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Critical Review of Cellular Automata(CA) Land Use Modeling Applications

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***Abstract* - Spatial simulation is a technique for mapping dynamic processes, supported by models and tools that interact with urban development. Spatial models are suitable applications for analyzing future direction and land use change. This article is on theoretical review on cellular automata land use modeling applications. Spatial planners are increasingly using land-use modeling techniques, among other simulation applications. Several simulation methods and tools are available in the field, but most of these approaches have limitations. FUTURES, Urban Sim, SLEUTH, CLUE, and METRONAMICA are popular land use modeling applications/tools that have been around for decades. This research consists with introduction session of CA applications, detailed review on CA applications on methodologies, inputs, parameters, outputs of each application and conclusion. Study aims to identify the best applications to estimate the land use changes.**

***Index Terms* - Clue, Futures, Metronamica, Sleuth, Urban sim.**

I. INTRODUCTION

Planning practice is primarily limited by arbitrary and subjective decisions instead of estimated and authenticated future decision-making using modern planning and decision modeling applications in developing nations [1]. Spatial simulation is a technique for mapping dynamic processes, supported by models and tools that interact with urban development. Spatial models are suitable applications for analyzing future direction and land use change. Results are important to assess policies and the influence of the land use on socioeconomic as well as the ecological factors. The primary driver of change the natural system is land use transformations. However, biophysical factors influence exactly where land-use change occurs. Assessment of environmental change requires spatially explicit assessment. Because not all locations are equally and diversely affected by environmental change, their impacts and responses provide strengths and weaknesses in land-use change. Therefore, there is a need to identify the increasing dynamics in people and places as global changes occur. Dynamic Simulation Models (DSM) use two general approaches: agent-based modeling and cellular automaton modeling. There is a recent trend is to use CA modeling approaches to model land use change [2].

Cellular Automata (CA)

Stanishlav and John von are the one who proposed Cellular Automata (CA) in 1943 for the first time [3]. The basic elements of the City CA model as follows:

a. Individual spatial unit (i.e. cell) defined by location (i.e. cell space)
b. Geometry (i.e. shape of cell on regular grid or irregular)
c. Attributes that evolve over time and space (i.e. cell state, e.g. land use type)
d. A set of specified rules governing cell state transitions within a neighborhood.

A general goal of urban CA modeling is to determine how the states of a cell change in relation to what is happening in its neighborhood, and how these changing states generate meaningful patterns. It's about capturing the rules that govern it [4]. The CA model framework can integrate both spatial and non-spatial data to simulate a various socioeconomic processes occurring inside separate spatial entities. Despite the fact that the CA modeling approach has been around since the 1950s, it hadn't been extensively popularized till desktop computers' computing capacity could effectively manage the computational demands of complicated models. The linkages among system components and the patterns of the landscape that result from the represented processes can be investigated using CA models. CA models can model the potential effects of alternative policy scenarios with reference to land use management.

Spatial planners are increasingly using land-use modeling techniques, among other simulation applications. Several simulation methods and tools are available in the field, but most of these approaches have limitations. FUTURES, Urban Sim, SLEUTH, CLUE, and METRONAMICA are popular land use modeling applications/tools that have been around for decades [5].

II. REVIEW ON CELLULAR AUTOMATA MODELS

1. Metronamica Model

Planners have used the METRONAMICA model as a highly effective estimation tool for modeling and analyzing the combined impact of urban and regional development strategies [6]. Known as SDSS called Spatial Decision Support System. GEONAMICA is the software that developed METRONAMICA as a separated software with user friendly interface. The Knowledge Systems Laboratory in Maastricht, Netherlands, is the laboratory that develops GEONAMICA and METRONAMICA [7]. Integration models for simulating traffic congestion and transportation models for simulating traffic strain in transportation networks support Metronamica. MAP COMPARISON KIT is included in the system for analyzing model results. Both METRONAMICA and GEONAMICA applications are adaptable with GIS software.

1.1. Types of Models in Metronamica

There are three types of models in Metronamica. Regional Interaction Model (Regional migration model) – Generate and Relocate the activities among the region. This model provides employment and population totals for each region. Four Stage Transport Model - Assigns traffic over the transport network using transport zones which smaller than the regions. Regional Interaction Model / modeling the impact on traffic and congestion on the transportation network. Cellular Automata LU Model - Operate at local level and assign land use types to cells considering one region at a time.

