Modelling land cover change with a CA-Markov Model for The Siliana Hydrological catchment (Northwestern Tunisia)

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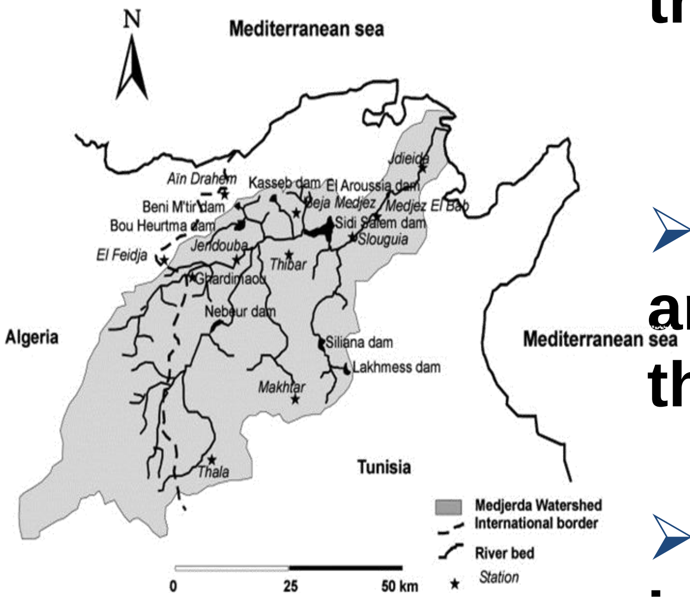
Context



➢The Medjerda catchment area represents 37% of Tunisia's surface water and provides water for half the population.

➢studies have shown that alterations in LULC have an impact on the availability of water resources and the hydrological cycle (Krause et al.,2008)

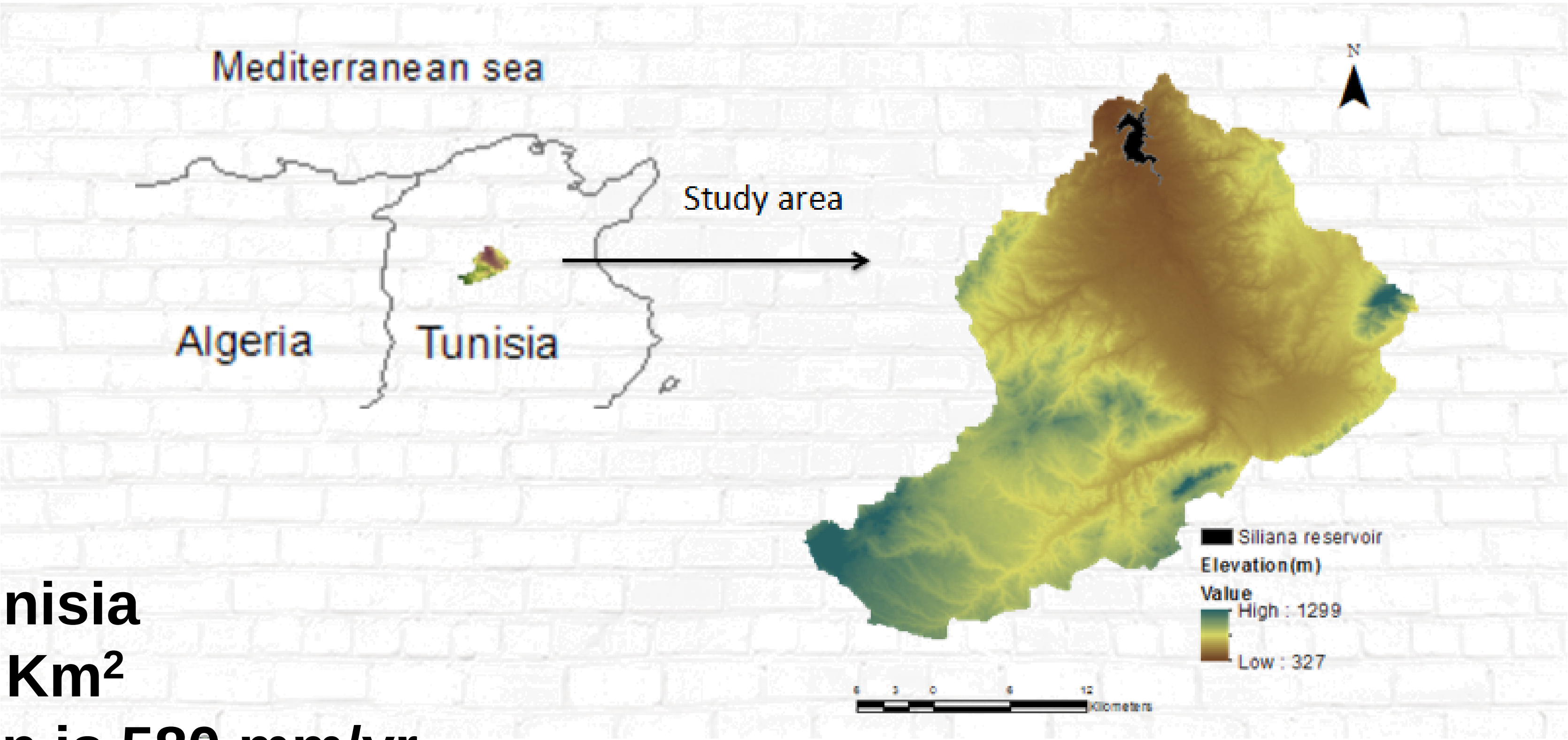
➢Remote sensing (RS) and (GIS) are essential tools in obtaining accurate and timely spatial data of LULC, as well as analyzing the changes in a study area (Srivastava PK et all 2013).

