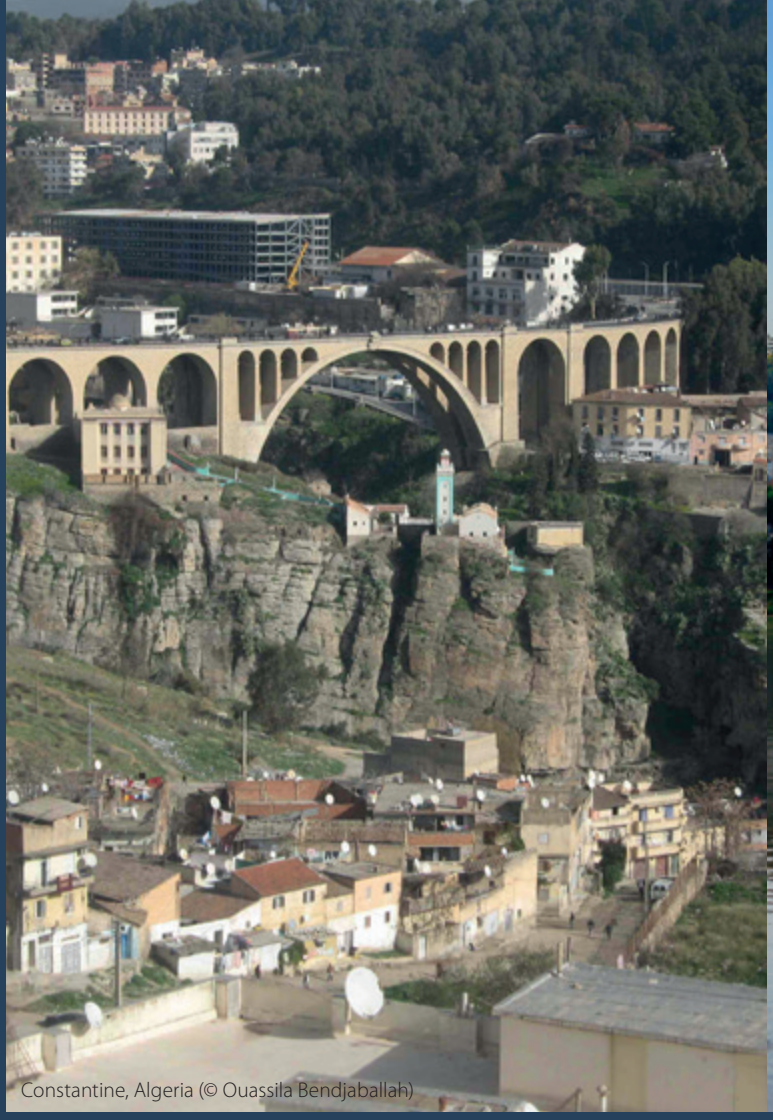

Constantine, Algeria (© Ouassila Bendjaballah)

Avignon, France (© Chiugoran)

A TALE OF TWO CITIES

WORKING OUT HOW TO MANAGE URBAN SPRAWL, WHILE PROTECTING FARMLAND AND NATURAL AREAS, IS A PROBLEM FACING URBAN PLANNERS AROUND THE WORLD. MICHEL MOULÉRY, ESTHER SANZ SANZ AND CLAUDE NAPOLÉONE ARE USING REMOTE SENSING IMAGERY TO LOOK AT HOW DIFFERENT POLICIES HAVE AFFECTED THE DEVELOPMENT OF TWO CITIES IN THE MEDITERRANEAN BASIN OVER THE PAST 30 YEARS

Growing urbanisation has become a problem for cities. Rapid urban sprawl is giving rise to major questions, such as how to protect farmland and natural areas and how to minimise pollution.

The political and strategic choices made by each city have shaped their urban morphologies. Consider on the one hand New York, US, a city of 8,405,837 inhabitants covering 784km2, with dwellings concentrated into skyscrapers to protect inhabitants against floods; on the other hand, London, UK, has the same population size but double the area (1,572km2), as the result of very fast, low-density growth, which has gobbled up lot of farmland and natural areas.

