Multi-temporal and multi-scale assessment of landscape pattern dynamics in Tunisia using MODIS and Landsat data

Final Workshop "Sustainable Land Management to Achieve Land Degradation Neutrality: Options-by-Context Approach and Tools"

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Tunis, Tunisia

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1. Background

2. Methodology

3. Results

4. Conclusions & Perspectives

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BACKGROUND

Monitoring land cover change is very crucial for assessing land performance, especially in the context of land degradation neutrality achievement (Symeonakis et al, 2015; Salvati et al, 2014)

Landscape pattern analysis based on spatial land cover data need continuous updates at various spatio-temporal scales (Senf et al. ,2015; Pilloni et al, 2010) for better monitoring and guided decision making

Research Questions:

- How has land change at the country and governorate levels been distributed between 2002 and 2013?
- What are the patterns of land improvement/degradation in Zaghouan governorate?

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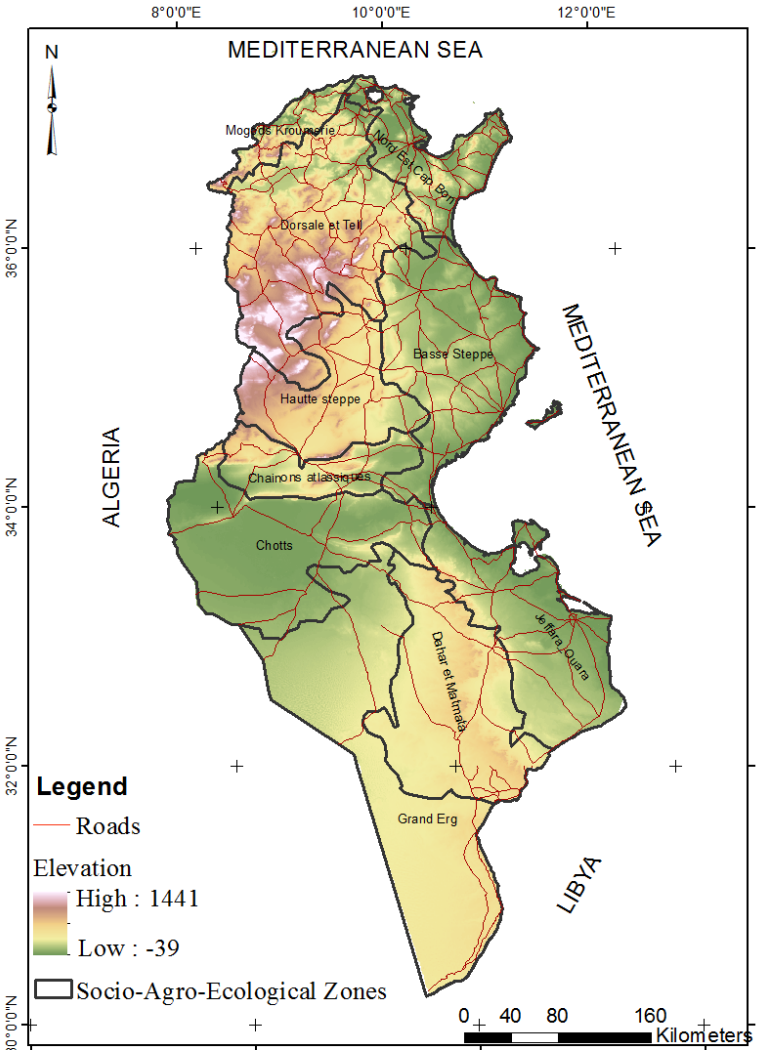
METHODOLOGY

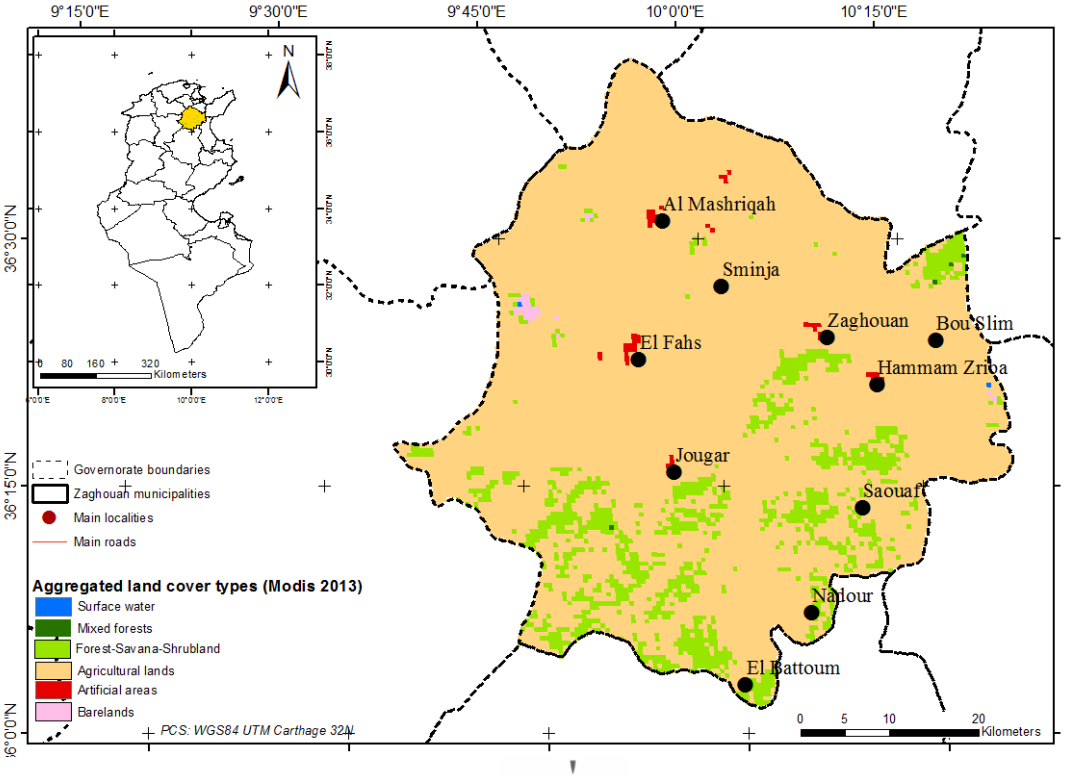
Study area:

Area: 163 610 km2
Admin units: 24 governorates
Population: ~ 12 Million (INS, 2016)
Land degradation: > 70 % of the national lands
Landscapes: deserts, savanna, forest, croplands
Climate: Semi-arid to Mediterranean

1. National level: Tunisia



2. Sub-national level: Governorate of Zaghouan



METHODOLOGY (CONT'D)

Main data and sources:

Data	Date	Sources	Scale of interest	Bands of interest
MODIS (MCD12Q1)	Yearly, 2001 & 2013	USGS	National + Governorate	Yearly composites
Landsat ETM+	Jun & Sept 2001 Feb & Jun 2002	USGS	Governorate	6 Bands (1 – 5 + 7) + vegetation indices
Landsat OLI	March & Sept 2013	USGS	Governorate	Bands 1 – 7 + vegetation indices
Google Earth images	2001/2002 and 2013	Google Earth engine	National & Governorate	High resolution images
LUCC maps	2005, 2010	LADA report & DGACTA (2005)	National & Governorate	- -

General approaches:

