Télédétection spatiale et décision territoriale

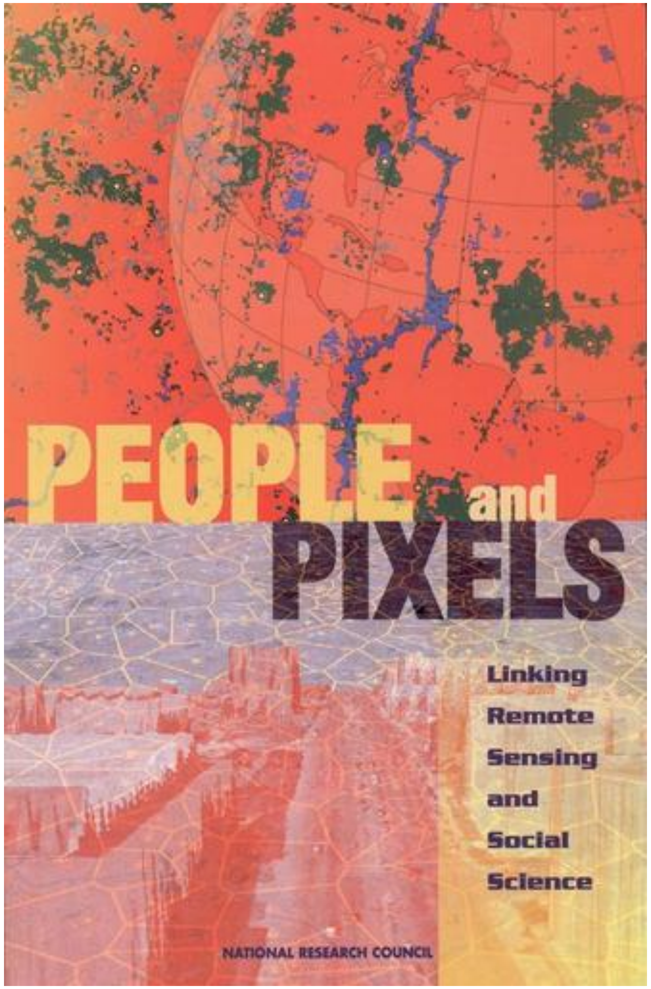
Remote sensing and spatial decision making

Sébastien Gadal
sebastien.gadal@univ-amu.fr

Aix-Marseille Univ., CNRS, ESPACE UMR 7300, Univ., Nice Sophia Antipolis, Avignon Univ., 13545 Aix-en-Provence, France, https://cv.hal.science/sebastien-gadal/

Introduction

- The use of the remote sensing approaches for the analysis of the societies is one of the base fundamentals with the first applications **in urban planning in 1856 on Paris**.
- The questions of territorial and societal analysis, the building of socio-economic geodatabases is considering since the 1960s as a strategic core for the States and enterprises giving advantages.
- **The recent progress in geo-computing allows to be modelling at the large scales and different geographic levels the human and territorial dynamics combined with cultural and environmental data**, and figure-out the possible futures.
- Several examples based on research conducted in Lithuania, the Siberian Arctic, and France will illustrate the advances and issues.



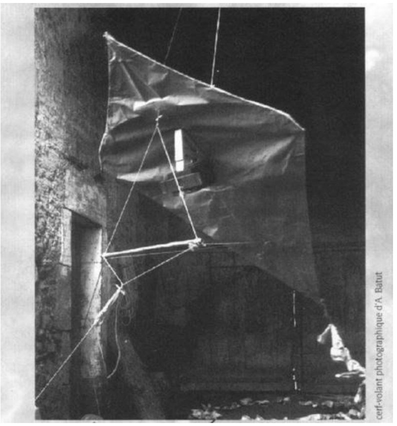
National Research Council. 1998. People and Pixels: Linking Remote Sensing and Social Science. Washington, DC: The National Academies Press. https://doi.org/10.17226/5963

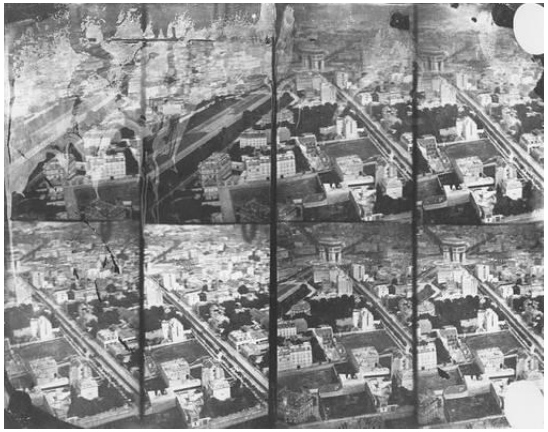
Remote sensing and urban planning

- The first application **of remote sensing was to analyze the urban fabric of Paris.**

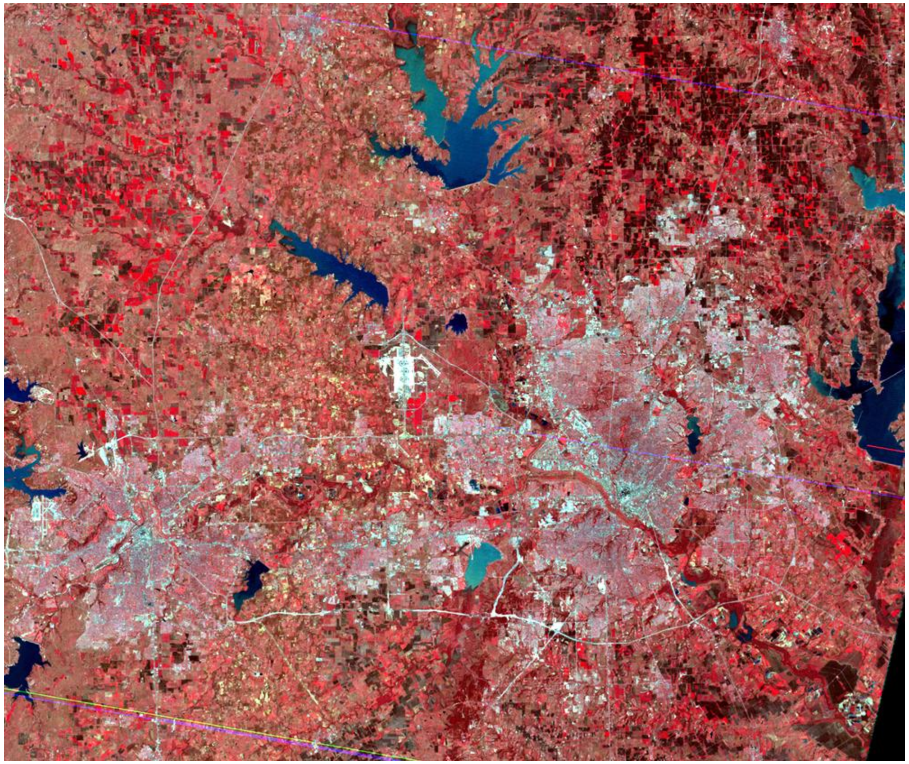
- First aerial photograph in **1858** by Aspard-Félix Tournachon (Nadar) of Petit Bicêtre (Petit Clamart).