In this article, we'll focus on two urban areas: Avignon in France and Constantine in Algeria. Our aim will be to analyse the similarities and differences between these two regions.

Avignon has strong urbanisation of the peri-urban area, with scattered isolated houses. The middle and upper classes have settled down in the city surroundings, looking for the quality of life of the countryside (sun, calm, proximity to nature) while keeping the advantages of reasonable costs while close to the city-centre and working areas. This development option was authorised by public policies and regulations.

Constantine also has great scatter development. In 2000, to manage this chaotic development, public stakeholders decided to create the city of Ali-Menjeli over 1,500ha to the south of Constantine. This new city is expected to eradicate Constantine's shantytowns, with urban development concentrated in this new city.

Avignon and Constantine have the same type of urban sprawl but a different geography and history, and particular constraints: floods for Avignon in 1856 and 2003, and an earthquake in Constantine in 1985. We will quantify urban progression for both of them over the past 30 years using remote sensing analysis of Landsat images to spatially represent and estimate land use changes. We will then analyse fragmentation using landscape indicators.

Turn to page 40

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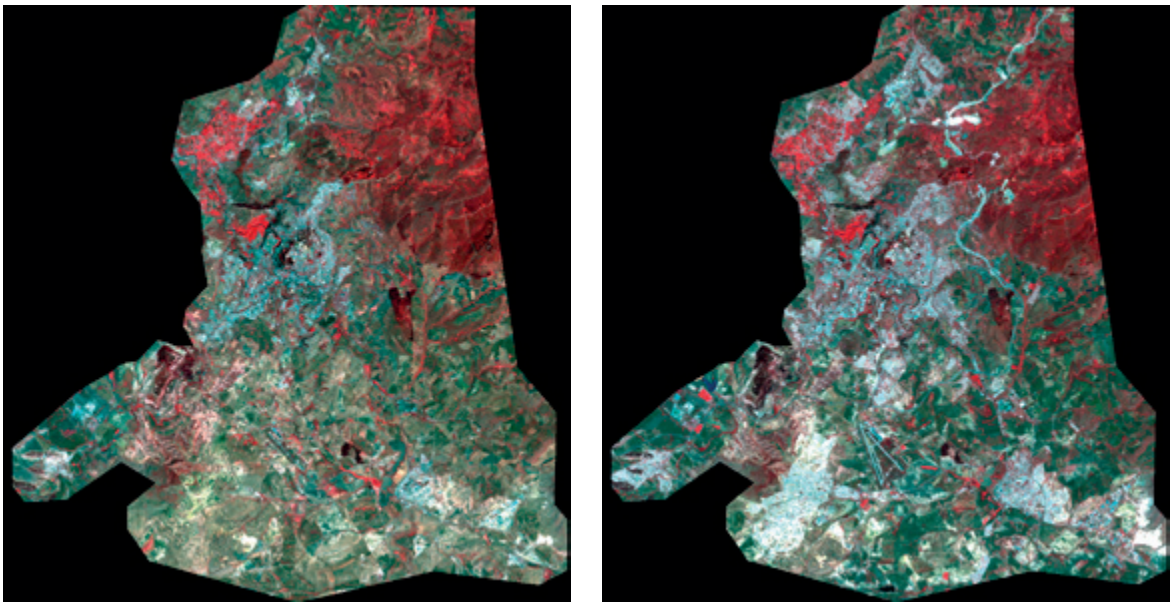
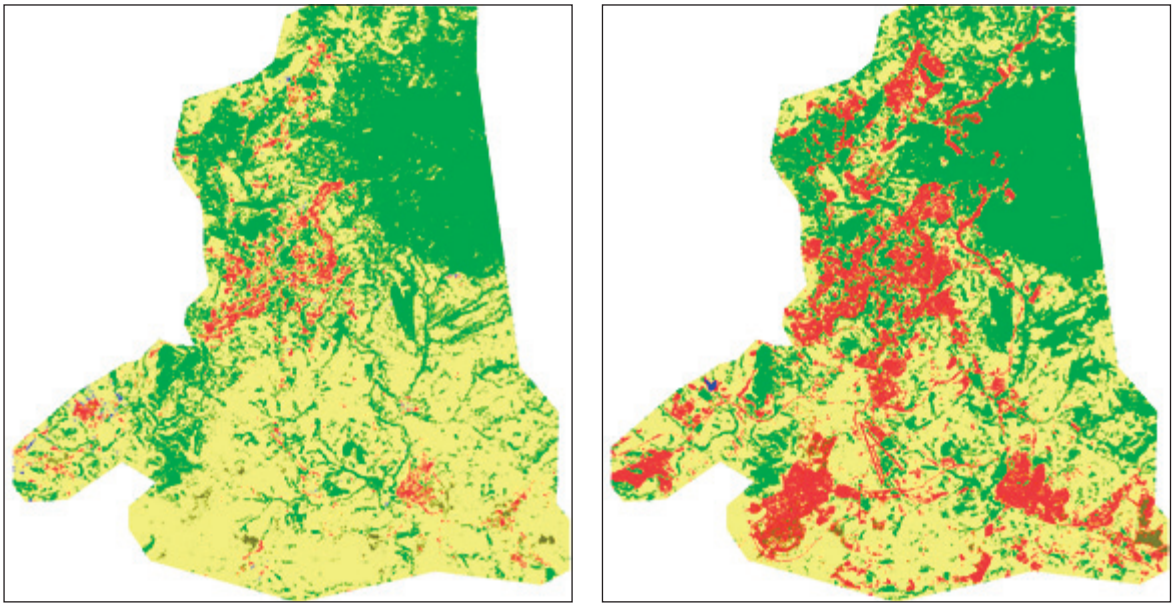