- Supervised classification (Random Forest Classifier) of Landsat OLI & ETM+
- Reclassification of MODIS MCD12Q1
- Post-classification change detection
- Land quality change analysis
- Landscape metrics calculation and comparison

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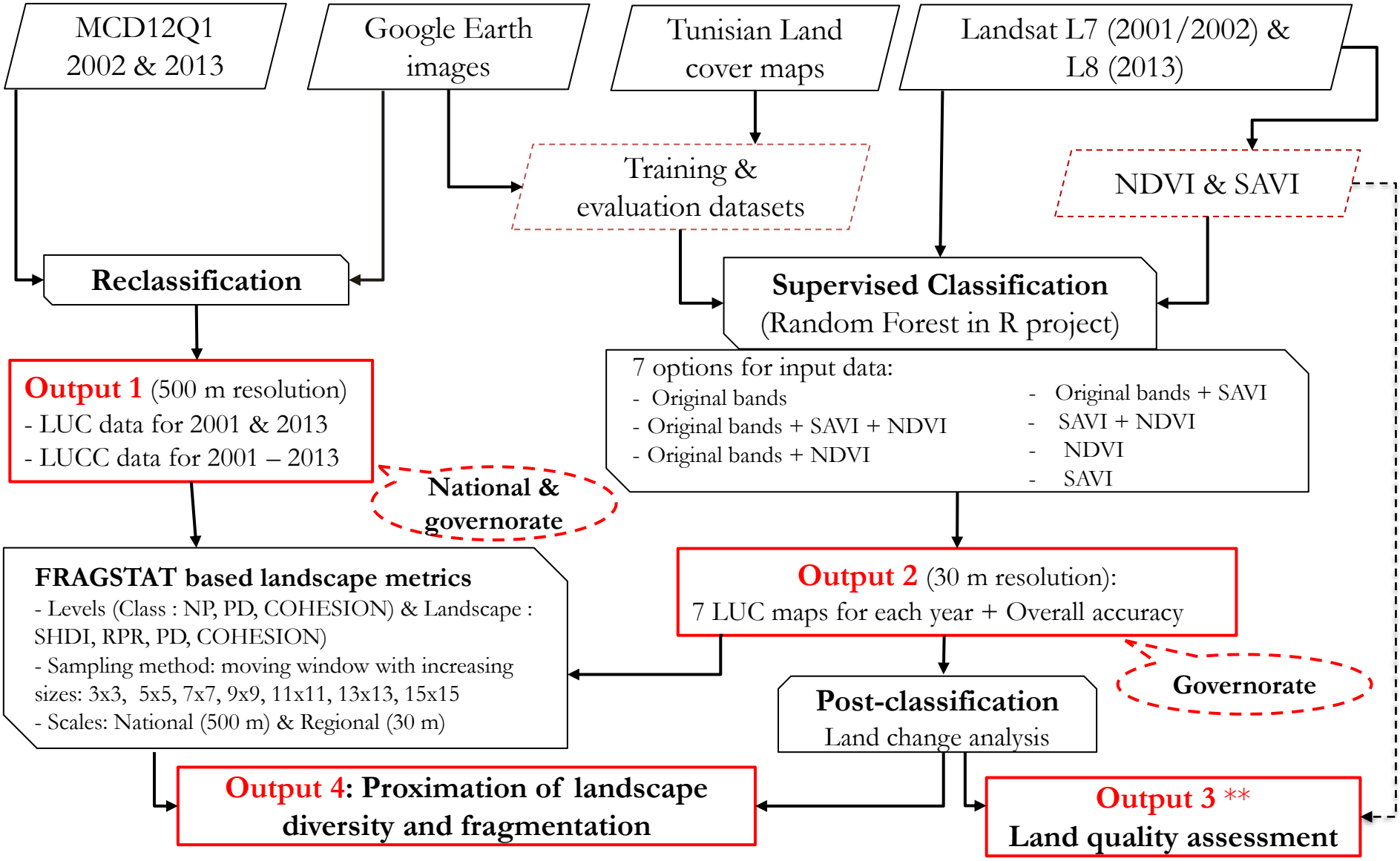
METHODOLOGY (CONT'D)

Definition of aggregated land use/cover types used in this study (adapted from **LADA-Tunisia, 2010)**

Land use/cover types	Definitions
Forests – Shrublands	Natural or semi-natural terrestrial vegetation, including closed trees, shrublands of any category. This includes reforested areas
Scrubs & Herbaceous vegetation	Natural or semi-natural herbaceous vegetation, including scrublands of all types (closed to open), and all herbaceous vegetation with sparse shrubs, on temporarily or permanently flooded lands
Tree crops	Mostly cultivated areas, including tree crops of large to small sized fields, and shrub crops, rainfed or irrigated.
Cereals crops	Herbaceous crops dominantly, including cereal crops of large to small sized fields, rainfed or irrigated crops.
Artificial areas	Mainly urban areas, roads, quarries, and other artificial areas (industrial areas, etc.)
Bare areas	Exposed bare surfaces, including rocks, unconsolidated surface materials, sands of all types
Water bodies	All types of surface water, including artificial and natural waterbodies, inland water, fresh and perennial water.

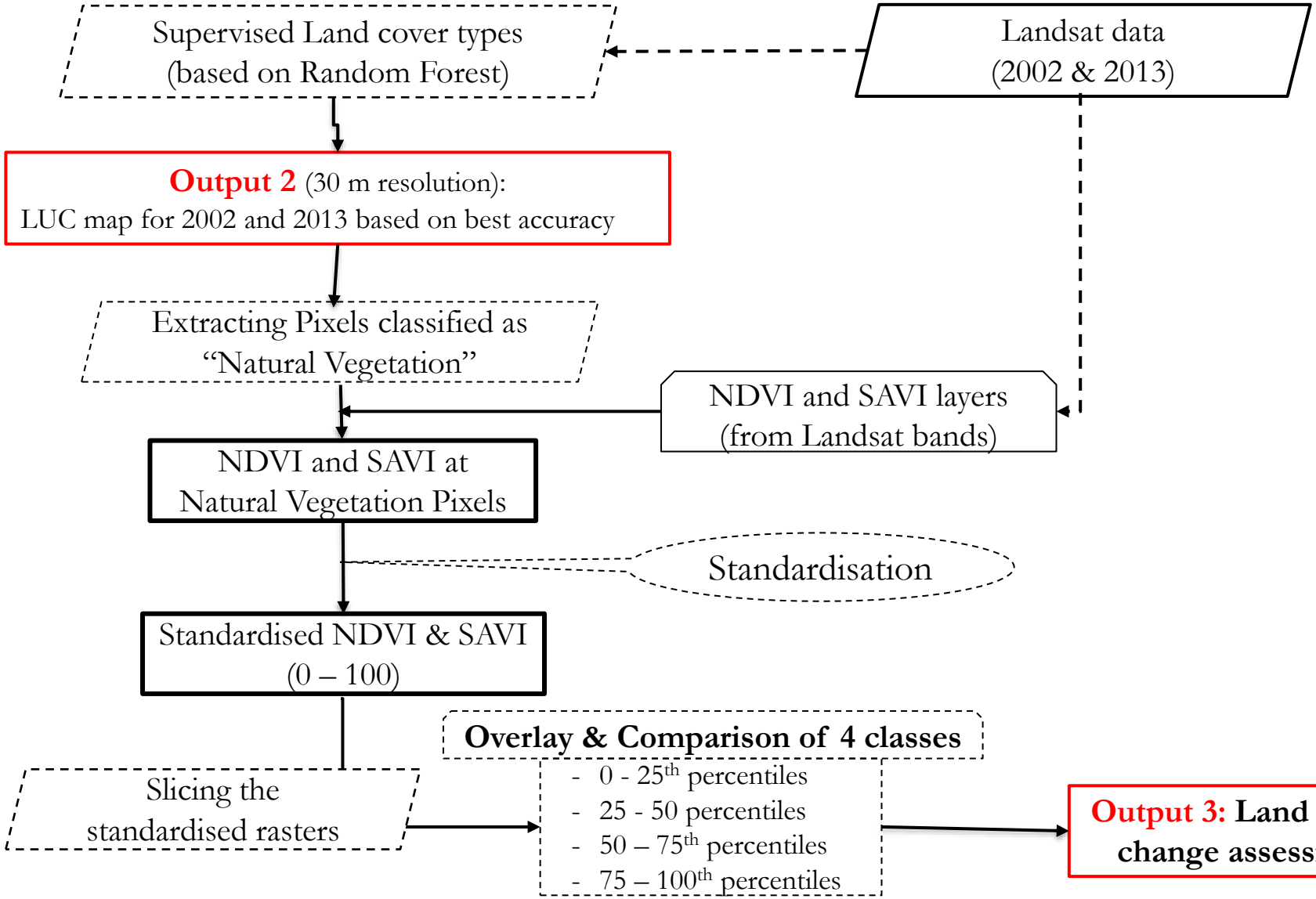
METHODOLOGY (CONT'D)