1.1.1. Regional Interaction Model

RIM is used in METRONAMICA to distribute the total population and employment of major economic sectors across regions nationwide, simulating migration between regions. The relative attractiveness of each location has a significant impact on the growth distribution among regions. Moreover, this model is of great importance for simulating the socioeconomic development and migration distances of a country. The attractiveness of the socioeconomic sectors (population, employment of the main economic sectors) is based on the local and regional characteristics as well as the socioeconomic activities currently existing in the study area.

1.1.2. Four Stage Transport Model

This model can simulate transportation networks on a regional scale. This provides essential insights into other model components, such as accessibility data and relative distances between local interaction and land use models. Transport model simultaneously obtains inputs from other models, particularly population distribution and employment distribution in selected regions. The Metronamica application represents high-resolution LUT models with interrelationships between different models. Intrinsic/dependent modes are cars or personal transport that model their association with networks. Extrinsic/independent modes are bus, train, or public transport modes in Metronamica. Normally it should have minimum one intrinsic mode and 0 to several dependent / extrinsic modes. Distances are expressed in terms of generalized costs in Metronamica LUTs because a real-world transportation model is built into the system and this is the assumption of this model. The transportation model is a traditional four-step model with four major stages.

i. Production and Attraction

The people and jobs in each zone are what cause the trips. If a person creates a trip to a zone it is called trip origins and if a person creates a trip out of zone it is called trip destination. People travel for many reasons. Trips are classified according to purpose as shopping, work, visits, etc.

ii. Distribution and Modal Split

The distribution step shows the linkage between origin and destination. When an individual goes to work, it establishes a link between home to work with the purpose of home work interaction. To determine a mode of transport, modal split steps are calculated within the same distribution time step. People choose their preferred mode of transportation. Preliminary trip distribution displaying the number of trips per hour among traffic zones by mode of transportation, duration, or trip purpose, starting with the model's first year.

iii. Assignment

Transport allocation steps occur in a series of iterations based on cost and congestion. Each iteration allocates a portion of the total number of moves. Movement between zones is done on specific routes. These routes are costly due to fuel consumption, driving time, driving distance, also other aspects as parking fees. People choose cheapest path. People increase road strength by choosing routes that affect the speed of travel on the road. Unable to find cost-effective alternative routes depending on people's reactions to dynamic situations. The type of activity is believed to help generate the number of trips. In fact, land-use density was assumed to be spatially uniform within a geographic region. Integration across space leads to activity in the transport zone. As a constraint, each cell in each state should have one accurate transportation network, and each cell in each transportation network should have only one region.

1.1.3. Cellular Automata Land Use Model

LU model shows the distribution (change) of land use demand centered on a land use map. Four key variables influence land-use change at local scales.

i. Physical Suitability

A map is used to represent each vacant land and each modeled LU feature. The term "fitness" refers to the identification of suitable land use function or economic and residential activities to a cell. A suitability map is created based on the physical characteristics of the site. Free land use suitability maps and land use features remain constant throughout the simulation.

ii. Zoning or Institutional Suitability

Each land-use feature is represented on the map. Zonal maps are used to impose spatial restrictions on land use allocations. Chronological area map series for each land use showing the plots able to use or not to use for each land use, allowing time-varying zoning limits. If the user does not change the zone maps, they remain constant throughout the simulation.

iii. Accessibility

Each land-use feature is represented on the map. Accessibility is the interpretation of how easily an activity can meet transportation and other infrastructure needs on a particular infrastructure system. Features of land use determine accessibility. There are four types of accessibility that should be considered;

➢ Local Accessibility

This indicates the scope of which land use needs are met with or without a transport system. The system consists of many network layers created using nodes as stations and linkages as routes. This indicator identified per node or link type before being joined into a unique rate per plot and land use.

➢ Zonal accessibility

The generalized costs from the transportation zone to the origin and destination are used to calculate the accessibility of the zone. The transport model calculates it. An additional region map specifies the transport zones.