Objectives

To model land use dynamics (historical and future) of the Siliana catchment in Tunisia

using stochastic GIS embedded LU dynamic model based on Markov Chain and Cellular Automata

The study area



Location: NW of Tunisia
Surface area: 1028 Km^2
Annual precipitation is 580 mm/yr
Main land use type : Cereals 64% of the catchment area
Major soil groups : Limestone and Luvisol (22% and 21,7%)

Data required: Satellite data

Period	Satellite and data type	Resolution (m)
1990	Landsat5,TM	30
2000	Landsat5,TM	30
2010	Landsat5,TM	30
2019	Landsat8,OLI	30

Data required: Biophysical data

Data type	Date of production	Source
Land cover map	2010	Siliana Agricultural map
DEM	2014	SRTM
Precipitation	Daily(2000-2010)	DGRE

Data required: Socio-economic data

Data type	Date of production	Source
Population	2000-2010	Siliana Agricultural map
Settlement	2000-2010	Siliana Agricultural map
Road Network	2000-2010	Siliana Agricultural map
Railway Network	2000-2010	Siliana Agricultural map

Method: Supervised classification

Preparing land use maps

Landsat satellite images (1990-2000-2010-2019)

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Correction and improvement of satellite images with ERDAS software

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Supervised classification of satellite images

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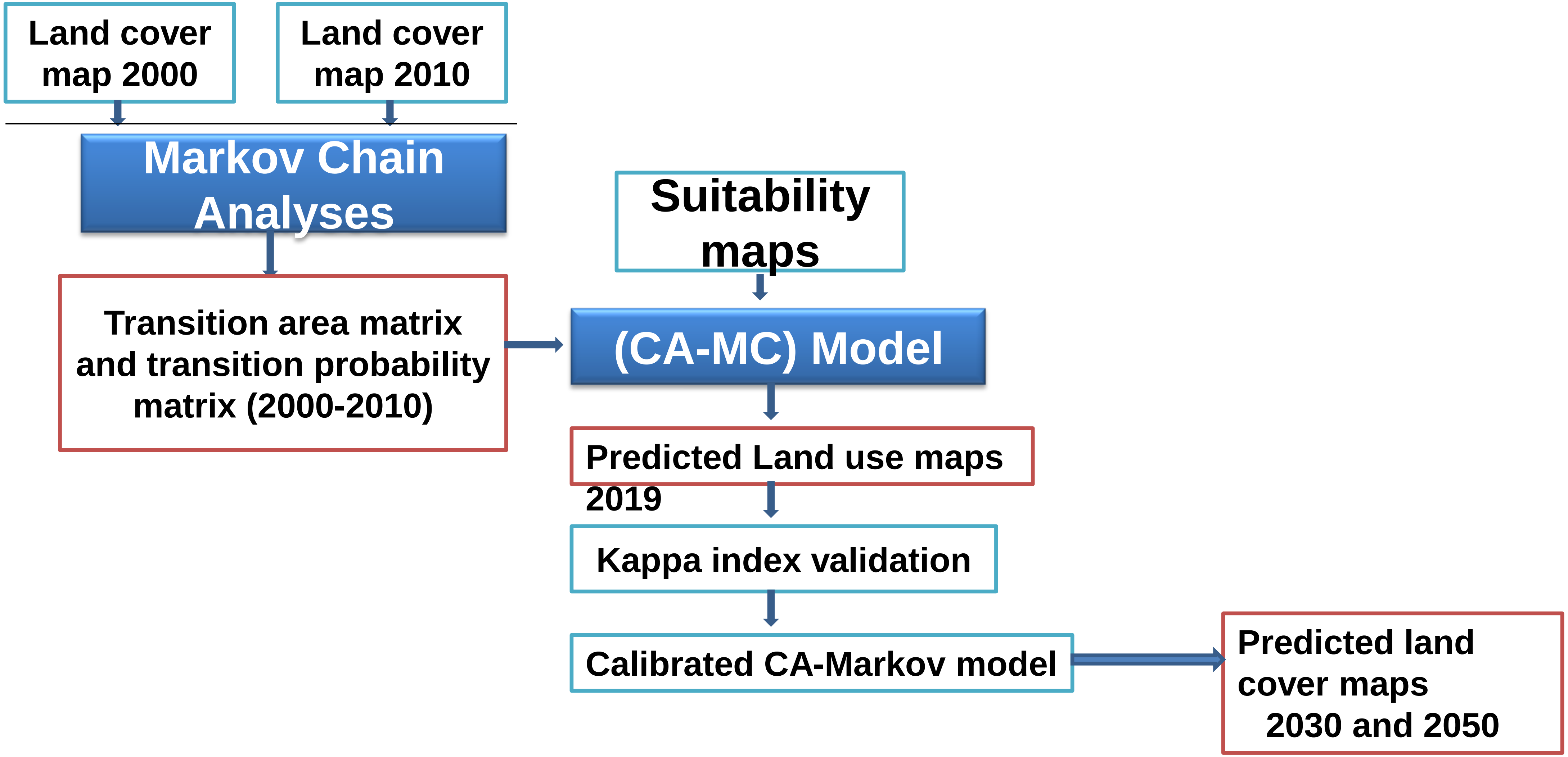
Elaboration of land use maps with Arcgis software