Summarised Analysis Flowchart (Source: Authors)



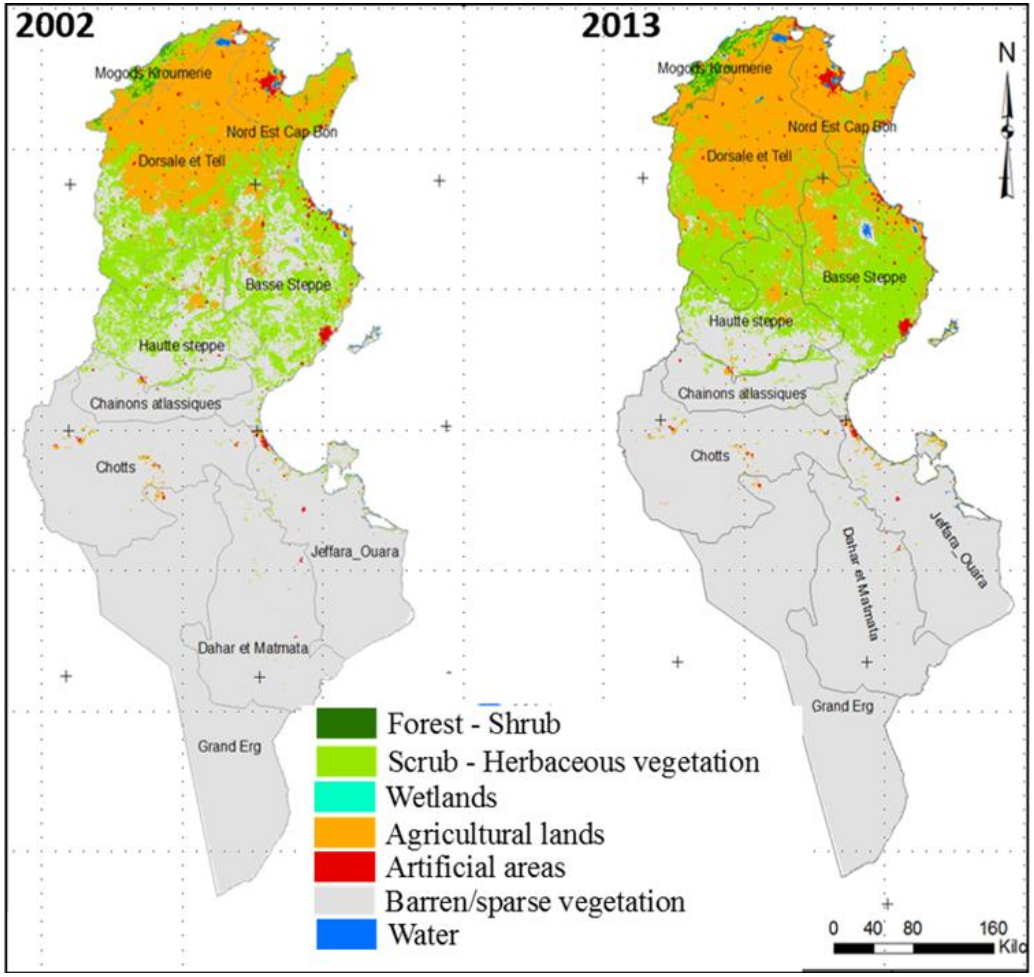
METHODOLOGY (CONT'D)

Summarised Flowchart for analysing land quality change (Source: Authors)



MAIN RESULTS

Output 1. MODIS based Land cover maps for Tunisia (National level)



LUC	2002 (Areas in ha)	2013 (Areas in ha)	Change (in ha)
Forest-Shrub	41094.96	88999.49	47904.53
Scrubland-grassland	2464316.49	2625209.54	160893.05
Wetlands	1115.15	6069.97	4954.83
Agric. lands	2279722.04	2938599.54	658877.50
Artificial areas	122087.67	121377.73	-709.94
Barren	10554889.26	9681449.17	-873440.09
Water	43777.37	45528.52	1751.15

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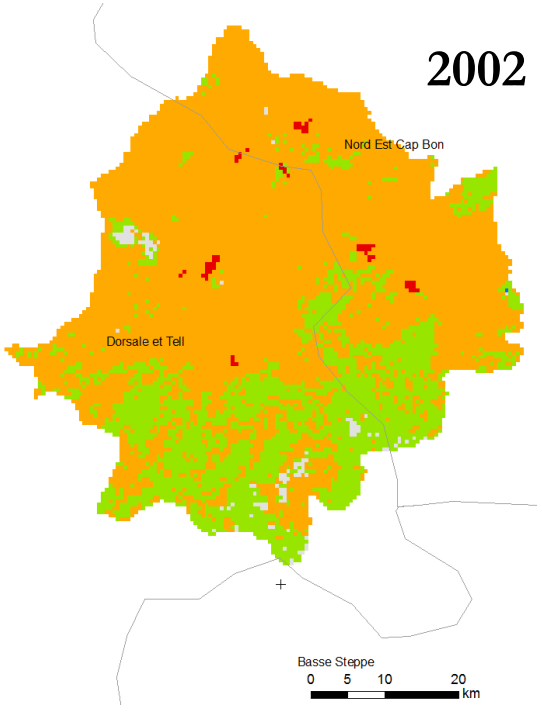
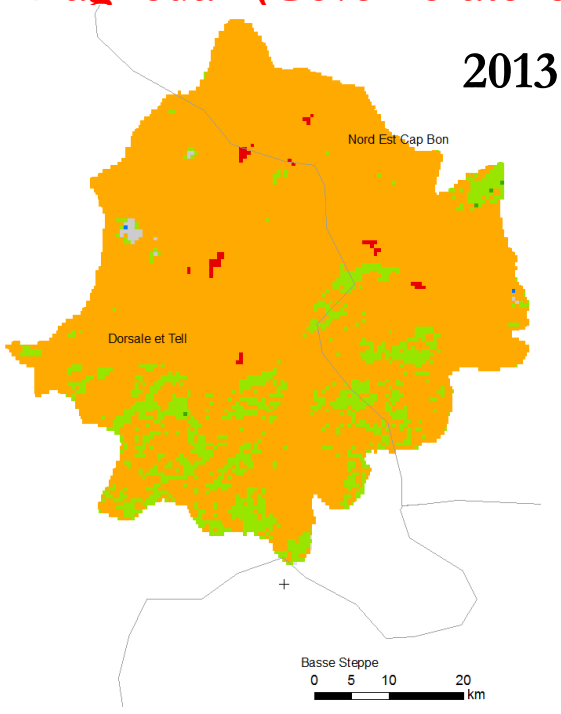
MAIN RESULTS