- From the 1870s onwards, the use of aerial photographs (aerostatistical photographs) for town and country planning became widespread. In 1888, Arthus Batut took the first automatic aerial photographs, followed in 1907 by stereoscopic shots at altitudes of up to 447 meters.

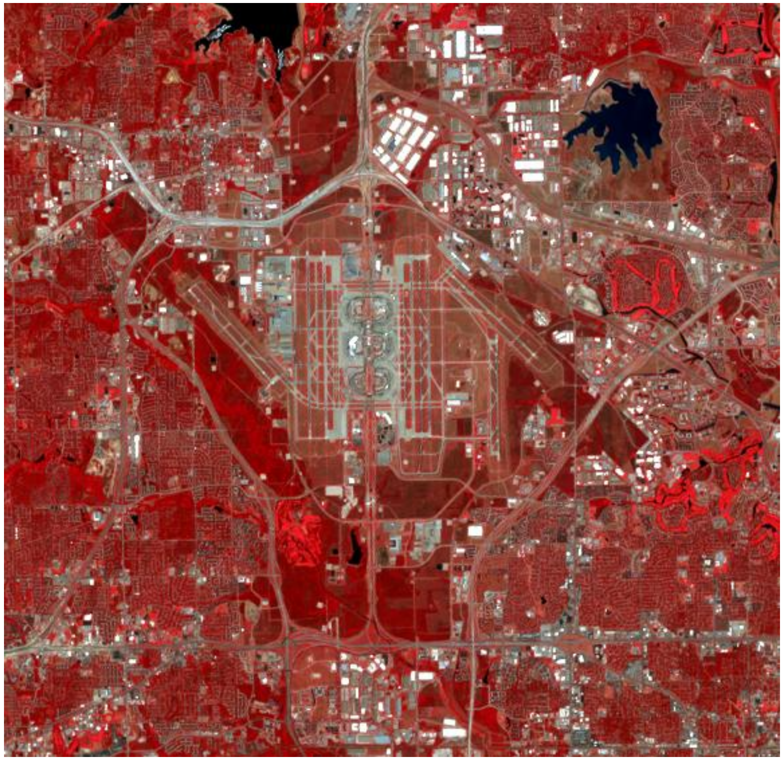




Remote sensing and urban planning



First Landsat 1 MSS image 12 March 1974 (color composite)



Dallas airport 12 March 1974 (color composite)
Dallas 31 August 2013 (color composite)

Remote sensing: Basics

"Remote sensing involves acquiring information about an object or area from a distance, typically using satellite or aerial imagery". Here are the basics:

- Remote sensing relies on detecting and measuring **the electromagnetic radiation reflected or emitted by objects**.

- **Applications**

-Urban Planning: Mapping urban areas, monitoring growth, and planning infrastructure.
-Environmental Monitoring: Tracking changes in land use, vegetation health, water bodies, and natural disasters.
-***Agriculture:*** Assessing crop health, soil conditions, and precision farming.
Climate Change: Studying atmospheric conditions, ice cover, and sea level changes.

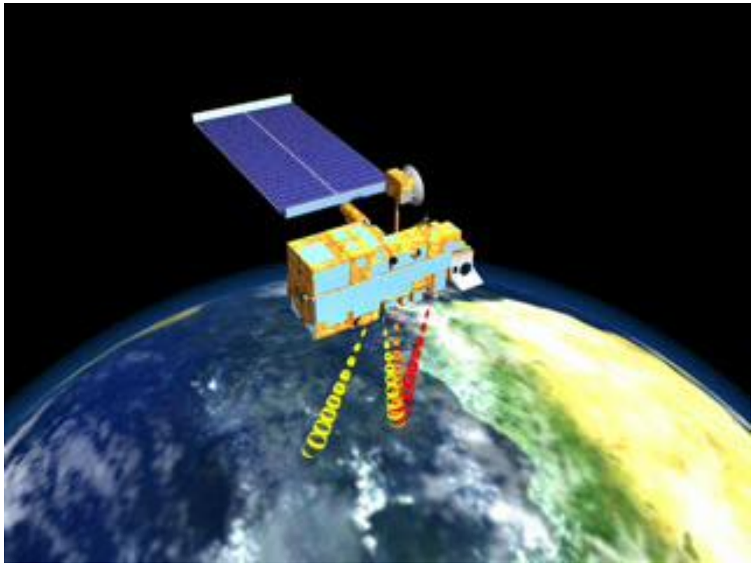
- **Types of Remote Sensing Sensors**

-Passive Optical Remote Sensing: Measures natural radiation that is emitted or reflected by objects. Examples include satellite imagery taken in the visible, infrared, and thermal wavelengths.
-Active Radar/Laser Remote Sensing: Sends out a signal (like a radar or laser) and measures the reflection from the object. Examples include radar and LiDAR systems.
Components.

