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BUILDING A CELLULAR AUTOMATA MODEL FOR LAND-USE CHANGE SIMULATION USING CADASTRAL DATA – A CASE STUDY IN NOTHERN GREECE

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"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

- **Framework**

Monitoring and modeling land-use change ➡
Integrated land administration models

Traditional LU models	*Innovative LU models*
✓Christaller ✓ Von Thunen ✓ Weber ✓ Losch	✓Spatial Econometry ✓ L.U.T.I ✓ Agent-based Models ✓ **Cellular Automata**

• CELLULAR AUTOMATA

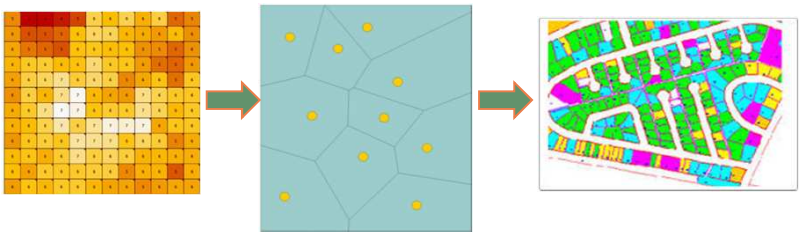
"…provide the ability to dynamically simulate very complex processes through a set of simple but clearly stated rules…" (Wolfram, 1994)

- Main Components

1. A **spatial unit** → Grid or lattice of homogeneous cells
2. A given **set of possible states** which can characterize each cell per time step → (0: dead, 1: alive), (0: rural, 1:urban)
3. A well defined **neighborhood** for each spatial unit
4. A set of simple **rules** that determine the possibility of cell state transition from one time step to another
5. A set of **time steps** during which the algorithm will evolve

• CONSTRAINED CELLULAR AUTOMATA

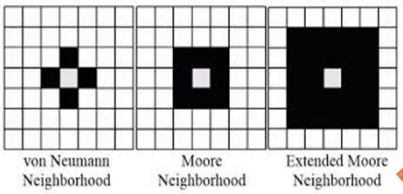
- **Spatial Unit**



- **States – Land-Use Categories**

0: rural 1: urban	→	4000: Residence 1500: Un-built Land . 3100: Commerce

- **CONSTRAINED CELLULAR AUTOMATA**
  - **Neighborhood Definition**



- **BUILDING A C.A MODEL USING CADASTRAL DATA**

A. Choosing the Appropriate Spatial Unit

Cadastral Parcel → "the continuous area of land that forms an independent and cohesive property that can belong to one or more individuals and constitutes the unit around which all the collected cadastral data is organized" (National Cadastre and Mapping Agency S.A,2014)

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

B. Selecting the Land-Use Categories

Various Land-Use Lists ➡ 1.) Nature of the issuing Agency
2.) The morphology of the area under study
3.) Scale of the study

CORINE	NATIONAL STATISTICS AGENCY	LAW 4269/2014 (Spatial & Urban Planning Reform)	NATIONAL CADASTRE & MAPPING AGENCY S.A
44 categories	-1991: 6 categories 2001-2011: 18 categories	18 major land-use categories	69 land-use categories
Strong emphasis on land-cover		Only for urban areas	**Covers both urban & rural areas**

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

C. Defining the Appropriate Neighborhood

✓ Trial-and-error process
✓ Vector Data: neighborhood defined as one or several buffer zones around the parcel

D. Defining the Appropriate Time Steps

✓ Urban Areas → 5-10 years
✓ Urban Plans need to be revised every 10-15 years by law

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

E. Extracting the Transition Rules

✓ Conditional: trial & error, data mining
✓ Mathematical: assigning weights

- Regression Techniques
- Multi-Criteria Analysis
- Analytical Hierarchy Process
- Fuzzy Logic
- Artificial Neural Networks
- **Rough Set Theory**

Historic Calibration

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

Rough-Set Theory (Pawlak, 1982)

"…a data mining technique that can derive an optimal set of factors from an original set while minimizing the redundancy and retaining the original factors" (Marceau & Wang, 2013)

Steps

a. Draft an initial thorough list of factors that are expected to play a role in L.U change process → mainly bibliographical

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

Rough-Set Theory - *Steps*

b. Prepare the "decision table"

LU_1990	LU_2010	DIST_ Transp	DIST_ PUBLIC_ SPACES	DIST_ ROAD	N4000-NH1	N7100-NH1
7100	4000	288,35	183,40	55,30	9	1
4000	3100	350,27	369,80	67,38	1	1

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

Rough-Set Theory - *Steps*

c. Extract the Factors that have a direct impact on L.U Change

Interpretation of Frequency Histograms

✓For Each Pair of Recorded L.U Change
✓For Each L.U Change Driving Factor

✓If the Histogram reveals that the L.U Change Factor follows some sort of mathematical distribution then it affects L.U Change Process.