Output 1: MODIS based Land cover maps for Zaghouan (Governorate level)





2002 (Areas in ha)	2013 (Areas in ha)	Change 2002-2013 (in ha)
25	50	+ 25
75	100	+ 25
72775	31300	- 41475
208102	252775	+ 44155
1575	1200	- 375
3050	725	-2325

Legend

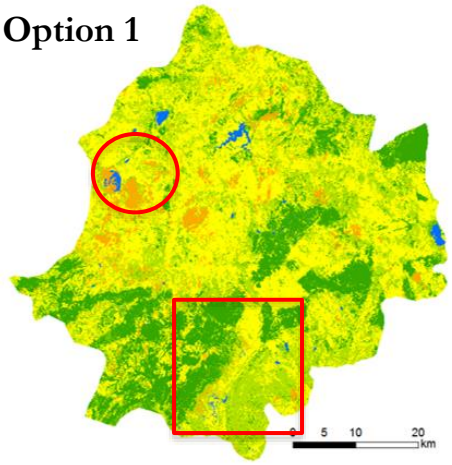
- Water bodies
- Forest-shrubs
- Herbaceous vegetation
- Agricultural lands
- Artificial areas
- Bare lands

MAIN RESULTS

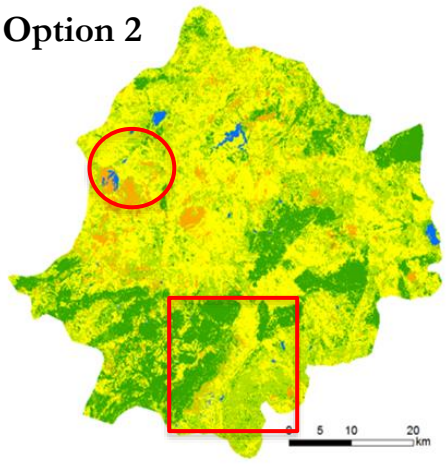
Output 2. Landsat based Land cover maps from the 7 options

Composite 2013

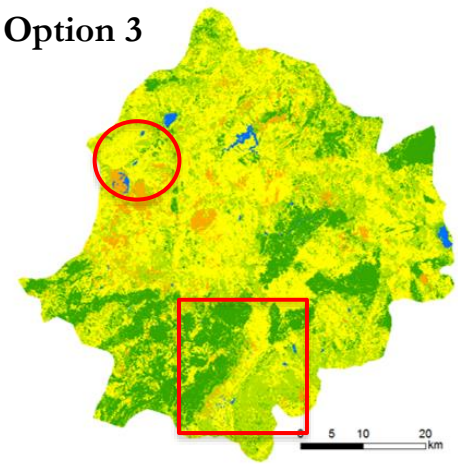
Option 1



Option 2



Option 3



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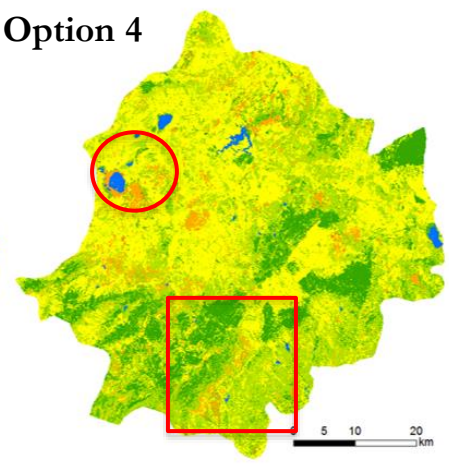
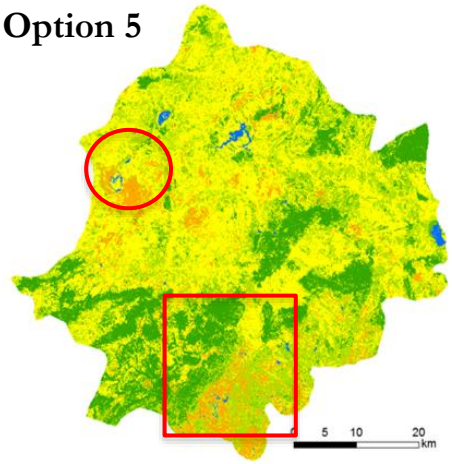


Option 5



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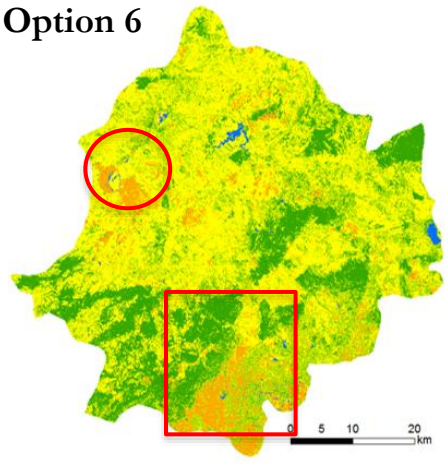
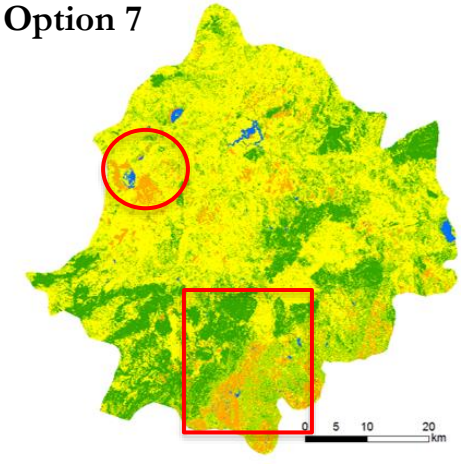


Option 7



1 = Forests – Shrublands
2 = Scrubs & Herbaceous vegetation
3 = Tree crops
4 = Cereal crops
5 = Artificial areas
6 = Bare lands
7 = Surface water

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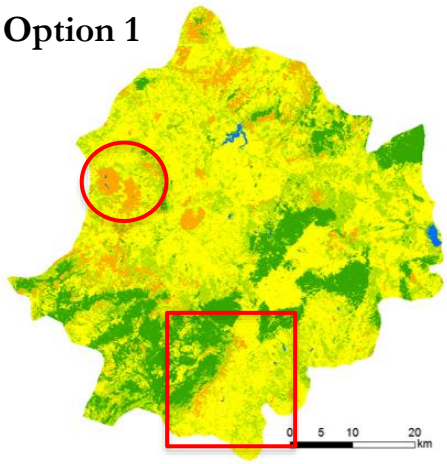
MAIN RESULTS