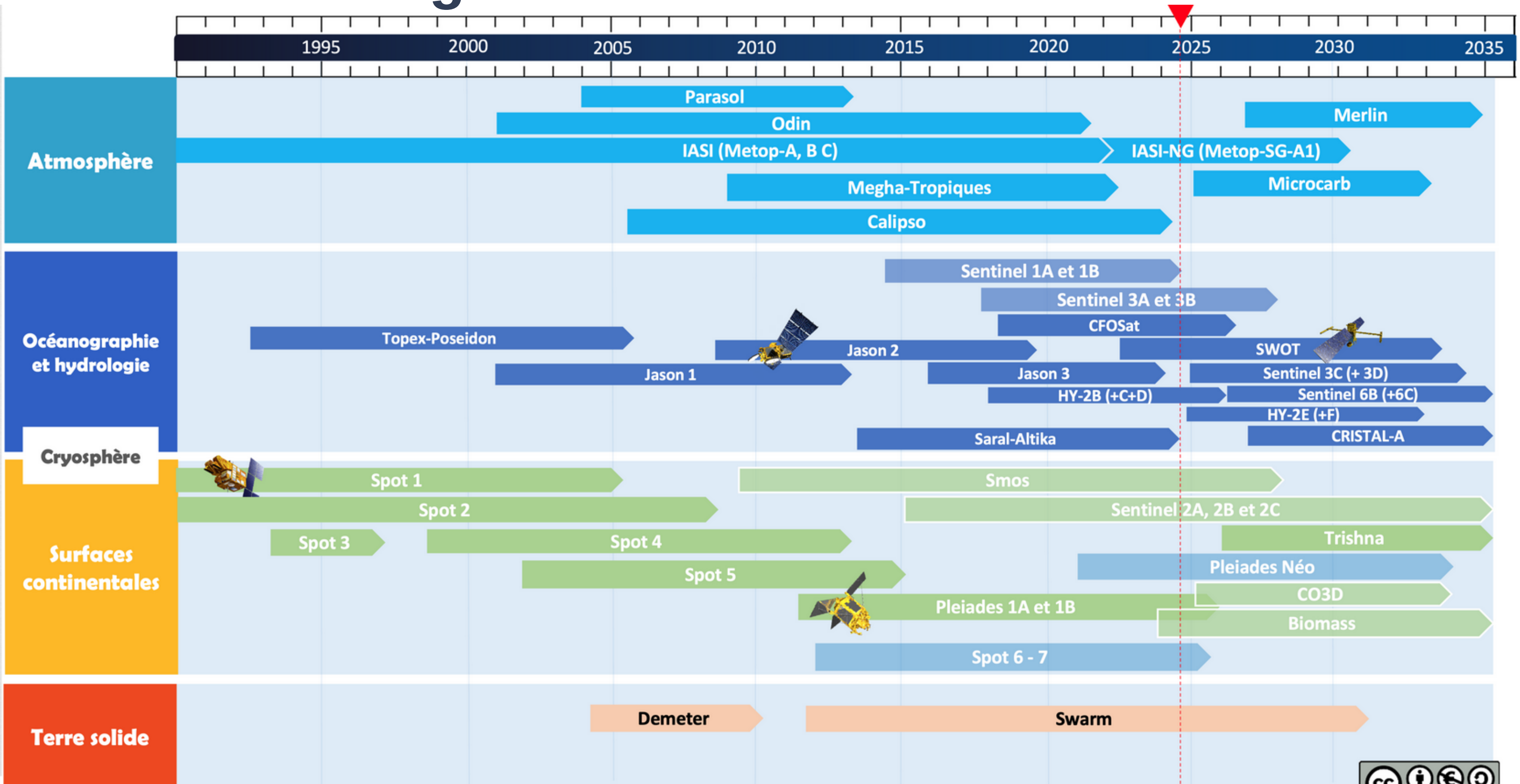
- **Sensors:** Devices that detect electromagnetic radiation. They can be onboard satellites or aircraft.

- **Interests**

-Large Area Coverage: Can cover vast and remote areas.
-Frequent Data Collection: Regularly updated data, especially from satellites.
-Non-Intrusive: Collects data without physically touching the objects.



Remote sensing: Basics – Satellites



https://www4.obs-mip.fr/wp-content-omp/uploads/sites/50/2024/11/Chronologie_projets-nov_24.png

Interest of remote sensing in planning

- By the ability to embrace parts of the **geographical space at different scales**, levels of geographical **analysis, periods and temporalities**.

- What do the new capacities for measuring geographical space and processing data contribute to the **understanding of metropolisation processes**?

- The progress made over the last ten years has been in the computing and storage power, the multiplication, diversification and specialization of remote sensing images, and the development of **integrated analysis approaches combining remote sensing, GIS and spatial modelling**.

- The construction of **geographical knowledge on society, the environment and territories**.

- The development of applications linked **to planning, environmental management, natural risks and safety**.

Science, society, and applications

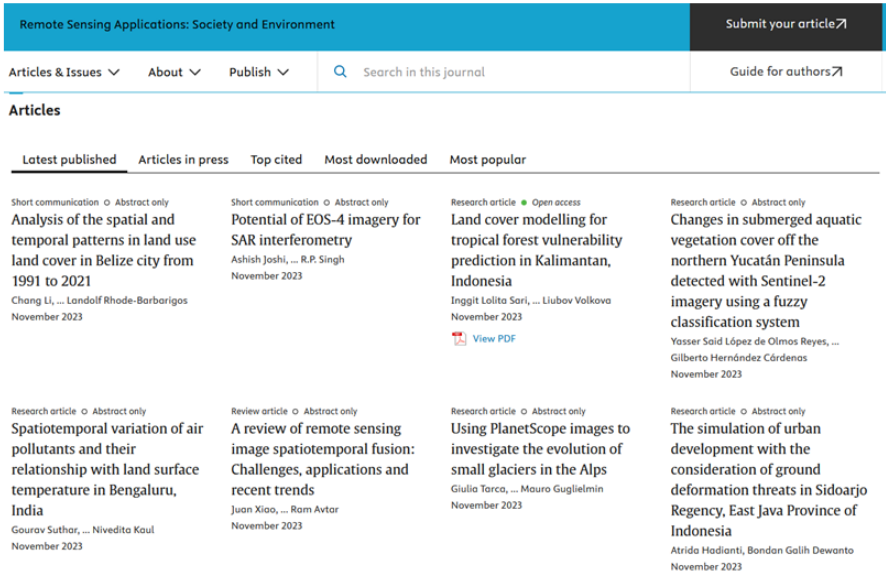
Business applications are directly irrigated by the end-user researches in remote sensing for social sciences and society applications.