Method:CA-MC modelling



Method:Markov Chain Analysis (MCA)

A **Markov model** is a stochastic model proposed by Russian mathematician Andrei Markov

The probability of moving from one state to another state is called **a transition probability.**

Transition Probability Matrix

$$P = P_{ij} = \begin{bmatrix} P_{11} & P_{12} & \cdots\cdots & P_{1n} \\ P_{21} & P_{22} & & P_{2n} \\ & & & \\ P_{n1} & P_{n2} & & P_{nn} \end{bmatrix}$$

where P = Markov transition probability matrix

i, j = the land type of the first and second time period

Pij= the probability from land type i to land type j

The Transition Area Matrix is produced by multiplying each column of the Transition Probability Matrix (P) by number of pixels of corresponding class in the latter image.

Method:Cellular Automata (CA) Model

A **cellular automaton** is a discrete model for modeling spatial dynamics.

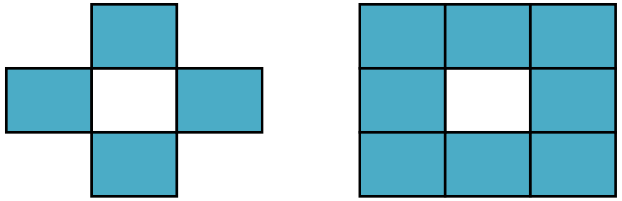
$$S_{t+1} = f(S_t, N, T)$$

where S_{t+1}= State at time t+1

S_t= State at time t

N = Neighbourhood

T = Transition Rule

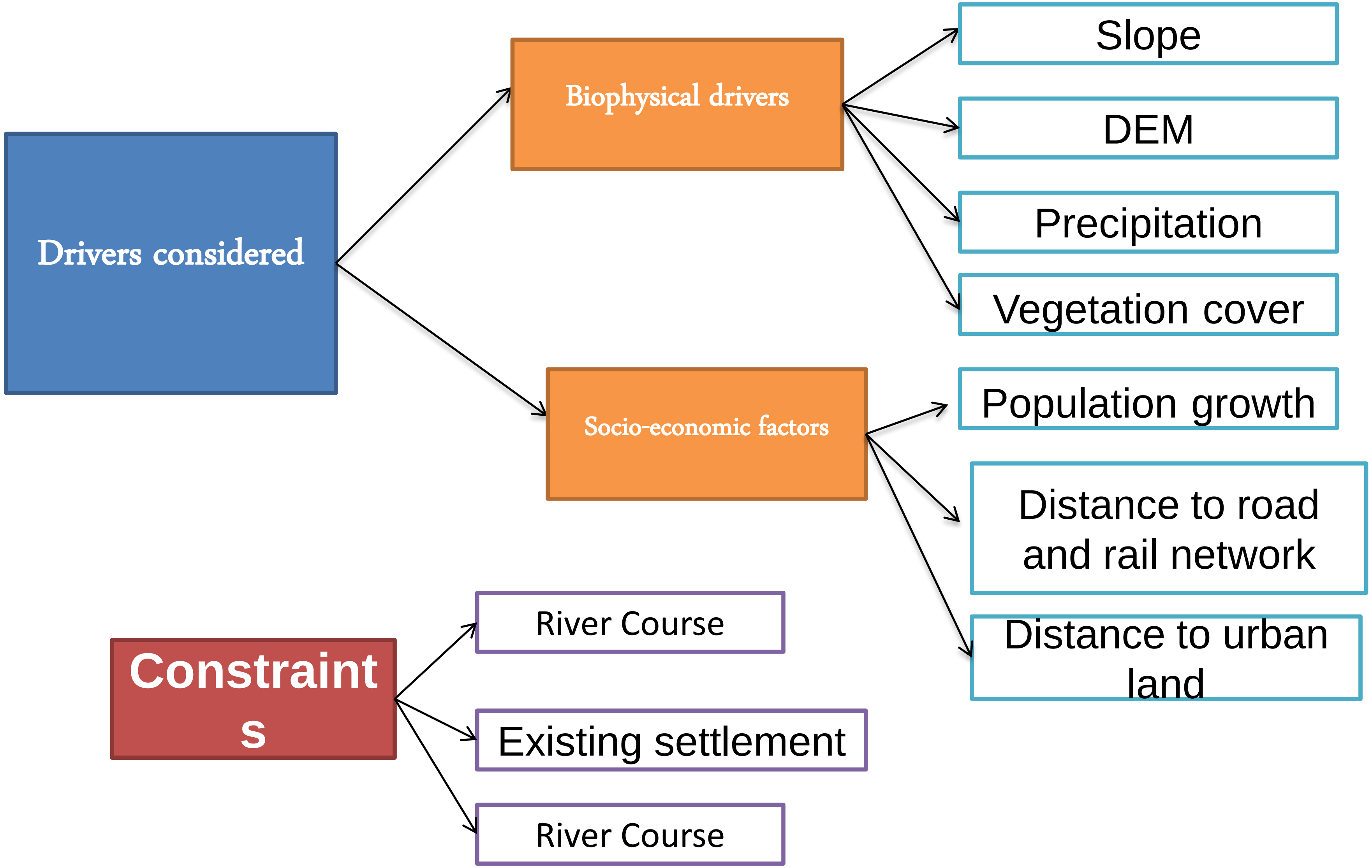


Ex. Von Neumann's Neighbor and Moore's Neighbor

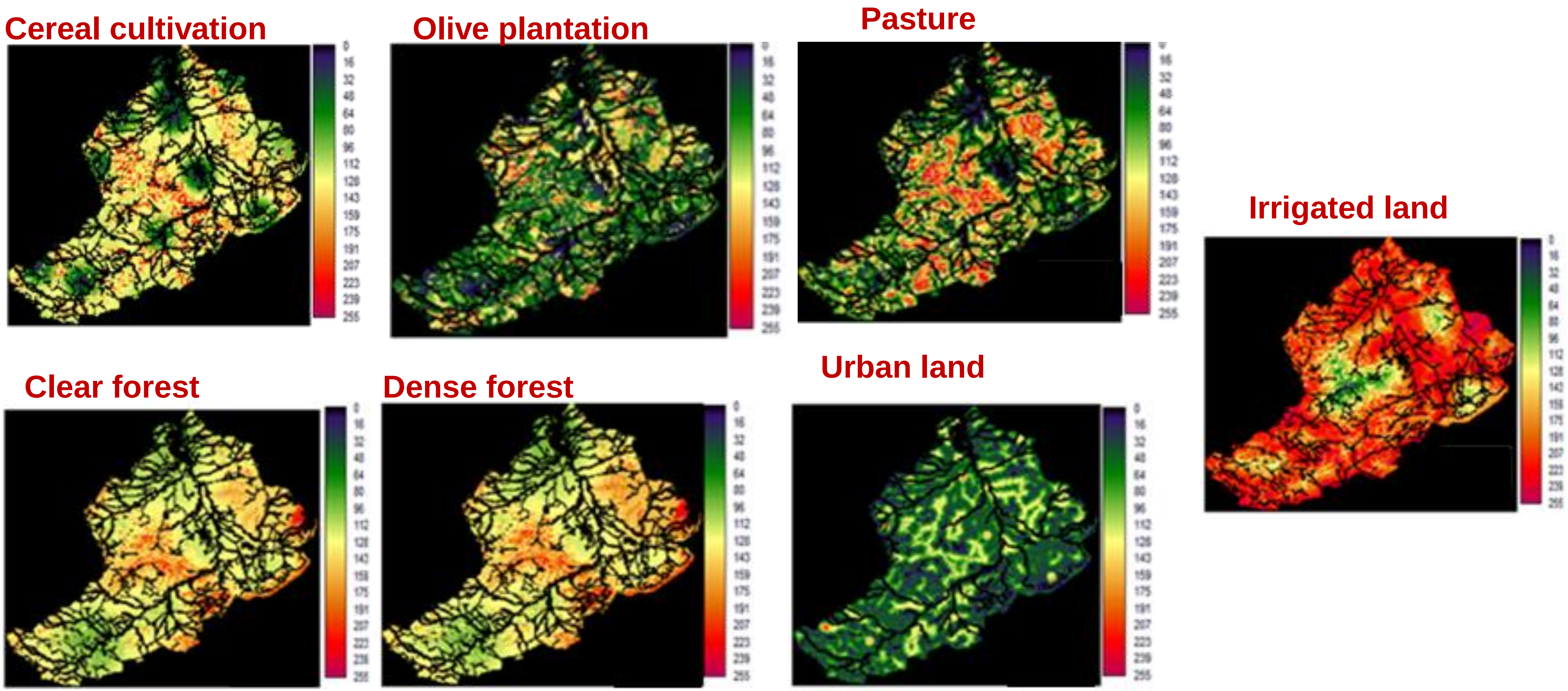
Transition rules: The evolution of each cell is affected by its own state and the state of its immediate neighbors to the left and right.