Output 2. Landsat based Land cover maps from the 7 scenarios

Composite 2002

Option 1



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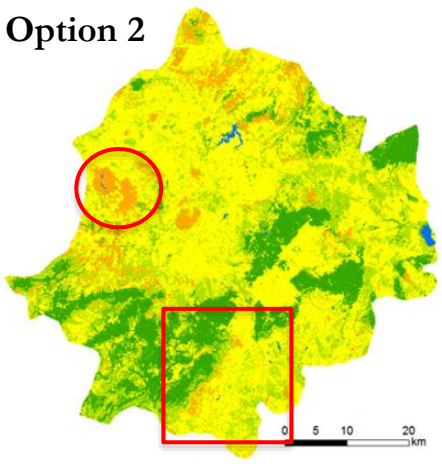

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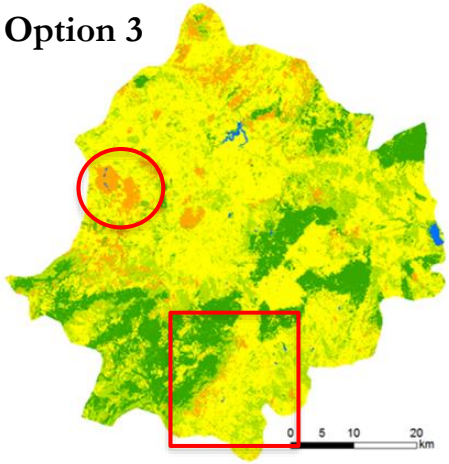
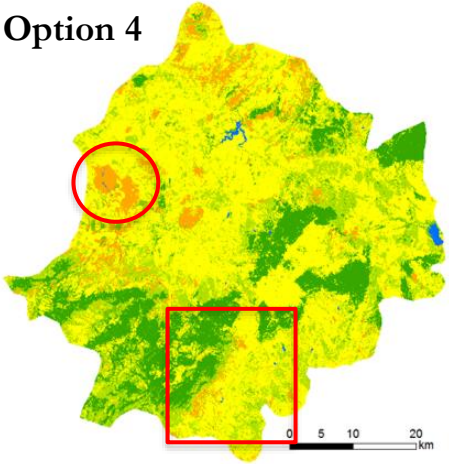
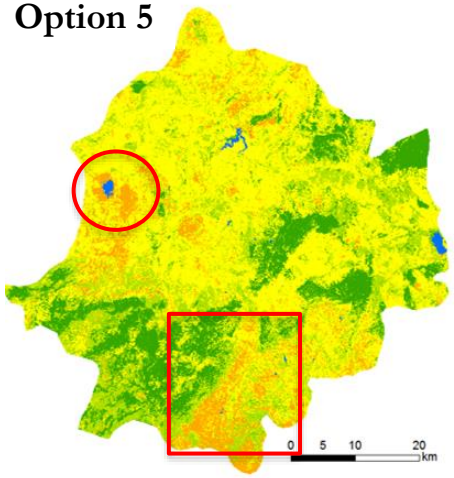