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

Rough-Set Theory - *Steps*

d. Extract Simple Stated Mathematical Rules

Frequency Histograms → Discrete Values → Continuous Values

IF 'LU_initial'='unbuilt urban parcel' AND 'number of built residential parcels in NH1'=(5-10] AND 'number of built commercial parcels in NH1'= (1-3] AND 'DISTANCE TO ROAD_1'=(50-100] AND ….. THEN LU_final' = 'residential'

- **BUILDING A C.A MODEL USING CADASTRAL DATA**

F. Measuring the Accuracy of the Simulation

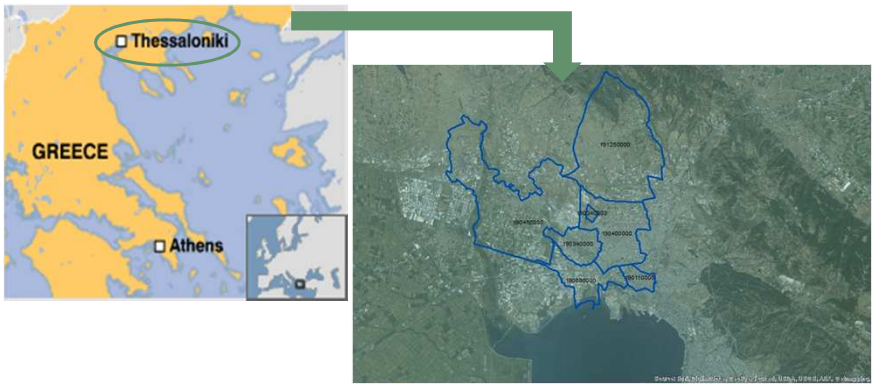
k - statistics
- $k_{histogram}$ → quantitative resemblance
- $k_{location}$ → spatial distribution resemblance

Over - Optimistic

Van Vliet(2010)
- k_{trans}
- $k_{transloc}$

→ Focus on the Spatial Units that did actually change their LU

- **Case Study – Northern Greece**



No. Municipalities	6
Area	6,800 hectares
Population	154,000
No. Parcels	33,500
No. Property Rights	200,000

- **Case Study – Northern Greece**

Software and Data

Software → ArcGIS, MS Access, R statistics

Data → Spatial and Descriptive Cadastral Data, Urban Plans, Thematic Maps, Census etc

Spatial Data

1. Parcel Boundaries
2. Urban & Rural Areas Boundaries
3. Easements, Right of Way etc
4. Points of Interest (Hospitals, Parks etc)
5. Transportation Networks
6. Permitted Land-Uses (polygons)
7. Building Regulations Polygons

- **Case Study – Northern Greece**

  - **Software and Data**

Descriptive Data

Cadastral D.B

Total of 46 Tables

4 Summarizing Tables

'BENEFICIARY'	Private Owner, Bank etc
'PROP_RIGHTS'	Type of Ownership or Right
'DEEDS'	Type, Date, Origin of Ownership
'PROPERTY'	Type, Land-Use, Construction, No. of Floors, BLD_Date et al

- **Case Study – Northern Greece**

  - **Model Calibration**

✓**Create Historic Data**

Building Permit
Date of Deed
Origin of Ownership

Create 3 distinct databases for the years 1990,2000,2010

✓**Define the Neighborhood for each Parcel**

1.) Immediate Proximate Parcels
2.) Buffer Ring/s – 50m, 100m

Neighborhood Definition Tested through Sensitivity Analysis

- **Case Study – Northern Greece**

Identify L.U Change Factors

Main Category	Sub-Category
Socio-economic	• Population Growth/ Distribution of Population in the Area
	• Demographic Attributes of the Population
	• G.D.P growth
	• Property Prices
	• Type of Ownership
Spatially Related	• Slope/Height
	• Accessibility to various infrastructure facilities
Town planning Related	• Land-Use planning Map
	• Building-permit regulations
	• Areas under protective regime
C.A Related	•Existing Land-Uses in the defined neighborhood

- **Case Study – Northern Greece**

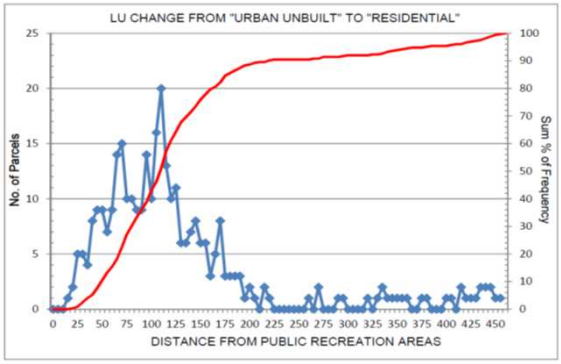
Model Calibration

✓**Exclusion of Parcels that are not expected to change LU (e.g road network, rivers, military facilities, public owned properties etc)**

✓**Decision Table**

Parcel_Code	LU_1990	LU_2010	DIST_ Transp	DIST_ PUBLIC	DIST_ ROAD	N4000-NH1	N7100-NH1
190110203004	7100	4000	245,24	155,40	76,54	8	1
190110205003	7100	4000	183,81	129,13	40,38	4	0
190110206007	7100	4000	157,12	91,35	76,85	2	0
190110207005	7100	4000	179,91	87,08	108,52	5	0

- **Case Study – Northern Greece**
  - **Model Calibration**
    - ✓**Frequency Histogram**



- ➢50% → distance from Public Recreation Areas <110m.
- ➢Two Intervals: (0,195] and [195,460)

- **Case Study – Northern Greece**
  - **Model Calibration**

✓Evaluation of the Effect of Each Factor on LU Change – Draft of the Final List

✓Move from discrete to continuous values

✓Extract Mathematical Transition Rules

✓Run the Simulation from 1990 to 2010

✓Measure the Accuracy of the Model

✓Run the Simulation for the target year 2020

- **Conclusions – Future Challenges**

  ✓ Use of cadastral data in more geosimulation models as they prove to be a valuable source of information on land.

  ✓ Extend the use of CA methodology.

  ✓ Ability to conform with geometric transformations of the parcels,

  ✓ Ability to incorporate spatial plans that are expected to create changes in the urban fabric.

Thank you for your attention!