Producing geopostial knowledge (high product values)

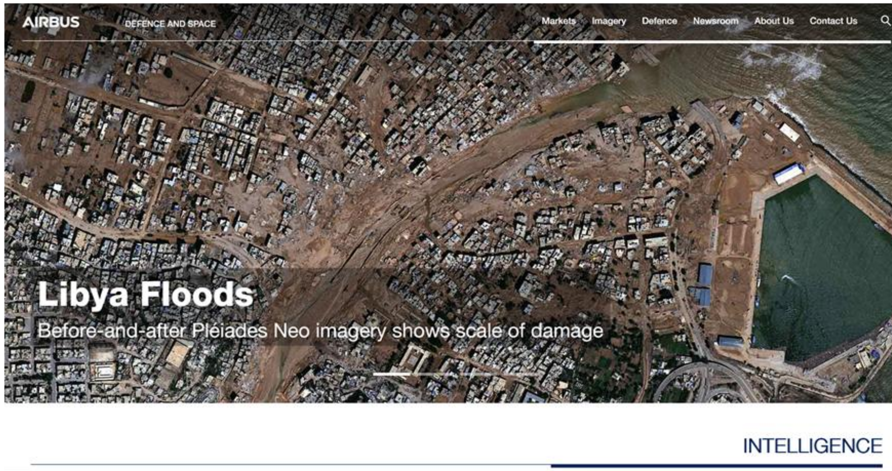
A large parts of the publications, institutional and private applications are related to the planning, urban planning, demography, and risk exposures, and environment.

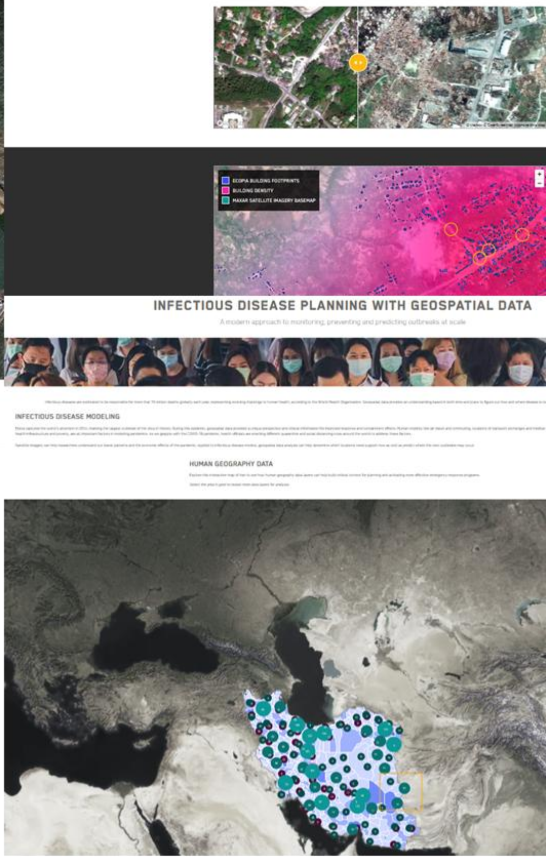
The use of remote sensing data in and for planning is not new!

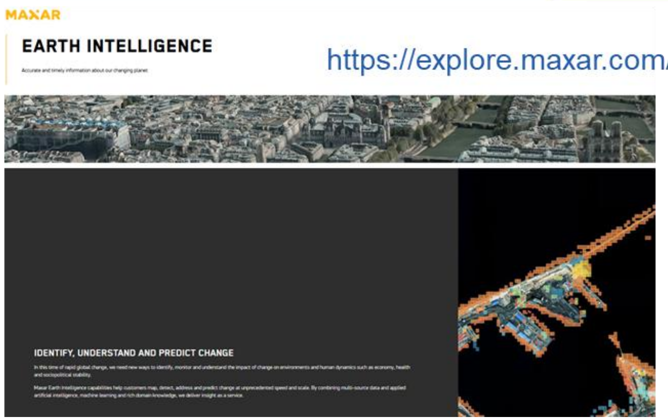
The main driver was the applications in urbanism and planning since the mid-19e century.



Earth observation and planning: The « new » driving business of geospatial services

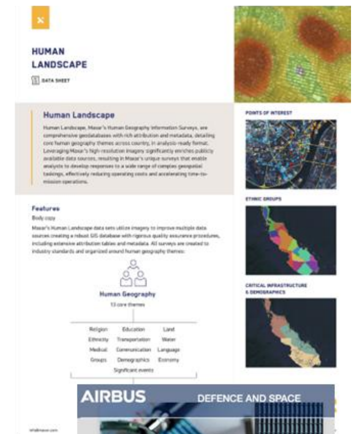


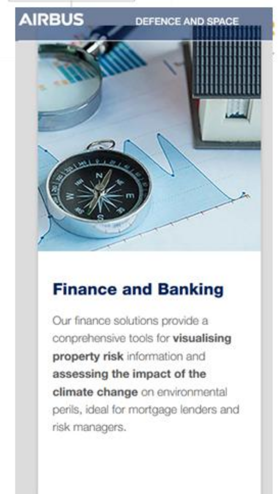


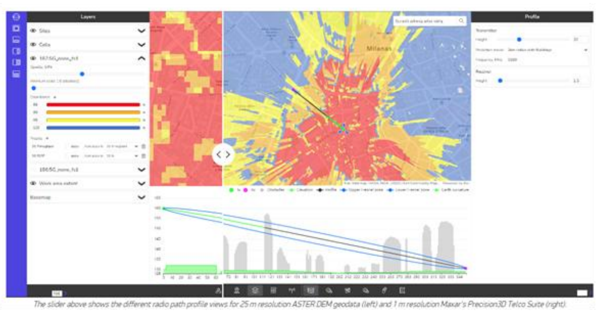


https://explore.maxar.com/census

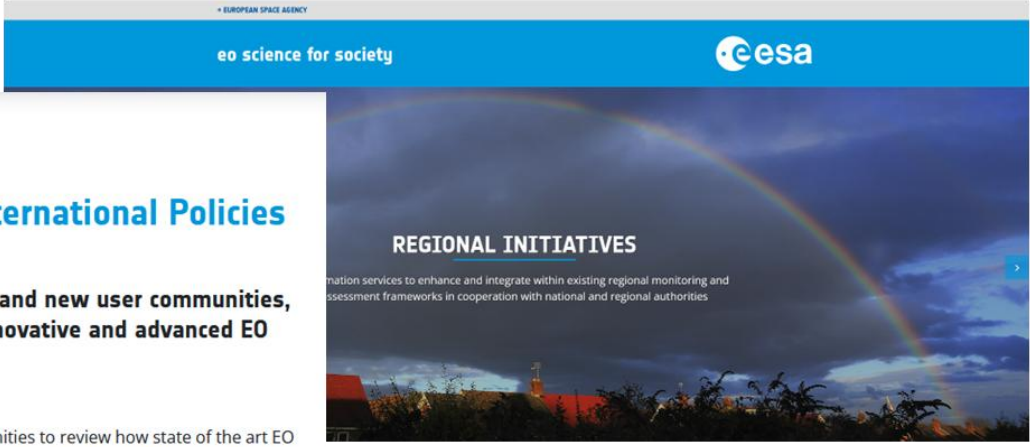
Earth observation and planning: The « new » driving business of geospatial services