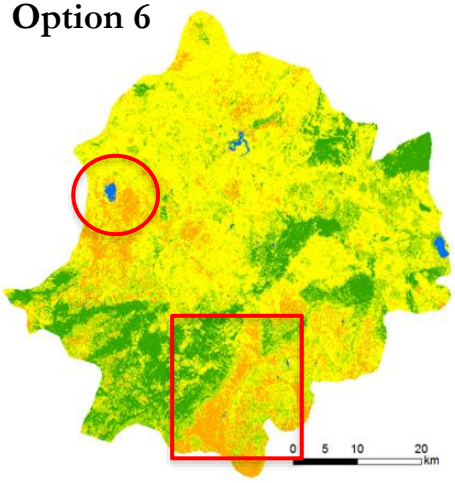
Option 4



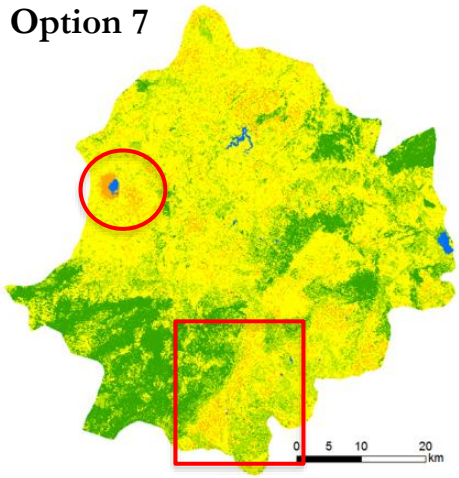
Option 5



Option 6



Option 7



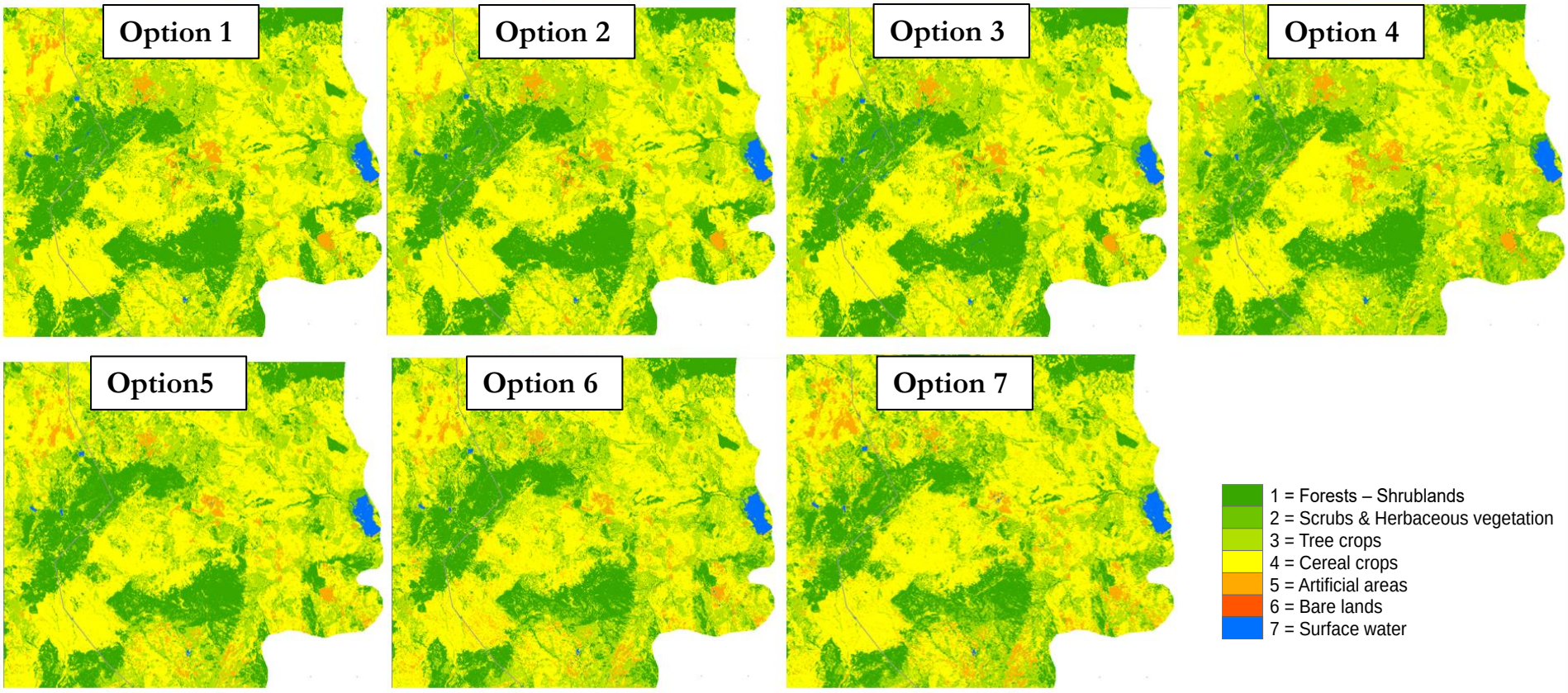
Legend

- 1 = Forests – Shrublands
- 2 = Scrubs & Herbaceous vegetation
- 3 = Tree crops
- 4 = Cereal crops
- 5 = Artificial areas
- 6 = Bare lands
- 7 = Surface water

MAIN RESULTS

Output 2. Landsat based land cover maps: zoom for screening differences

Composite 2013



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MAIN RESULTS

Overall Accuracy and Kappa Index of Agreement

	2002		2013	
Options	Accuracy	Kappa	Accuracy	Kappa
1	**0.74**	**0.62**	**0.77**	**0.69**
2	0.71	0.67	0.76	0.67
3	0.68	0.61	0.76	0.67
4	0.7	0.6	0.73	0.63
5	0.66	0.53	0.71	0.61
6	0.67	0.55	0.69	0.57
7	0.65	0.53	0.71	0.6

Note: Reported values of accuracy at 95 % CI

Options	Composite 2002	Composite 2013
Option 1: all original bands	24 bands	14 bands
Option 2: All original bands + NDVI	28 bands	16 bands
Option 3: All original bands + SAVI	28 bands	16 bands
Option 4: All original bands + SAVI + NDVI	32 bands	18 bands
Option 5: Vegetation indices (SAVI + NDVI)	08 bands	04 bands
Option 6: Only NDVI	04 bands	02 bands
Option 7: Only SAVI	04 bands	02 bands

Confusion matrix (Proportions) for Option 1

2002		Reference							
		1	2	3	4	5	6	7	Class error
Mapped	1	89.87	5.32	9.32	2.63	0.19	0.00	0.00	0.09
	2	3.03	85.11	2.32	2.95	0.29	0.00	0.00	0.66
	3	4.93	3.99	75.40	10.42	2.78	0.00	0.00	0.26
	4	2.15	4.52	12.22	82.56	3.84	0.00	0.65	0.10
	5	0.00	0.00	0.31	0.98	89.84	0.00	0.00	0.10
	6	0.01	0.00	0.25	0.33	2.78	0.00	0.00	1.00
	7	0.00	1.06	0.19	0.13	0.29	0.00	99.35	0.05
2013									
Mapped	1	93.95	1.16	4.80	1.66	0.09	0.00	0.00	0.05
	2	2.29	95.93	2.34	1.65	0.09	0.00	0.00	0.47
	3	2.01	1.36	86.87	4.58	2.49	0.00	0.00	0.11
	4	1.66	1.36	5.31	91.83	0.28	0.00	0.81	0.05
	5	0.00	0.00	0.17	0.07	94.56	0.00	0.00	0.01
	6	0.04	0.00	0.41	0.11	2.12	100	0.00	0.78
	7	0.05	0.19	0.11	0.11	0.37	0.00	99.19	0.04

Legend for LUC types:

1 = Forests – Shrublands
2 = Scrubs & Herbaceous vegetation
3 = Tree crops
4 = Cereal crops
5 = Artificial areas
6 = Bare lands
7 = Surface water

Accuracy levels:

Very high accuracy (> 95 %)
High accuracy (85 – 95 %)
Adequate accuracy (75 – 85%)
Low accuracy (< 75%)

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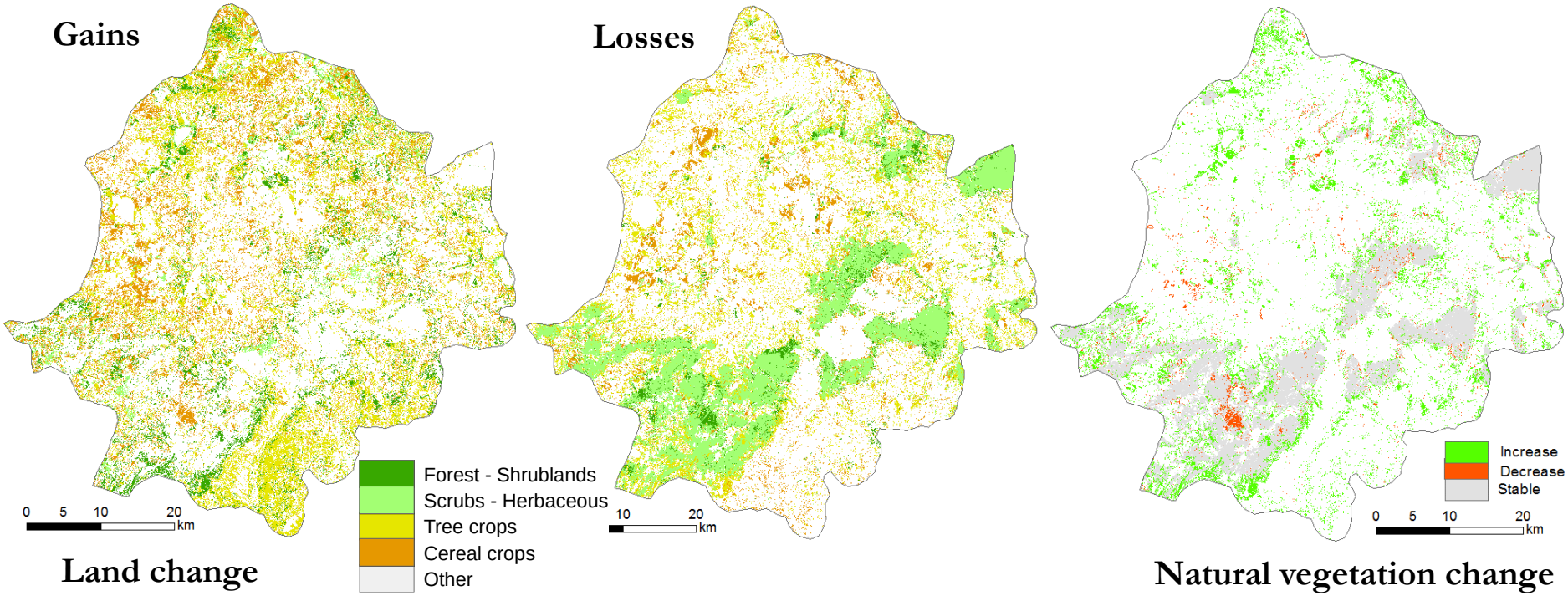
RESULTS