➢ Implicit accessibility

If an area occupied for an urban land use it need to measure potential or implicit accessibility. It is important for land use models. For each land use type, implicit accessibility takes one of two values. Those are the values for urbanized area and non-urbanized areas. If a current land use type of a plot is marked as "built-up area", the plot is considered urbanized. Therefore, these flags are accessibility model block parameters.

➢ Explicit accessibility.

Some land uses seem inaccessible, because those activities created through other LU activities. But those are accessible to activities created by their own. If a land uses inaccessible, when a land use is inaccessible, it takes 0 explicit accessibility.

2. FUTURES (FUTure Urban Regional Environment Simulation)

FUTURES can define as patch based, stochastic model to predict land use changes and growth of urbanization [8]. As well as this is a cellular automata model. [9]. FUTURES is a multilevel simulation model for developing urban and rural landscape structures. Multi-level can be applied to FUTURES as regional and local context. [10, 11]. FUTURES software has integrated in to GRASS GIS and it has a raster library that can read data efficiently for model developers. The FUTURES model has higher technical depth and the Patch Augmentation Algorithm was a key component of the original FUTURES implementation. [8]

2.1. Structure of Model

The FUTURES model is modular, with three main sub-models that account for land use changes over a diverse district: DEMAND, POTENTIAL, and PGA (patch-growing algorithm) [12]. The DEMAND sub-model computes projected population demand, and the POTENTIAL sub-model derives a probability surface from environmental and socioeconomic predictors [13]. The main strength of FUTURES lies in its realistic modeling of the land use change using growth plots selected by their magnitude, compactness as well as measured historical data. [13]

➢ Demand

Per capita demand modeling, which determines the amount of change expected in each land cover. Application to calculate the land use rate per capita for each sub-region and grade. Land use estimates are based on extrapolation of historical population changes and land conversions based on projected or hypothesized future population growth scenarios. To construct demand relationships, it can use available data, observations, prescriptive approaches. Change analyze of existing maps and remote sensing data are used to acquire inputs on change of land use for a time period [8]

This method produces two results in particular:

i. To identify the linkage between growth of population and emerging developments
ii. To identify the plots can be change from undeveloped to developed

The DEMAND submodule was calculated in a spreadsheet ([13].

The Python module estimates the relationship among population and land consumption using a statistical model described by a linear, logarithmic, or exponential curve using the GRASS GIS Python script and libraries. Connection among growth of urbanization and change of population in respective district is examined according to population using least squares regression techniques, generating linear or logarithmic relationships [14].

➢ Potential

Sub-models of Potential combine the location fitness prediction models for calculating the spatial gradient of land development potential. It is based primarily on a multidimensional link between changes observed in socio, environmental, and infrastructure contexts. As well as this model use hierarchical characters of land use [15], such as differences between jurisdictional structures, as well as taking into account the different interactions among forecaster and reaction variables [16].

Potential can model dynamic soil change probability gradients that underlie growth of region models and deliver a "playground" arranged which the FUTURES can simulate land change by integrating elements are evident in space and time, including positive feedback estimating the impact of future land development on new and existing land (development pressure). As topographical change events occur, the potential probability gradient changes and new development pressures affect future terrain variation in a trajectory reliant on method with positive feedback ([17]. As the stochastic arrangements depend on the path affected by the initial conditions [17].

A transition potential model defines each cell's ability to be impacted using a change among land use types. Models development suitability using multilevel logistic regression based on environmental, infrastructure, and socioeconomic forecasters, as distance to streets or geographic slope. It also generates a map that describes positions of prospect expansion. A cell's transition from an underdeveloped state to a developed state can be predicted using the output map of potential [18]

➢ Patch Growing Algorithm(PGA)

PGA is a stochastic model can interpret a pattern of land change and spatial allocation utilizing alternative location selection and a context aware region growth mechanism to switch cells from state to state. undeveloped" to the "developed" end state. By merging cell-based and object-based terrain change demonstrations, the PGA creates transformation event objects. Over time, the expanded cells organize themselves into new arrays of predefined sizes and shapes, which can then be aggregated into super arrays. Changing of simulation at any step will return development pressure into POTENTIAL submodule, affecting site suitability. Irrationality or human agents are represented as random factors in the PGA, affecting both location selection and patch arrangement [19].