Example of false colour images of Constantine in 1987 and 2011 obtained using MultiSpec. Natural/wood is in red, infrastructure in cyan, bare soil in white and pink, and farmland in green-blue or dark green. Constantine is in the middle in both images; the new city can be seen in the bottom left of the second image, a new motorway in the top right



Example of Constantine supervised classification. Left to right: June 1987 to June 2011.

(Red: urban; yellow: agriculture; green: natural/wood; grey: bare soil; blue: water streams)

Tools and methods

We used images of Constantine and Avignon without clouds that were taken by Landsat satellites 4, 5 and 7 and which had a temporality of 30 years between them (1987-2011). Landsat provides 30m resolution images, which is sufficient to analyse the dynamics of urbanisation and farmland of large study areas. Each satellite also has a thematic mapper sensor, meaning that electromagnetic radiation can be decomposed in seven bands, depending on the reflectance of the soil.

The most interesting bands for us are the following:

- Band four – near-infrared: this emphasises biomass content and shorelines.
- Band three – red: this discriminates vegetation slopes.
- Band two – green: this emphasises peak vegetation, which is useful for assessing the vigour of plants.

The season when Landsat images are taken is important in correctly detecting farmland. In both our study areas, the most recurrent farmlands are cereal, pasture land and market gardening. The images we chose were taken in June, because this is when extensive cereal crops are ready to be reaped and so it is easy to recognise annual crops.