Output 3. Landsat based Land cover changes between 2002 and 2013



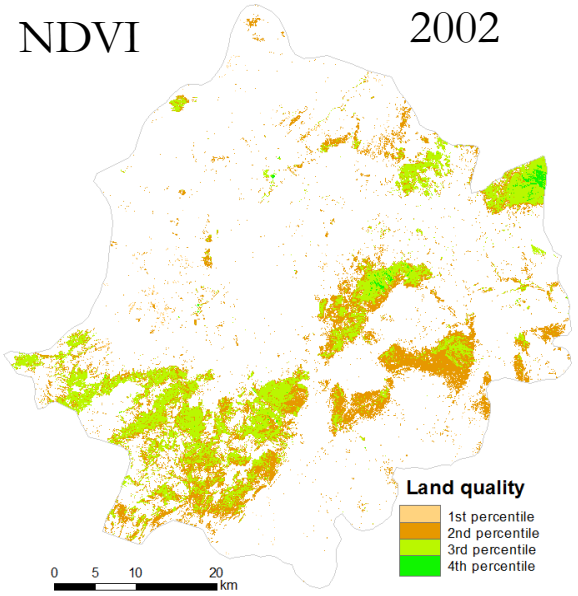
Land types	Gains	Losses	Net
Forest - Shrublands	18476.19	8191.26	10284.93
Scrubs - herbaceous	6365.7	45068.85	-38703.15
Tree crops	41650.47	32950.44	8700.03
Cereal crops	27736.11	14239.26	13496.85

RESULTS

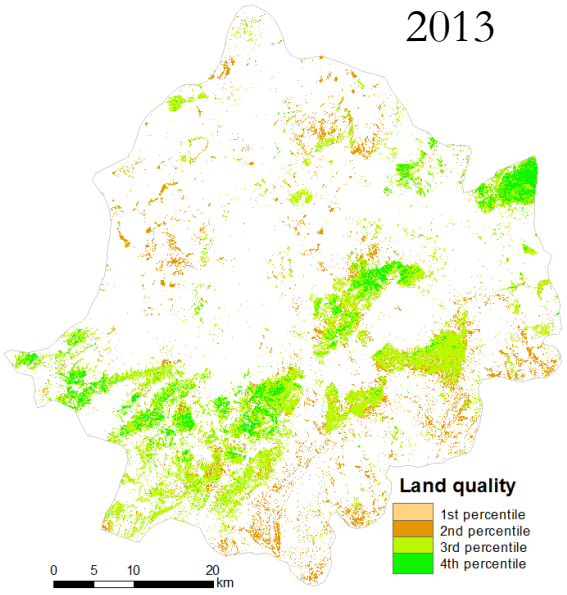
Output 3. Land quality change based on Landsat NDVI and SAVI

NDVI

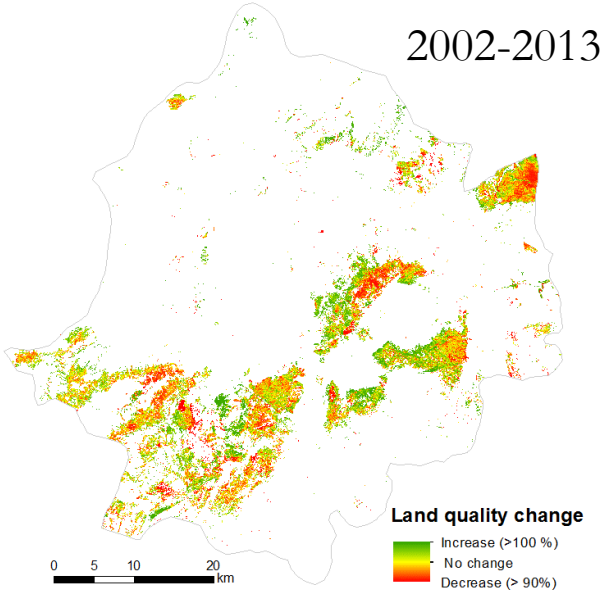
2002



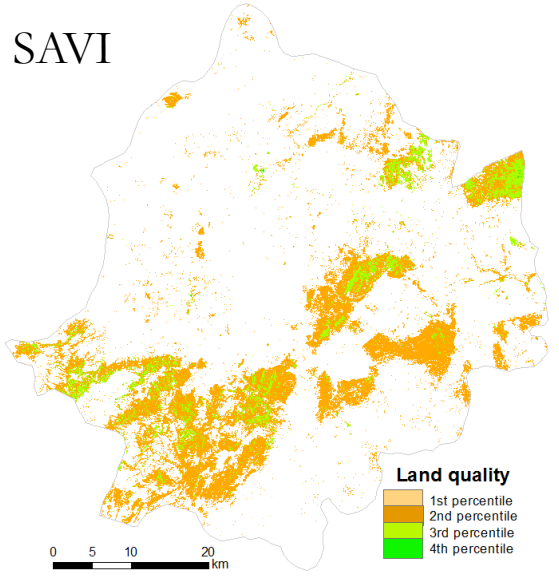
2013

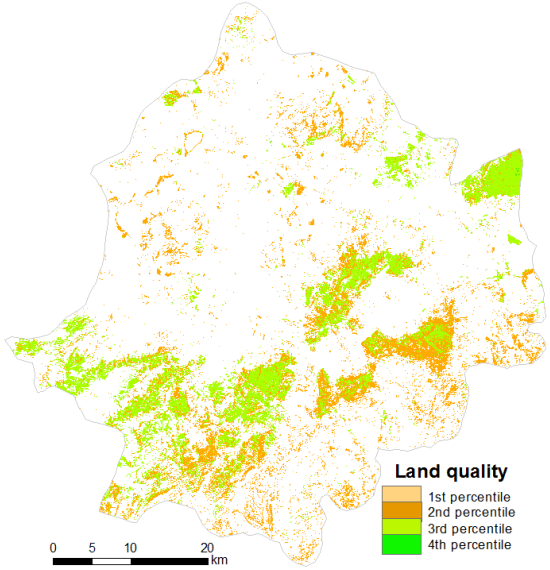


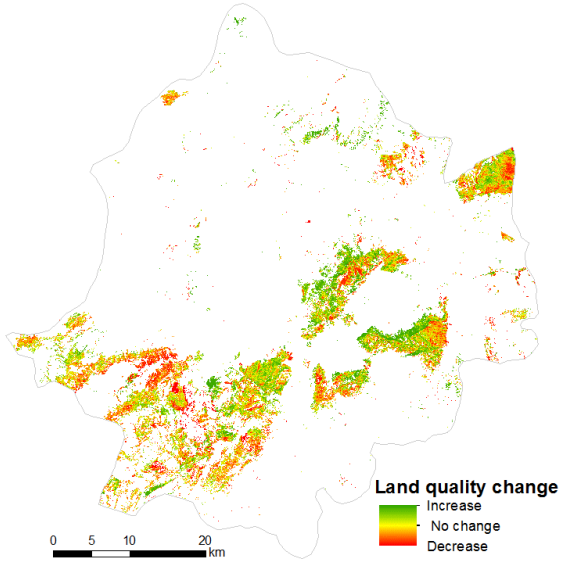
2002-2013



SAVI







CONCLUSIONS AND PERSPECTIVES

In conclusion

- When comparing the landscape pattern on different levels and scales, area and diversity metrics showed similar trends.