The PGA will continue to allocate plots until the DEMAND for land per capita until that can interact with urban growth. PGA method offers a stochastic substitute to definite area growth procedures commonly utilized in conservation planning and location selection. FUTURE can be calibrated for accuracy using user-defined parameters in the PGA sub-model and able to visualize alternate prospects of expansion and landscape destruction. PGA is the core of FUTURES, simulating urban development with input of DEMAND and POTENTIAL sub-models [8].

2.2. Model Parameters

Sub Model	Parameter	Sub Parameter
Potential	Environmental	1. Farmland Forest
		2. Open areas
		Topography
		Hydrography
	Infrastructural	1. Accessibility
		2. Municipalities
		3. Sewerage and water supply systems
	Socio and economic	1. Age and income
		2. Attraction of Employment
		3. Multi-level arrangement
	Dynamic	1. Development pressure
Demand		1. Population
		2. Development
Patch-growing algorithm		1. Size of Patch
		2. Compactness of Patch

3. URBAN SIM MODEL

UrbanSim, open-source software developed by Dr. Paul Waddell with a team at University of Washington, is possibly the most comprehensive land use modeling kit available. Since 1996, the UrbanSim model has been in development. Urban sim can compare by using two alternative methods as Lowry gravity model. Lowry model use the gravitational law, can use for forecasting the movement flow among sites based on the size and ending points. Ease of movement is a best method for land cover modeling [20]. The first UrbanSim application was designed in the United States for the Eugene/Springfield region. Urban Sim essentially extends a microsimulation tradition in land-use transportation modeling. The integrated transportation/land use model known as Urban Sim is becoming increasingly popular. Urban Sim is particularly appealing to planners and researchers due to two features. Urban Sim use as a simulation system for urban development planning and analysis that incorporates collaborations of land uses, transport network, economic system, as well as environment. A tool aimed at planners, policymakers and other community stakeholders to use in the development and assessment. The UrbanSim application had developed in a small area to facilitate model testing and analysis.

This model identifies as Reusable with the facilities with applying another region without restricting to one area. This is the very first application that use small geographic units as small grid cells. Framework contains a clear illustration the demand for real estate, quantity of supply as well as the prices, as well as evolution for a time period. UrbanSim utilizes independent logit models to simulate existing household and firm relocation decisions, place households and jobs in grid cells that are traditionally 150 m by 150 m in size, and forecast the changes of grid cell changes with the type of development [21].

3.1. Types of models

3.1.1. Accounting Models

The household and employment transition models are included in the accounting tool. The household transition model takes into account features as income of household, ages of persons, size of the household and status of parental to model births and deaths. A similar methodology is used in job displacement models to model creation of occupations and loss of the occupations.Invalid source specified. This model identifies as economic transition model also. Demographic Transition framework also one of the accounting tool that analyze the birth and death rates of a household population. This allows you to model changes in population distribution over time. Employment monitoring results define the targets of employment and determined accordance to finance sector distribution.

3.1.2. Probabilistic Choice Models

Models that based on rates used for **relocation** and logistic models used for **location** characters. These two are sub models of Probabilistic Choice Models. Employability, neighborhood characteristics, and location characteristics all play a role in defining a multinomial logit model of household location. To simulate job movement, movement and employment location models follow a similar methodology.

- Mobility model for relocation of employment and household

Mobility Model estimates a household's decision to move or not. Historical data is used to calculate move probabilities. When a household decides to relocate, though it is placed, but does not have a current address, and the previously occupied space becomes available. Employment mobility models, like household mobility models, predict which occupations will move from their own current location in given time period.

- Location Model of employment and household

This model identifies as Location Choice model also and select locations which are not having location for household. Vacant housing samples select considering the all vacant units in a neighborhood. A polynomial logit model calibrated for the observed data is used to assess the desirability of each alternative in the sample. Household will be allocated to the most appropriated location that available. Job placement simulation serves to determine the location of each unoccupied job. Every possible option is taken into account when choosing a random sample of open square meters of land or housing units for a job that allows for telecommunication.

3.1.3. Model of Land Price

This is the linear regression simulation tool used to determine value of any grid over a time period. This has developed based on theory of urban economics. Local character, accessibility measures and policies all affect land values.

- Real Estate Development Model

Property development models can simulate developer decisions about what type of construction and where to do it, including new construction as well as renovations to current configurations. This model evaluates every grid cell values and allowed to develop and produce available conversion choices.