Earth observation for society: the new space app



Pioneer

new EO applications to support International Policies

→ engaging, expanding and building up on existing and new user communities, collecting user requirements for development of innovative and advanced EO products, tools and services

- Convene thematic workshops with EO experts and user communities to review how state of the art EO applications can respond to the priority needs of user communities, and develop agenda for new R&D activities (e.g. MWBS, MUAS, WorldCover series)
- Cooperate with international conventions, UN Agencies and international organisations to leverage the uptake and facilitate the sustainable use of EO in key policy sectors (e.g. Multilateral Environmental Agreements, SDGs, EU directives)
- Build strategic partnerships (via MOI, MOU, white papers) with key authoritative user organisations to contribute on the international responses to global societal challenges
- Develop open source algorithms and tools to stimulate growth of EO application developers and facilitate uptake of EO applications by user communities
- Identify opportunities for strategic collaboration in EO exploitation with key international and private sector stakeholders
- Support and stimulate innovative capability development among relevant suppliers including IT/geomatics /analytics providers, specialist EO service providers, software developers, commercial EO satellite operators and start-ups
- Build awareness and acceptance of EO based information across international, regional, national and private sector stakeholders to foster the longer term adoption of commercial EO based products and services
- Perform stakeholder requirement consolidation – gathering information requirements; defining and agreeing specific activities to be executed in partnership that promote the use of EO information in

2024 European Space Agency

News space economy

Institutional and industrial approaches of EO implementations of the remote sensing for urban planning.

https://eo4society.esa.int/

Modelling the urban futures for planning

Multi-temporal recognition of built-up area and land cover changes using machine learning approach in the Metropolis of Aix-Marseille-Provence in France

Sébastien Gadal
Aix-Marseille University, CNRS, ESPACE UMR 7300, Univ. Nice Sophia Antipolis, Avignon University
Aix-en-Provence, France
& North-Eastern Federal University, Republic of Sakha-Yakutia
sebastien.gadal@univ-amu.fr

Mounir Oukhattar
Aix-Marseille University, CNRS, ESPACE UMR 7300, Univ. Nice Sophia Antipolis, Avignon University
Aix-en-Provence, France
mounir.oukhattar@etu.univ-amu.fr

Solomon Abody Otobo
Aix-Marseille University, CNRS, ESPACE UMR 7300, Univ. Nice Sophia Antipolis, Avignon University
Aix-en-Provence, France
solomon-abody.otobo@etu.univ-amu.fr

2023 Joint Urban Remote Sensing Event (JURSE) | 978-1-6654-9373-4/23/$31.00 ©2023 IEEE | DOI: 10.1109/JURSE57346.2023.10144184

***Abstract*— Over the last thirty years, the extension of built-up areas has affected all areas of the Aix-Marseille-Provence (AMP) Metropolis. Urban sprawl has been particularly important in generating fragmented urban territories with various forms and spatial patterns. The modelling of the evolution of AMP is fundamental in the context of the implementation of climate plans for the horizon of 2050. It is based on spatial modelling by remote sensing of land cover change (LCC) between 1984 and 2021 using a classification approach that combines spectral transformations and indices applied to Landsat 5 TM and Sentinel 2 MSI.**

The geo-simulations of the LCC and built-up areas dynamics by 2050 are modelled on Markov chain cellular automata. The future trends of AMP Metropolis are characterised by the evolution of built-up areas, estimated at 4,9% in 1984, 9,6% in 2021 and 11,2% in 2050 mainly to the loss of agricultural lands. The forests and semi-natural environments tend to be mainly more resilient to urban growth. The modelling of spatial dynamics of urbanisation is correlated with those of the evolution of the territorial distribution of populations. Geo-simulation of spatial dynamic changes is one of the decision-making planning tools for better management of the use of AMP territories.

***Index Terms*—Urbanisation, LCC, remote sensing, machine learning, geo-simulation, Aix-Marseille-Provence Metropolis.**

I. Introduction

Urban growth and land cover changes (LCC) of metropolis in developing countries have drawn considerable attention from urban geographers, urbanists, and regional planners. Population increase and economic development are considered to be major factors directly inducing changes in LCC and urban dynamics. Population growth and economic development induced the construction of new residential, commercial, utility and transport infrastructures impacting the natural environments and agricultural areas. Remote sensing and geographic information system (GIS) have been widely used in recent decades to measure, model, and analyse the LCC [1]. Many land cover change methods and classifier algorithms have been developed for land cover mapping, change modelling, and urban recognition [2, 3, 4]. The methodology implemented on AMP Metropolis combines principal component analysis (PCA) factorial data transformation and machine learning minimum noise fraction (MNF), spectral indices and machine learning Cellular Automata-Markov Chain (CA-Markov) geo-simulation model. PCA and MNF and spectral indices are used to calculate the built-up areas. Spectral transformations and indices such as MNF, PCA, built-up area index and bare land index have been implemented to extract the built-up areas [5, 6, 7]. Thus, the Markov chain was used to attempt to predict urban sprawl and LCC and their potential impacts on the environment. Markov chain analysis is a stochastic model to predict the spatial change characteristics of land covers based on historical and current geographic conditions [8, 9].

In the Aix-Marseille Provence metropolis, as early as 2000, the law on solidarity and urban renewal (SRU) introduced urban sprawl into the local urban plans: the territorial coherence scheme and local urban plan. The SRU calls for the economical and balanced use of natural, urban, peri-urban, and rural spaces [10]. It is designed for limiting the expansion of urban areas a general principle of sustainable urbanisation with the land possibility constraints of new diffuse build-ups and by restricting the use of minimum sizes for building plots [10]. The mapping of the land cover changes of the Aix-Marseille Provence (AMP) Metropolis is a requirement for planning and managing the dynamics of urbanisation, territorial, potential evolutions, and consequences. It is based on the recognition of artificial areas between 1984 and 2021 with Landsat 5 TM and Sentinel 2 MSI images. Remote sensing data were used based on existing geographic land use databases such as Corine Land Cover (CLC) and the land use pattern (MOS) of 2009 and 2017. The effectiveness of different classification methods has been tested for the analysis and decision-making supports as well as for the CA-Markov geo-simulation of Land covers and built-up dynamics to 2050.