Method: Transition suitability maps

Transition suitability implies the suitability of a cell for a particular land cover.



Method: Suitability maps



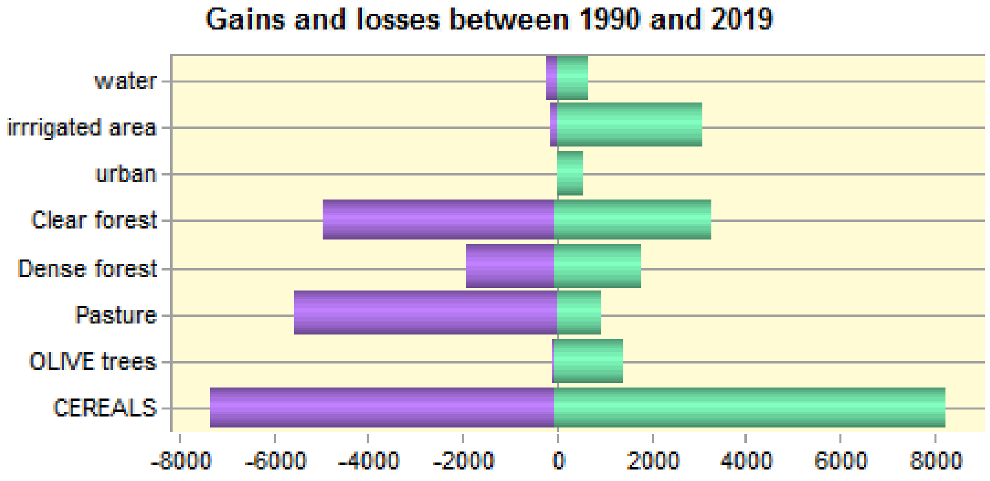
Results: Accuracy assessment

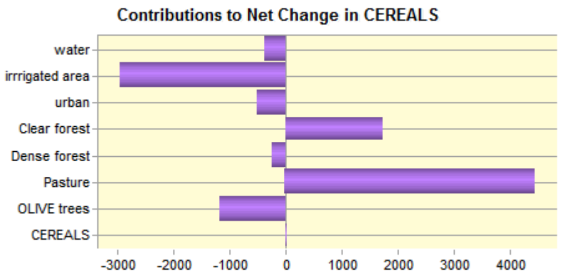
Land Cover Class	1990		2000		2010		2019	
	Procedure accuracy	User accuracy	Procedure accuracy	User accuracy	Procedure accuracy	User accuracy	Procedure accuracy	User accuracy
Agriculture	0.88	0.8	0.9	0.7	0.91	0.85	1	0.88
Pasture	0.75	0.74	0.75	0.713	0.74	0.69	0.79	0.84
Forest	0.85	0.92	0.83	0.96	0.8	0.88	0.91	0.98
urban	0.9	0.88	0.87	0.925	0.89	0.95	1	0.98
Water	0.88	0.9	0.93	0.98	0.91	1	0.91	1
Overall accuracy	83.7		85.5		85.25		91.75	
Kappa	80.4		81.8		81.56		89.7	