4. SLEUTH MODEL

Sleuth is a model of a cellular automaton (CA) that simulates changes in land use and urban growth over time. Model has been used in many different urban settings throughout the world. [22]; [23]; [23] Slopes, land use, exclusion planes (areas without development), urban traffic, and hill shadows are all included in SLEUTH, which was developed utilizing GIS data imagery. [24]

Urban Growth Model (UGM) and Deltatron Land Cover (LCD) Model are two modules that make up the firmly coupled SLEUTH model. Although LCD is constrained by an urban legislation, UGM can operate independently. These connected models are together referred to as SLEUTH.

2.2. Model Simulation

This involved the evolution of the growth cycle. There are Four types of growth rules can occur with this tool as Spontaneous, Diffusive, Organic, and Road influenced growth on non-urbanized cells. Additional to basic growth rules, there are second level rules identify as “self-modifying” rules can use for governing large scale structures. These rules are corresponding to growth cycle of the model. To prevent the zone in the model from expanding exponentially or linearly, self-modification is essential. Below table interpret the relationship of growth rule.

Growth Rules	Controlling Coefficients
Spontaneous	1. Dispersion 2. Slope
New Spreading Center	1. Breed 2. Slope
Edge	1. Spread 2. Slope
Road-Influenced	1. Road Gravity 2. Breed 3. Slope 4. Dispersion
Slope Resistance	1. Slope
Excluded Layer	2. User-Defined

Coefficient values define the degree to which each of the four growth rules influences the system's urban expansion. [23, 24];.

2.2.1. Method

The most common calibration method is called "brute force calibration". Three phases of changing a set of control parameters are used in this modeling approach as Coarse, Fine, and Final. This model process in three stages. Those are testing, calibration and prediction. Test mode run confirmed that the input data preparation was accurate, and if there were any outstanding errors, it displayed the relevant error messages. The most critical step of the model was the calibration phase where the tool should be used to generate the maximum possible value of the growth factor. Calibration was performed in three different ways: coarse, fine, and final. The data set used in this study has spatial resolutions of 120 m, 60 m, and 30 m for coarse, fine, and final calibrations. [25]

2.2.2. Input Data

Six different input layers are necessary used for calibration of the SLEUTH model. The SLEUTH model requires six input layers. Slope, land use, exclusion, urban, transportation, and hill shade were among these layers. All information should be presented in shades of gray in a gif format image file with a uniform number of lines and segments.

➢ Slope layer

Topography, which is usually characterized through slope, is an important element in urban development. Apparently, flat and broad regions are best adapted for urban sprawl. A DEM (Digital Elevation Model) is used to create a slope layer, which is then categorized into numerical values between 0 and 100. As an example, if slope is 10%, the reclassified value is 45. The cost of construction rises as the slope of the terrain rises. As a result, slope in topography exceeds higher limit, a dangerous slope imposes a restriction on urban expansion. The essential gradient for urban development varies across cities of. It is mostly set at 20% for grasslands and 25% for rocky or mountainous extents. Because the topography won’t change dramatically in the near future, slope layer persists constant during simulation and forecasting section.

➢ Land use layer

The land cover layer will be converted from vector to raster format and reclassified into six categories according to requirements of model as well as and the conditions of selected area: lands of urban industrial, settlements in rural, lands of agricultural, bodies of water, pastures as well as vacant lands. Land use categories are encoded as ascending integers from 1 to 6. It was then converted to format of GIF.

➢ Excluded Layer

The excluded layer contributes significantly to urbanization by establishing urbanization resistance features. Excluded layer able to make it possible or prohibit urbanization in a specific district by using SLEUTH model. While making changes on factor of resistance of urbanization, the weighting of layers can slow or change the rate of urbanization. Cell values can be evaluated from 0 to 255, so they can be sorted into strata according to their exclusion probabilities. A value of 0 indicates areas can be fully urbanized, and values above 100 indicate that it cannot be urbanized. Variation of values from 0 to 100 can use for monitoring of urbanization opportunities with the areas dictated by political and urban planning plans, including exposed wetlands, protected arable land, or vegetable gardens. Exclusion layers are therefore important in SLEUTH modeling because they are able to incorporate urban planning, politics, macro factors for predicting regional urban development.