II. Materials and Methods

A. Study Area

The Aix-Marseille-Provence (AMP) Metropolis is the largest of the French metropolises territory, with a surface area of 3,173 km². It represents 10% of the surface area of the region SUD "Fig. 1". It is twice as large as the metropolis of London and three times as large as Berlin or New York [10]. This territory is characterised by the juxtapositions of densely built-up urban areas and forest ridges, agricultural plains, valleys, and plateaux: 61% (1910 km²) of the surface area is occupied by natural areas, 15% (480 km²) is covered by urban areas, and 24% (760 km²) by agricultural areas. The territory of the AMP Metropolis largely overlaps the agglomerations of Marseille and Aix-en-Provence. The 92 districts of AMP Metropolis hosted 1603840 inhabitants in 1982, (density of 509,3 inhabitants/km²) and 1889666 inhabitants, (density of 600

Institut des sciences humaines et sociales

Prospective URBAIN - 2 juin 2023 - Mucem, Marseille

Géosimulation de l'évolution urbaine

Modélisation des dynamiques territoriales artificialisées à des fins d'aménagement

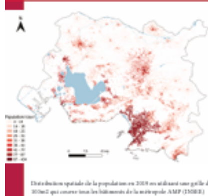
ASBIG (analyse spatiale basée sur l'imagerie géographique), CNRS/UMR 7300 ESPACE

Sébastien Gadal, Mounir Oukhattar, Solomon Abody Otobo

Durée : 3 ans (2022-2025) - Relation entre Teneur en carbone Organique et Occupation du Sol : application aux sols de la Métropole Aix-Marseille Provence. Recherche et développement pour la connaissance du stockage carbone organique de la métropole Aix-Marseille-Provence

OBJECTIFS ET MÉTHODES

Cette étude analyse l'évolution de l'occupation du sol dans la métropole AMP en se concentrant sur l'impact de la croissance urbaine. Des techniques telles que les transformations spectrales, les indices spectraux et la géosimulation sont utilisées pour cartographier les changements dans l'occupation des sols et prédire l'étalement urbain d'ici 2050. Les résultats pourraient aider les autorités à mieux planifier l'utilisation du sol de manière durable.

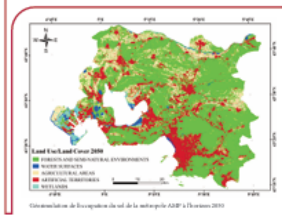


OBJET DE LA RECHERCHE

En 30 ans, l'étalement urbain a fragmenté le territoire de la métropole Aix-Marseille-Provence (AMP). Les constructions et le développement économique ont eu des impacts directs sur les zones agricoles et environnementales. Ainsi, la modélisation de l'occupation du sol est essentielle pour une planification durable visant à minimiser les impacts négatifs de la croissance urbaine sur l'environnement et les zones agricoles.

ACTEURS / ÉCOSYSTÈME DU PROJET

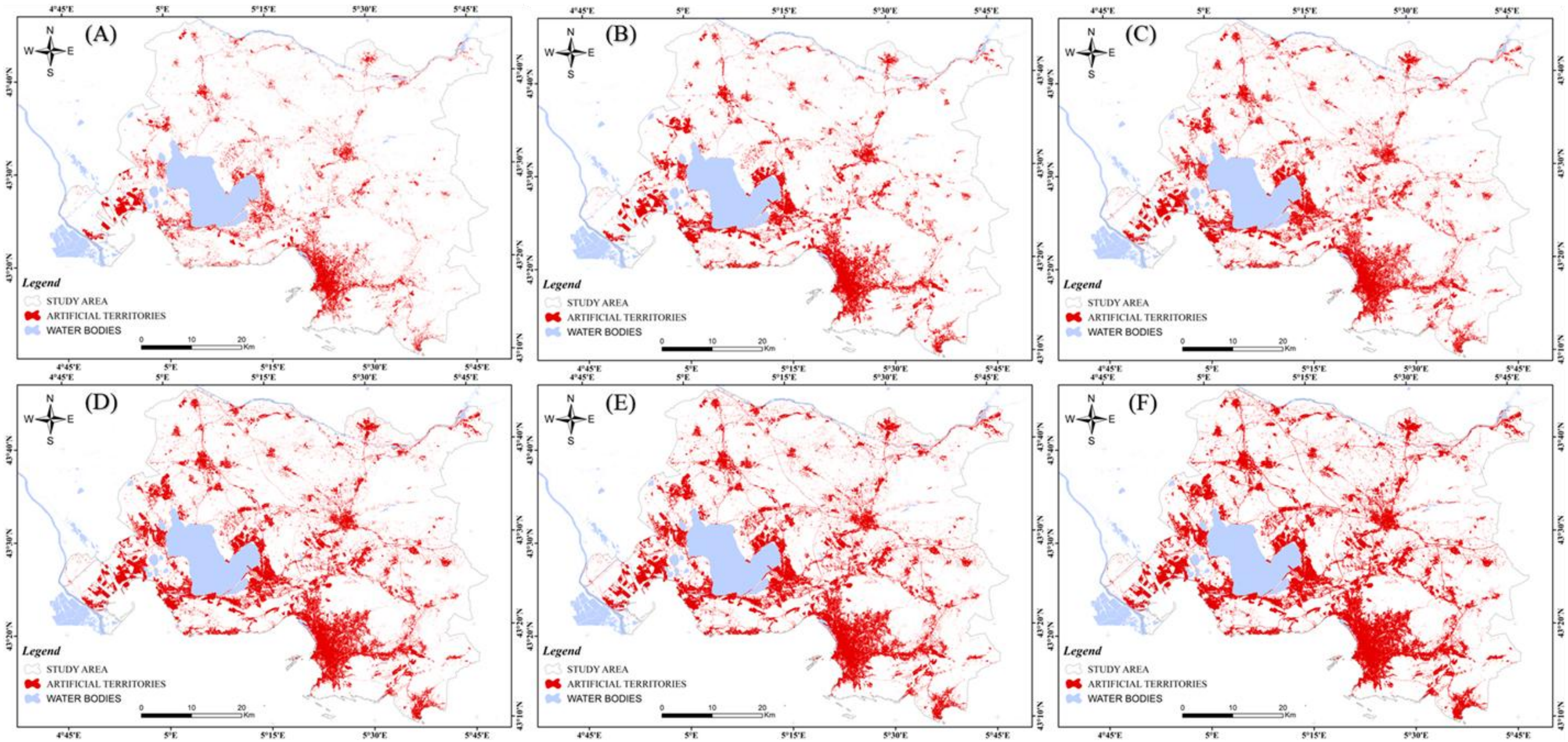
Ce projet de recherche et développement est financé par la Métropole Aix-Marseille-Provence et se fait en relation étroite avec Aix-Marseille Métropole (AMP), le CNRS, l'UMR 7300 ESPACE, ITEM, ECCOREV et l'UM 34 CEREGE. Il s'inscrit dans la nouvelle règlementation Climat et résilience. Il a pour objectif de mieux comprendre le stockage de carbone organique dans la métropole AMP, et de le modéliser, de cartographier, et de projeter en 2050 les possibles évolutions en couplant images de télédétection spatiale et mesures de carbone organique du sol.



