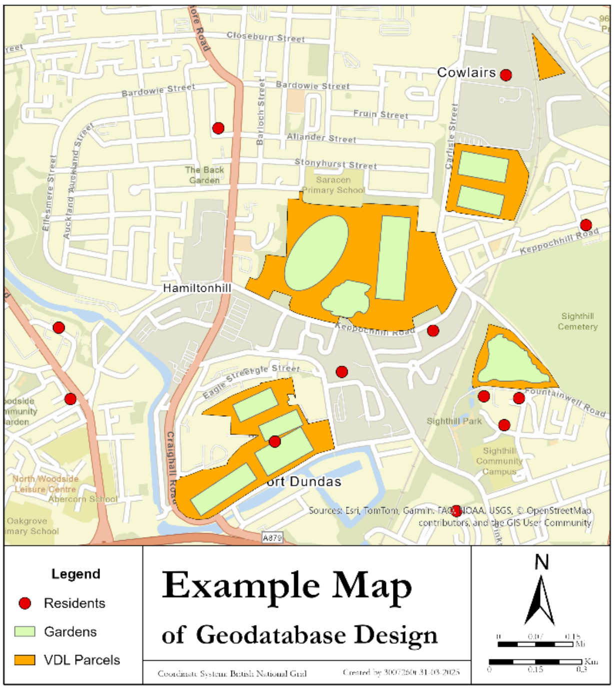


Figure 6 Example Map of The Geodatabase

3. Discussion and Limitations

Limitations:

1) Simplified Resident Allocation: The "Closest" spatial join may overlook social factors (e.g., community preferences). Future work could integrate multi-criteria decision models (Malczewski, 2006).
2) M:N Relationship Complexity: The intermediate table Garden_Residents requires periodic maintenance. Automation through scripting could make the process more efficient and reduce the risk of errors.

Future Enhancements:

1) Using information from satellites: The integration of soil quality indices and other remote sensing data (e.g. via a soil quality field) could refine site selection.
2) Topology tolerance optimisation: Making adjustments based on how accurate measurements are can improve the quality of the spatial data.
3) Enriching data sources: Integrating demographic or food security data may improve the overall analysis and decision-making process.

4. Conclusion

This geodatabase design supports Glasgow's urban agriculture initiatives through structured spatial data management, domain constraints, and topology validation. Implemented in ArcGIS Pro, it provides a scalable framework for tracking land conversion, optimizing resources, and analyzing community engagement. Future efforts will focus on integrating real-time monitoring and advanced spatial models to enhance decision-making.

5. Reference

Malczewski, J. (2006) 'GIS-based multicriteria decision analysis: a survey of the literature', *International Journal of Geographical Information Science*, 20(7), pp. 703–726. Available at: https://doi.org/10.1080/13658810600661508.

Russell, A., Li, Z. and Wang, M. (2023) 'Equalizing urban agriculture access in Glasgow: A spatial optimization approach', *International Journal of Applied Earth Observation and Geoinformation*, 124, p. 103525. Available at: https://doi.org/10.1016/j.jag.2023.103525.