➢ Urbanization layer

Determine built-up strata using digitalized land-use maps, airborne photos, or time series remote sensing imagery. First year's city coverage if not seed can be utilized used to initialization of the model, while the other years or control plane can be applied during phase of simulation.

➢ Transportation layer

Transportation systems created a significant impact on urban sprawl, as cities tend to develop from the city center in the direction along the transportation system. To simulate dynamic effects, one or more years of transportation data should be used. Values since 0 to 255, with Zero is representing zero street and also other values indicating the absolute accessibility of transport network. The transport layer able to have binary values (0 or 1), as well as relative weight values like (0, 1, 2, 4), or relative accessibility of roads (0, 25, 50, 100). I can do it. (high, medium, low, none). Transport levels are classified on a scale of 0 to 4. For example, highways, federal highways, and state highways are assigned a scale of 4, railroads and highways are assigned a scale of 3, and lanes and trails are assigned a scale of 1. A non-street cell has a score of 0. Street values can change in two years.

➢ Hill shade

Hill Shade is representing as background of the created picture for better spatial visualization. Shadows are usually extracted from a DEM. Large body of water can be superimposed on hill shades.

5. CLUE MODEL - Conversion of Land Use and its Effects

Wageningen University created the CLUE modeling framework, which was originally released in 1996. This model was developed and applied for continental and national level in Central America, China and Java, Ecuador, Indonesia. This model is a tool to examine potential future changes in land use at regional level and to clear understand the factors that influence in changing the spatial pattern of land use.

The CLUE model was initially created to manage soft classified data, and all earlier applications were based on data from land-use censuses, but the regions are countries like Costa Rica, Ecuador, and China. was supranational like Central America, with alternating spatial domains between 7x7 km and 32x32 km.

CLUE model needs following as inputs: Type of land-use conversions, land use demands (requirements), characteristics of location, spatial policies and restrictions. [26]

- Land-use demands

The quantity of land allocated to different purposes is estimated based on factors related to the socioeconomic and/or demographic context.

- Characteristics of Location

Demonstrating regional suitability for a specific land use, which is determined by a number of criteria

- Spatial policies

Policies restrict the places where land use changes. These regulations must be presented as maps that outline the locations in which they will be enforced, such as national parks.

- Restrictions

Areas where LUC is prohibited by law

5.1. Types of Clue Model

CLUE model cannot be directly applied at the regional level due to the changes in data representation and other characteristics that are common for regional applications. As a result, modelling method has been modified and improved. Two applications available as, CLUE-S and Dyna-CLUE.

5.1.1. CLUE-S (Conversion of Land Use and its Effects at Small regional extent) model

The CLUE-S model was created for applications involving regional data and high-resolution spatial data. This approach was created especially for spatially explicit modeling of land use change. Based on empirical research on site suitability and dynamic simulations of competitiveness and relationships between spatial and temporal dynamics of land use system. The CLUE-s model is a widely used simulation method for land-use change. Combined the CLUE-S model with a standard logistic regression model to find explanatory factors without considering the effect of spatial autocorrelation. The learning unit for the CLUE-S model is the grid. The grid size for this work was 300m x 300m in order to represent the spatial features at high resolution given sufficient accuracy. The CLUE-S model should be inserted into the transfer matrix of potential transformations between different types of land use. All land-use types in this study can be differentiated into non-self-convertible urban land, green land, bare land, or non-wetland types.

5.1.2. Dyna-CLUE (Dynamic Conversion of Land Use and its Effects) model

The most recent version of the CLUE model includes autonomous developments through bottom - up simulation. Dyna - CLUE has also been applied at detailed local scales all around the world: Austrian Alps, the Philippines, Iran, China. user - interface of Dyna - CLUE model supports only for the spatial distribution of the change of land use type.

Dynamic CLUE defines land use category conversion sets in conversion matrix. conversion matrix's objective is to:

- Define what other land use categories which permitted to convert from the initial land use.
- Specify how long a land use type must be in place before it can be converted to a different one at a particular site.