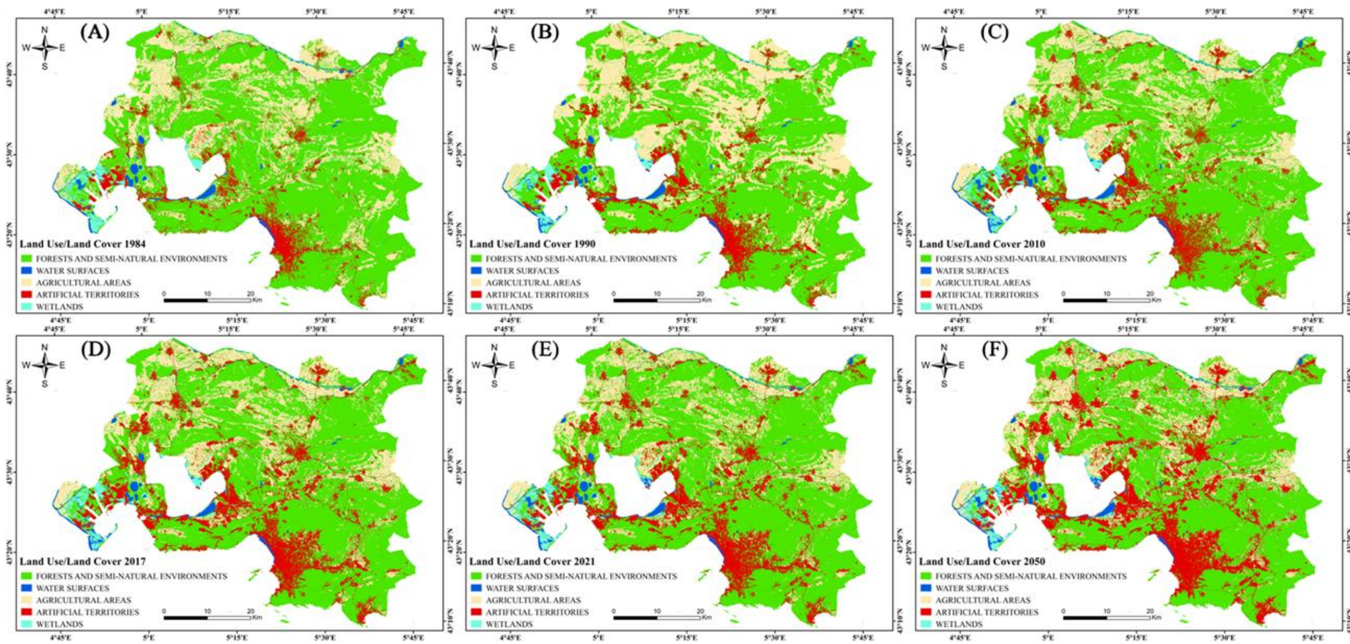
RÉALISATIONS ET RÉSULTATS

L'étude présente des cartes d'occupation des sols de la métropole AMP de 1984 à 2021, ainsi que leurs géosimulations à l'horizon 2050. Les cartes ont montré une augmentation possible des zones urbaines au niveau des réseaux de transport et des structures urbaines de 4,9% en 1984 à 11,2% en 2050. Inversement, à la croissance démographique et socio-économique, les terres agricoles ont diminué, tandis que les zones forestières et semi-naturelles ont augmenté.

Geo-simulation of possible futures: Métropole Aix-Marseille Provence (1984 to 2050)



Geo-simulation of possible futures: Métropole Aix-Marseille Provence (1984 to 2050)



Land Cover Type	Land cover class surfaces											
	1984		1990		2010		2017		2021		2050	
	Km²	%	Km²	%	Km²	%	Km²	%	Km²	%	Km²	%
Artificial areas	252,5	4,9	298,4	5,8	363,2	7,0	486,2	9,4	498,3	9,6	581,7	11,2
Agricultural areas	713,2	13,9	869,8	16,9	660,7	12,8	609,5	11,8	554,7	10,7	503,1	9,7
Forests and semi-natural areas	2041,1	39,7	1878,6	36,5	1998,0	38,7	1929,8	37,3	1973,1	38,1	1934,7	37,2
Wetlands	93,5	1,8	63,9	1,2	76,2	1,5	81,7	1,6	80,0	1,5	80,5	1,5
Water surfaces	53,7	1,0	43,7	0,9	57,2	1,1	52,9	1,0	58,0	1,1	56,7	1,1

ESPACE

Integrating environmental variables (Carbon) into urban planning

SN Computer Science (2024) 5:561
https://doi.org/10.1007/s42979-024-02872-8

Check for updates

ORIGINAL RESEARCH

SN

Spatiotemporal Modelling of Soil Organic Carbon Stocks in a Semi-Arid Region Using a Multilayer Perceptron Algorithm

Sébastien Gadal[1] · Mounir Oukhattar[1,2] · Catherine Keller[2] · Ismaguil Hanadé Houmma[1,3]