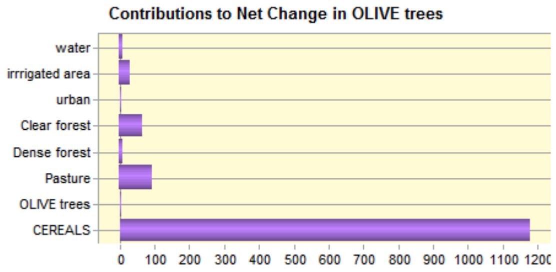
Results:LULC distribution(1990-2019)

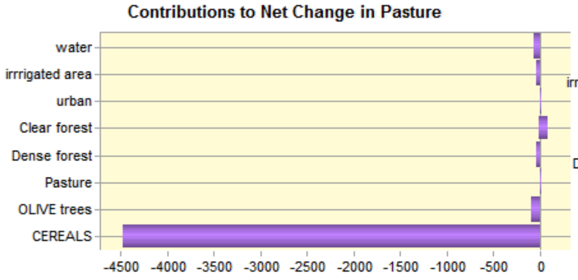
Class	1990		2000		2010		2019	
	Area(ha)	(%)	Area(ha)	(%)	Area(ha)	(%)	Area(ha)	(%)
Cereal cultivation	73678	71.69	73387	71.43	74082	72.11	74627	72.61
Olive plantation	357	0.35	807	0.79	1647	1.60	1748	1.70
Pasture	7302	7.10	6331	6.16	5990	5.83	2691	2.62
Dense forest	4481	4.36	4251	4.14	3183	3.10	4423	4.30
Clear forest	14617	14.22	14633	14.24	13724	13.36	12967	12.62
Urban land	271	0.26	441	0.43	686	0.67	828	0.81
Irrigated land	967	0.94	1462	1.42	2042	1.99	3960	3.85
Water	1104	1.07	1429	1.39	1423	1.39	1533	1.49

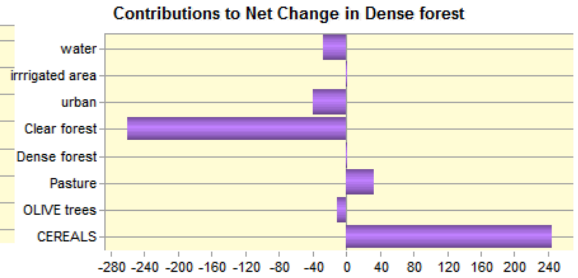
Results: LULC dynamic(1990-2019)