A dynamic CLUE defines conversion rates for land-use categories in a conversion matrix. The goals of transformation matrix are:

- Describe other land use categories that allow conversion from the original land use.
- Specify how long a land use type must exist before it can be converted to another land use type at a particular location

The multi-scale relationships generated between land-use change and its drivers serve as direct inputs for dynamic CLUE models. Modeling strategy exhibits these features.

- Every simulation is created with spatial explicitness to produce the ensuing geographic pattern of land use change.
- Provisions for land use change are based on dynamic simulation or modeling of competition between different land use categories.
- Calculated correlations between land-use and a broad range of descriptive elements, along with multi-scale analyses, determine the suitability of several land-use categories, including "local" and "regional".
- Multiple land use change scenarios can be simulated. Different scenarios for agricultural demand growth at the country level can be identified based on changes in consumption patterns, demographics, land use regulations, and export volumes. Various restrictions on the distribution of land use change can be implemented at the sub-national level. For example, conservation of protected areas and restriction of land distribution in areas affected by land degradation.

5.1.3. Model Description

The CLUE model was developed to form statistical relationships between the spatial distribution of land use and its drivers to study land use prospects considering system theory. A first assumption is made: demand for different land-use types in a given area is the main driver, with total demand area, socio-economic status, local natural environment, and specific land-use patterns. The relationship between remains in dynamic equilibrium.

CLUE model consist of 02 different modules, as non-spatial demand module and spatially explicit allocation procedure. The non-spatial analysis module analyzes regional changes in all types of land use over a specified time period, or changes in all types of areas over this time period, based on investigations of ecological, social and economic variables. The Spatial Studies module interprets these requirements into appropriate regional land-use changes according to spatial factors influenced by land-use categories to create spatial simulations of land-use.

5.1.4. Methods

The CLUE methodology is based on functioning of the land-use system theories which are resulting by landscape ecology. There are many structural, functional, and change similarities in natural ecosystems with the social systems and land use patterns that support land use changes. Similar to natural ecosystems, social systems and agroecosystems are complex adaptive systems that may be explained by ecological theories and methods.

The mapping of different land-use types at the grid-cell level in the CLUE modeling framework is based on the combined effects of variables related to geographic suitability, agent competition, and political and socioeconomic environment. The conversion elasticity, which ranges from 0 (easy) to 1 (difficult), is established based on capital investment to define the level of competition between various land use categories. Low capital land uses such as agricultural land were assigned low values (0.2) and high capital land uses such as urban construction were assigned high values. Not all types of land use change are logically and rationally possible, so for example the conversion of urban areas to agricultural areas or the conversion of savannahs to forests is a rational land use change. It is highly questionable whether change is possible. The time series should be listed in the transformation matrix.

5.1.5. Data Representation

These different scale of study require slightly different methods for analyzing the change of land-use. Important variance is that in grid-based methods, the data representation describes land use by most prominent land use category within a grid cell. Though, in large area implementations, for example, land use was represented by specifying the relative extent of each type of land use within each grid cell. A grid cell can contain 30% cropland, 30% forest, and 40% grassland. For individual administrative units, census data represent the number of hectares (ha) allocated to various land-use categories. Presenting the study's data at a large scale and correspondingly coarser resolution introduces significant biases when the data are presented by major land-use categories in the grid cells. For applications in small regions, the situation is different.

III.CONCLUSION

Criteria	METRONMICA	FUTURES	URBAN SIM	SLEUTH	CLUE
1.	Possibility to run with available data				
	√	√	√	x	√
2.	Higher Quality of spatial resolution				
	√	√	√	√	√
3.	Annual evolution				
	√	√	√	x	√
4.	Neighborhood influence / effect				
	√	√	√	√	√
5.	Approach of Multi-scale				
	√	√	√	√	√
6.	Ranking of roles				
	√	√	x	√	x
7.	Fitness of the model				
	√	√	√	√	√
8.	Policies involvement				
	√	√	√	√	√
9	Active accessibility				
	√	√	√	√	√
10.	Support of Policies				
	√	√	√	√	x

The reviewed applications are the trending applications that currently use for decision making. Table 1 shows the differences and similarities between selected land-use models used in simulation practice over the past decades. A check (√) indicates model fit and a cross (x) indicates lack of fit.

Metronamica and futures tools are showed excellent performance according to all criteria listed in Table 1. Though some applications have some limitations, those have brilliant performance on land use change.

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