- At different scales and resolutions, satellite imagery (MODIS & Landsat) based landscape analysis showed an overall increase in agricultural lands and decrease in natural vegetation

- Combined approach of land cover classification with land quality change detection provided good understanding in the natural vegetation change in the Zaghouan governorate

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CONCLUSIONS AND PERSPECTIVES

In perspectives

- Extend the assessment in the semi-arid environment (e.g. Medenine governorate)

- Explore the influence of the integration of other variables (e.g. elevation, soil types) on landscape patterns analysis

- Explore the connections between land cover changes, SLM practices and changes in ecosystem services

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IRESA

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CodeObia

Thank You!

Key References

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Senf et al. (2015). "Mapping land cover in complex Mediterranean landscapes using Landsat: Improved classification accuracies from integrating multi-seasonal and synthetic imagery." *Remote Sensing of Environment* 156: 527–536.

Symeonakis et al. (2015). "Multi-temporal Forest Cover Change and Forest Density Trend Detection in a Mediterranean Environment." *Land Degradation & Development* 28(4): 1188-1198.

Supplementary information

- Software and Packages used for the classification and mapping:
  - ArcGIS 10.4.1 Desktop
  - QGIS 2.18.1
  - Google Earth Pro
  - R project & packages (Rgdal, Raster, Snow, Caret, ggplot2, sp)

- **Formula for radiance calculation**

  Radiance = (Gain * DN) + Bias

- **Formula used for calculating reflectance from radiance**

  Reflectance = $(3.14 * \text{Radiance} * d^2)/(E * \sin((SA * 3.14)/180))$

- **Code for correcting reflectance image, i.e., reclassify the negative value to 0**

  Corrected_reflectance = CON([Reflectance] < 0.0, 0.0, [Reflectance])

Gain = Band specific gain (see Chander et al, 2009)
Bias = Band specific offset (see Chander et al, 2009)
DN = Digital Number (ranges 0 - 255)
d = distance Earth- Sun (see Table in next slide)
E = Band specific radiance emitted by sun (Chander et al, 2009) (see Table in next slide)

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Supplementary information

Table SI1. Input parameters for radiance and reflectance computation of Landsat ETM+ (Sources: USGS Landsat Metadata of the scenes, Chander et al, 2009)

Band	Gain	Bias	Band specific radiance emitted by the sun (Watts/(m^2 * µm))	06/2001		09/2001		02/2002		06/2002	
				d (distance earth- sun)	Solar angle	d (distance earth- sun)	Solar angle	d (distance earth- sun)	Solar angle	d (distance earth- sun)	Solar angle
1	0.778740	-6.98	1997	1.01589392	65.88644586	1.00841406	53.89595078	0.9903779	38.90608791	1.0161154	65.62710913
2	0.798819	-7.20	1812	1.01589392	65.88644586	1.00841406	53.89595078	0.9903779	38.90608791	1.0161154	65.62710913
3	0.621654	-5.62	1533	1.01589392	65.88644586	1.00841406	53.89595078	0.9903779	38.90608791	1.0161154	65.62710913
4	0.639764	-5.74	1039	1.01589392	65.88644586	1.00841406	53.89595078	0.9903779	38.90608791	1.0161154	65.62710913
5	0.126220	-1.13	230.8	1.01589392	65.88644586	1.00841406	53.89595078	0.9903779	38.90608791	1.0161154	65.62710913
7	0.043898	-0.39	84.9	1.01589392	65.88644586	1.00841406	53.89595078	0.9903779	38.90608791	1.0161154	65.62710913

Supplementary information

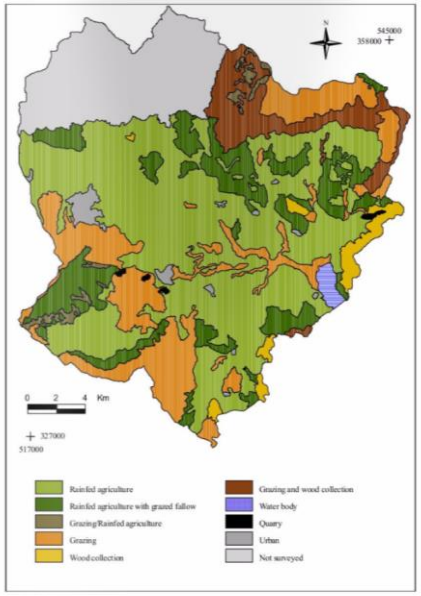

Figure 15 - Land Use map

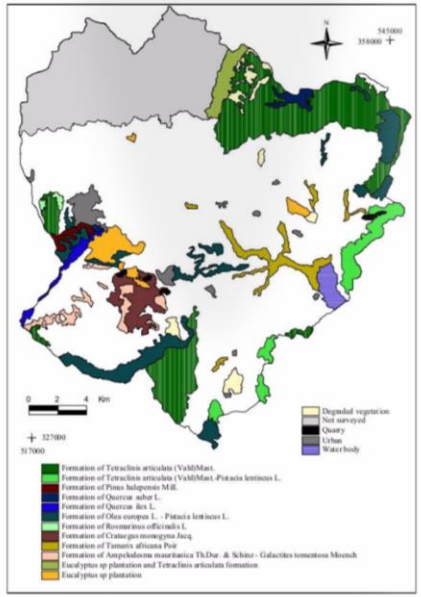

Figure 14 - Vegetation map

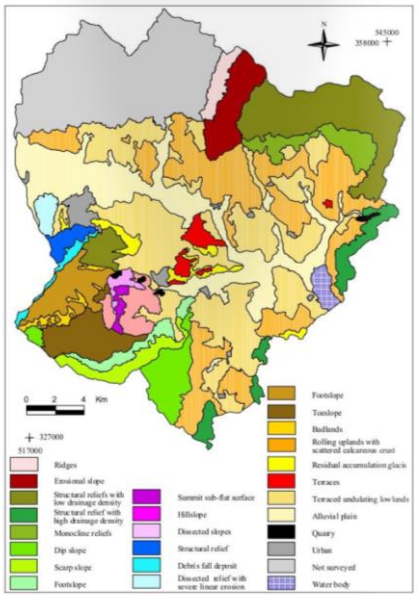

Figure 12 - Land System and Landform map

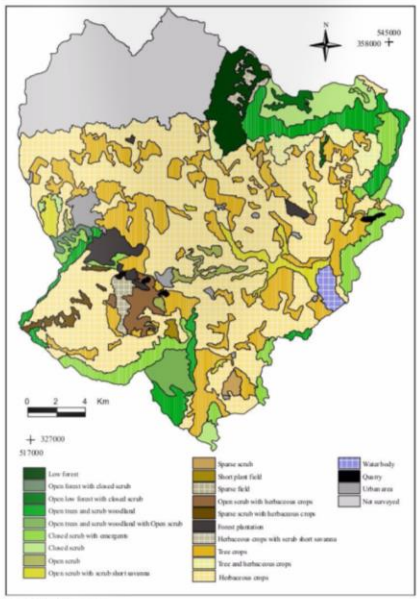

Figure 13 - Land Cover map

The four maps are here derived from the following document:
"Ministry of foreign affairs-Instituto Agronomico Fer L'Oltremare (2004). Land Evaluation in the Oued Rmel Catchment - Tunisia. 24th Course profefessional Master. Geomatics and Natural Resources Evaluation. Florence 2004".