Image processing

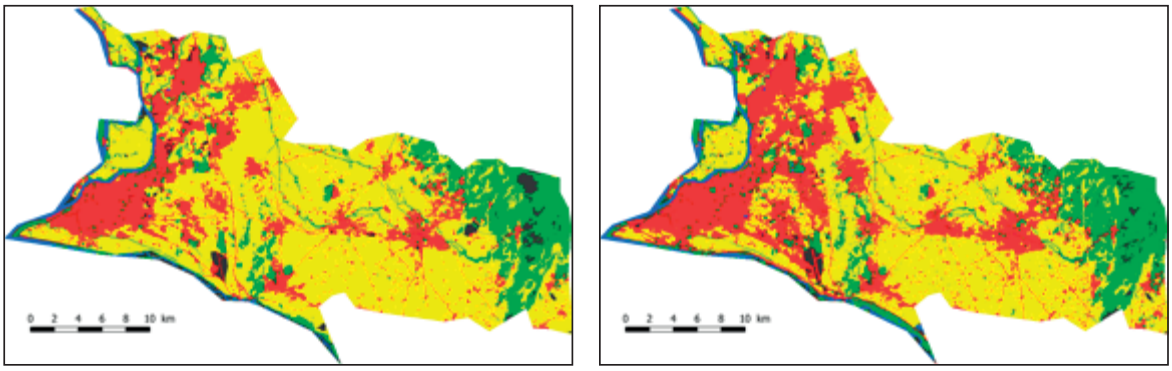
These images needed to be analysed with remote-sensing software because land-use changes are not visible to the naked eye. We used the freeware Multispec software package, which has many functions including image enhancement, false colour and supervised classification.

We delimited a study area of 500km^2 and established five classes of land use: urban, agriculture, natural/wood, bare soil and water/streams. The result was a map of land use for each date: 1987 and 2011. The outputs of the remote sensing analysis were corroborated by surveys, experts and aerial pictures analysis.

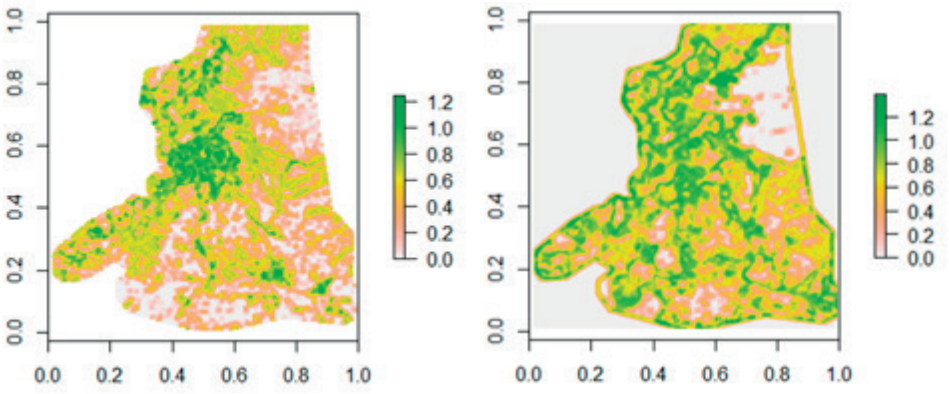
The land use image for each date was then transformed into a matrix containing numerical values corresponding to each pixel's land-use class. The matrix of transition calculates the changes between both dates. We used the open source R software package (http://cran.r-project.org/) with its library raster to create this transition matrix, expressed as percentages of change for each land use related to the total number of pixels of this class in 1987.

For Constantine, the loss of farmland is meaningful: 19% of farmland in 1987 changed into urban in 2011, 15% into natural and just 64% remained agricultural. These transformations are due to various urban policies focused on the construction of a significant number of housing and equipment to respond to a great demographic and social pressure in the detriment of farmland.

In Avignon, despite urban pressure, agriculture remains an important land use (81% of the area), because of historic and efficient irrigation, production, commercialisation and distribution facilities compared to Constantine's.



Example of Avignon supervised classification. Left: June 1987 Right: June 2011



Change in SHDI for Constantine between 1987 and 2011

Landscape metrics

This first approach with the transition matrix allows us to compare and understand the evolution of land use. But to consolidate our study, we needed to analyse the landscape structure, too.

From the result of the supervised classification, it was possible to report the spatial organisation of each of the land-use classes, as well as their morphology. We used the Fragstats software package to calculate a meaningful number of landscape metrics by class and landscape, such as the number of patches for each class, the index of the biggest landscape use or even the extension, the distance or the juxtaposition of objects in the landscape.