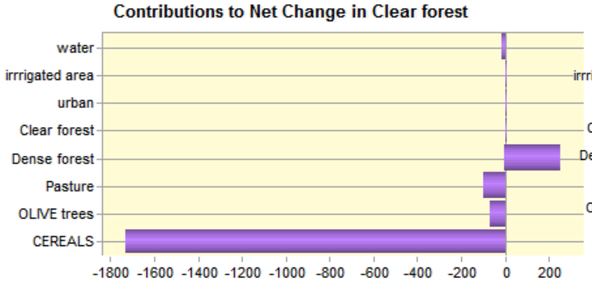


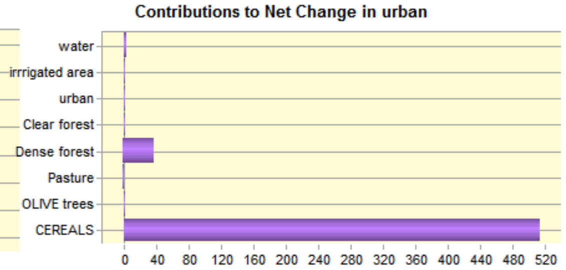


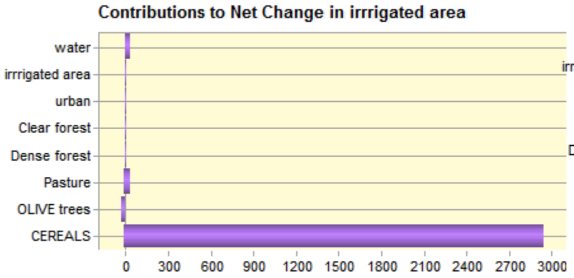


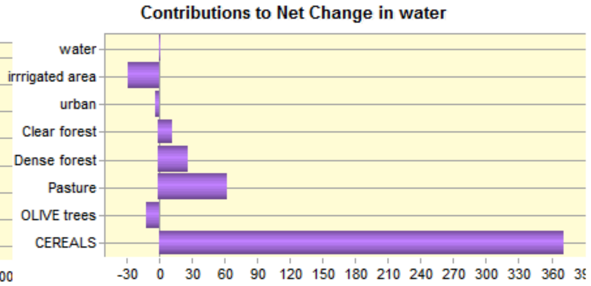




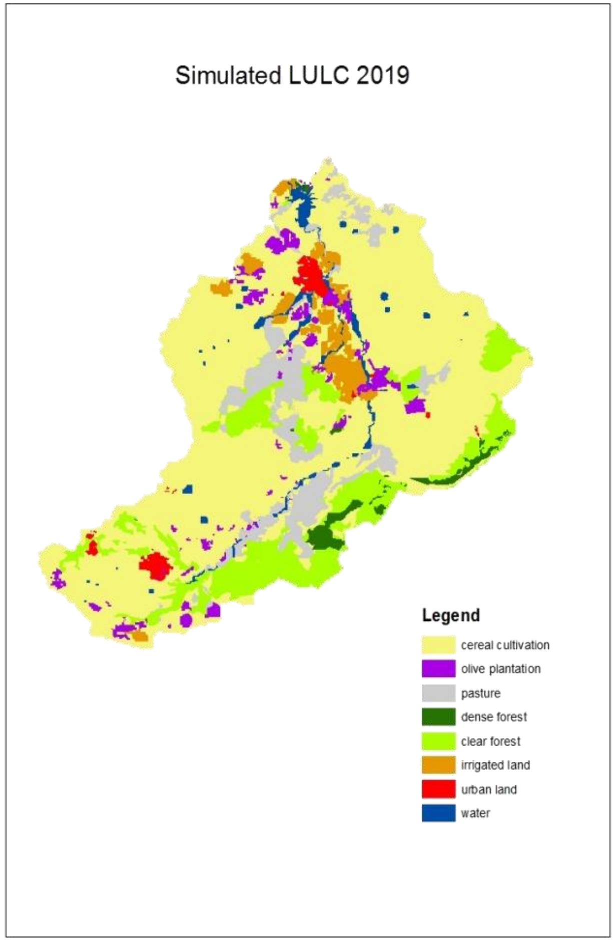


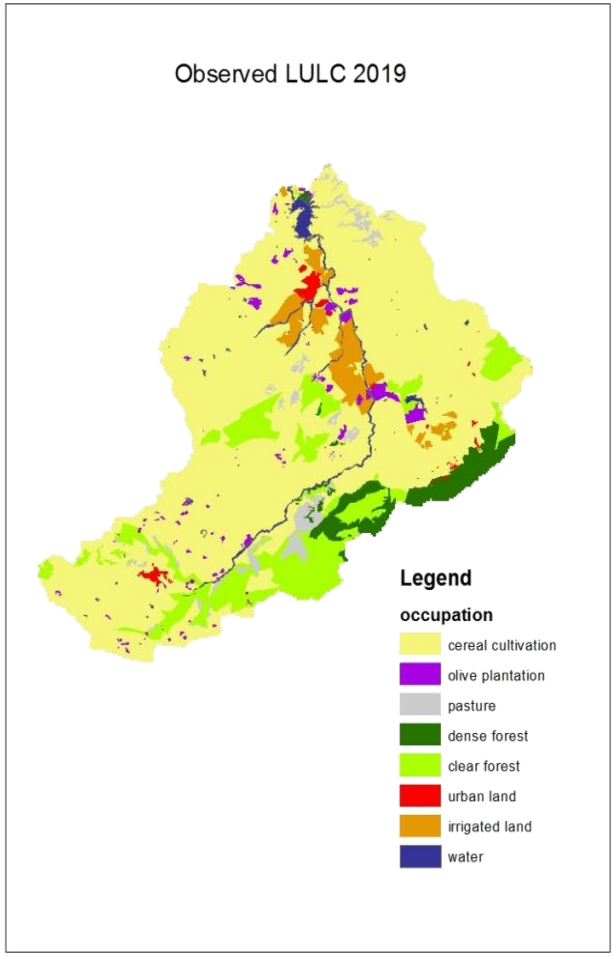






Results: CA-Markov simulation

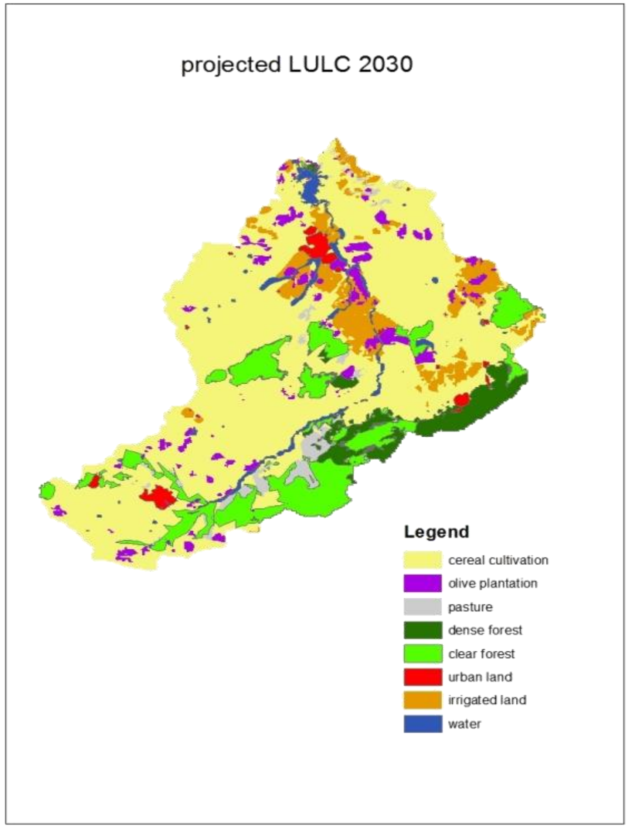


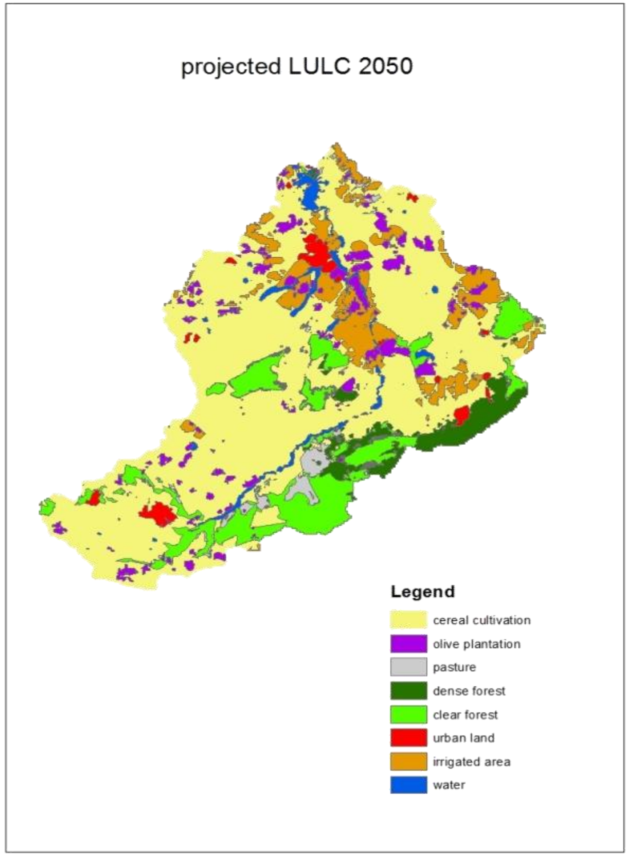


Kappa

Poor agreement: < 0,20
Fair agreement: 0,20 à 0,40
Moderate agreement: 0,40 à 0,60
Good agreement: 0,60 à 0,80
Very good agreement: 0.80 à 1.00

Results:CA-Markov prediction





Results:LULC future

	2030		2050	
	Area(ha)	Percent(%)	Area(ha)	Percent(%)
Cereal cultivation	65322	63.56	64255	62.52
Olive plantation	4737	4.61	5426	5.28
Pasture	2694	2.62	1890	1.48
Clear forest	4974	4.84	4750	4.62
Dense forest	13082	12.73	12276	11.94
Urban	1637	1.59	2008	1.95
Irrigated land	8042	7.82	9694	9.43
Water	2289	2.23	2480	2.41

Conclusion

- ✓ The study has demonstrated the applicability of a stochastic model that combines Markov Chain (MC) and Cellular Automata (CA) model to model land use dynamics.

- ✓ The combination of Markov and CA was reasonably accurate for projecting future LULC since it produed a kappa coefficient over 60%.

- ✓ We can prepare the future watershed management plan on the basis of projected land use land cover of watershed dynamics by MC-CA model.

Thank you