In our study, we sought to characterise the link between urban areas and farmland in the Mediterranean Basin at the scale of smaller regions. For this, we selected four indices measuring the landscape fragmentation and the arrangement of the urban and agriculture land-use classes:

- **Shannon's Diversity Index (SHDI):** Diversity of a landscape measured by the number of contiguous classes. In Constantine, the SHDI has increased, with classes more fragmented and imbricated.
- **Patch density (PD):** Number of patches in a 100ha area. Used to estimate the fragmentation of the landscape and the classes of land use. Unlike Avignon, the landscape has changed in Constantine. This disruption by new constructions scattered on former farmland is corroborated by the increase of PD for the urban and agricultural classes.
- **Interspersion and Juxtaposition Index (IJI):** This takes into account the relations of neighbourhood between the various classes of land use. Agriculture and urban classes are more in contact in Constantine (34% for urban classes) than in Avignon (11%).
- **Edge density (ED):** A measurement of the complexity of the shapes of patches in a landscape mosaic. The augmentation of PD of urban class over the past 30 years is stronger in Constantine than for Avignon, with greater urban sprawl and a more complex boundary.

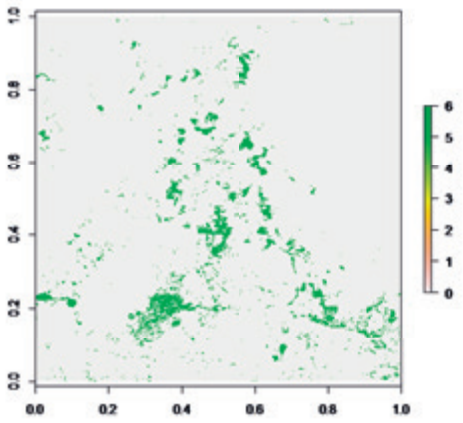


Image of Constantine (1987-2011) fast urban expansion with transition matrix

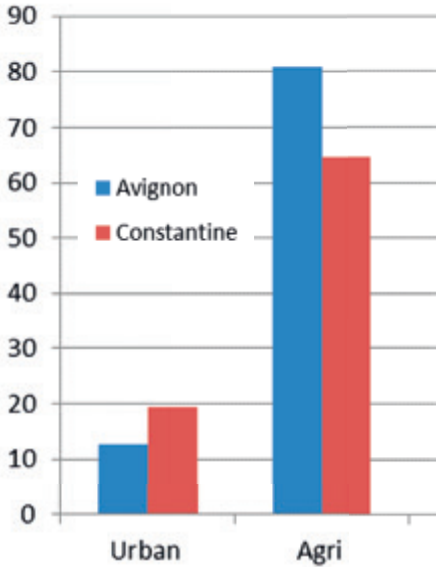
Conclusion

Spatial image analysis and landscape metrics help us to have a first quantitative approach to better understanding changes in land use. Nevertheless, quantitative results should be contrasted to qualitative fieldwork (surveys, interviews with farmers and stakeholders) involving various scientific disciplines (geography, ecology, sociology, economy), as well as a multi-scale approach in time and space.

The next stage of our research is to characterise in detail an extract of our study cases to describe farming dynamics in the urban fringe concerning crop changes and the evolution of farms. This will require images with higher resolutions than those provided by Landsat and so we will use SPOT images.

THE NEXT STAGE OF OUR RESEARCH IS TO CHARACTERISE IN DETAIL AN EXTRACT OF OUR STUDY CASES TO DESCRIBE FARMING DYNAMICS IN THE URBAN FRINGE

Michel Mouléry is a spatial analysis engineer, Esther Sanz Sanz is an urban studies and geography PhD student, and Claude Napoléone is a researcher in economy at National Institute for Agricultural Research (INRA) (www.inra.fr). ***The authors would like to thank Elisa Marraccini, Sylvie Ladet, François Calatayud, Professor Salah Bouchemal, Professor Ouassila Benjaballah and Professor Emeritus Marc Cote***



Loss (urban) and conservation (agri) of farmland, 1987-2011