Received: 30 September 2023 / Accepted: 4 April 2024

Abstract
Spatial modelling of soil organic carbon stock (SOCS) and its future dynamics are essential for the sustainable management of terrestrial ecosystems and the planning of carbon sequestration measures. In this study, a spatial modelling approach of the dynamics of the SOCS distribution between 1985 and 2050 and its relationship with land use/land cover (LULC) change in the Béni-Mellal region was accomplished by performing a spatial regression using a multilayer perceptron (MLP) driven by 10 predictors and SOCS data from 40 soil samples. Predictors were extracted from Landsat 5 TM/8 OLI and Sentinel-2 MSI multispectral images and CA-Markov was used for geo-simulations predicting future dynamics. This result shows that the spatial distribution of SOCS and its temporal dynamics in terms of positive and negative variations are strongly linked to spatiotemporal changes in LULC. Over the period 1985–2018, the results showed both progressive variations in the soils of tree crops, unused land and soils in urban areas, slight variations in forest soils and significantly regressive variations in the soils of cropland (– 606 kg.10^6). The future dynamics from 2018 to 2050 suggest a very significant positive evolution of the SOCS in forest soils with a rate of change of 35.6 kg.10^6, while the regressive evolution of the SOCS in cropland should continue at – 73.1 kg.10^6. Furthermore, the spatial autocorrelation results suggest that the spatial distribution of LULC units, topography and vegetation indices are the main factors influencing the quantitative distribution of SOCS in the study area, with correlations ranging from 0.8 to 0.94.

Keywords Soil organic carbon stock · Land use/land cover · Multilayer perceptron · Landsat 5 TM/8 OLI · Sentinel-2 MSI · Semi-arid region

Introduction

Soils are essential to the global carbon cycle and are a precious, non-renewable resource in the context of the human lifespan [1]. They play a crucial role as the basis for agricultural and forestry production. However, soils are under increasing pressure from a variety of sources, leading to conflicts between their different uses [2].

Changes in agricultural production methods, the process of turning over grassland, the increasing conversion of arable or wooded land to urban areas, and the increased extraction of biomass, among other factors, are leading to changes that are potentially harmful to soil quality and the stability of its carbon reserves [3]. As complex systems, soils play an essential role in agricultural and forest ecosystems by orchestrating various natural cycles, including that of greenhouse gases. Because of their agro-environmental functions, soils fulfil a dual role as reservoirs and sinks of organic carbon while at the same time being the source of carbon dioxide (CO_2) emissions into the atmosphere, a major greenhouse gas contributing to the phenomenon of climate change [2, 4, 5].

Soils are the largest terrestrial reservoir of organic carbon, surpassing 2 to 3 the amount present in the atmosphere and 2.5 to 3 times that of the oceans [6]. As a result, they play a key role in the global carbon cycle [3]. Any change, whether positive or negative, in the levels of organic carbon in the soil can lead to emissions or absorptions of atmospheric CO_2 [7]. Changes in land use and development are a major source of man-made greenhouse gas emissions. These soil carbon stocks are highly sensitive to changes in land use and practices, and their state is also influenced by climatic

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Extended author information available on the last page of the article

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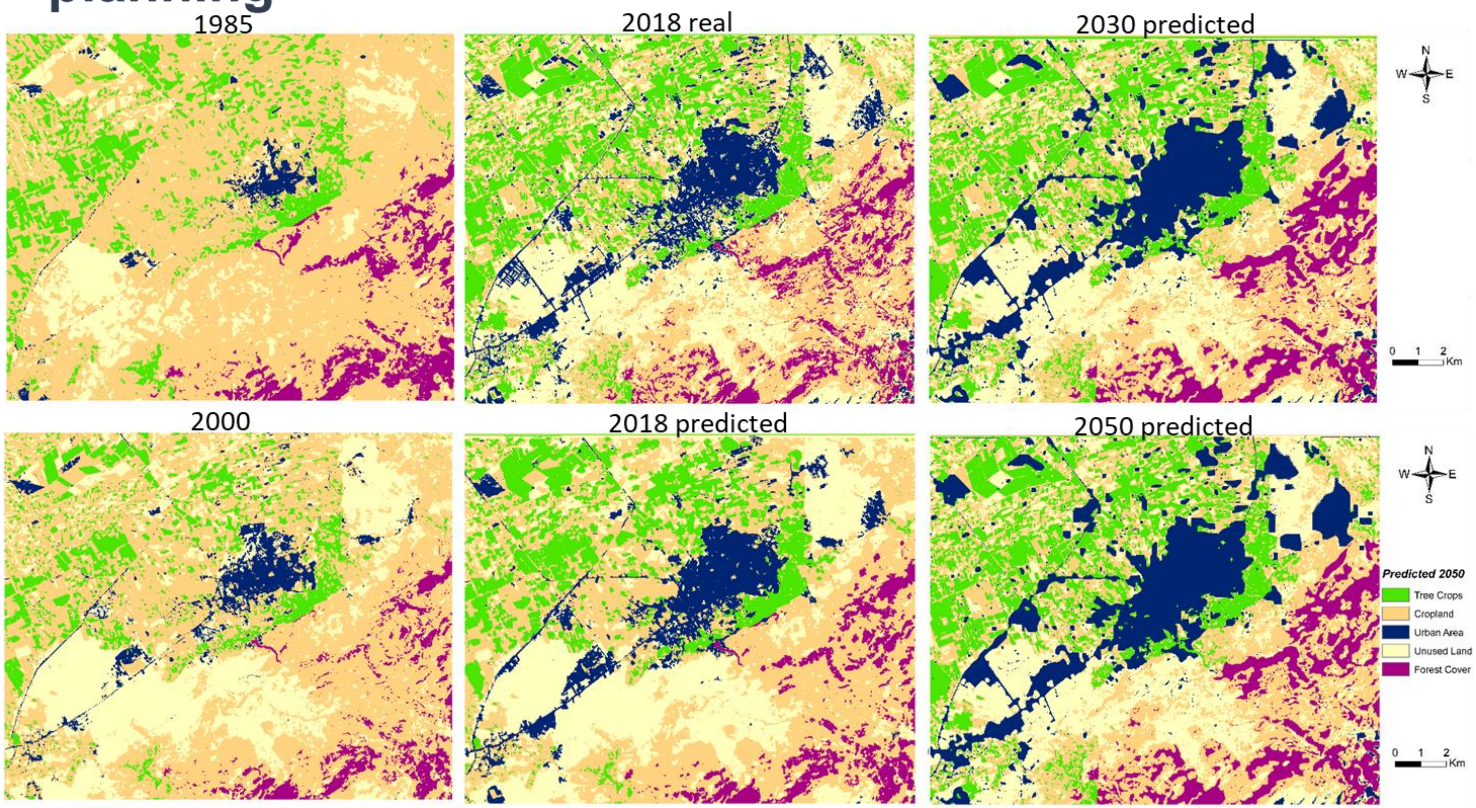
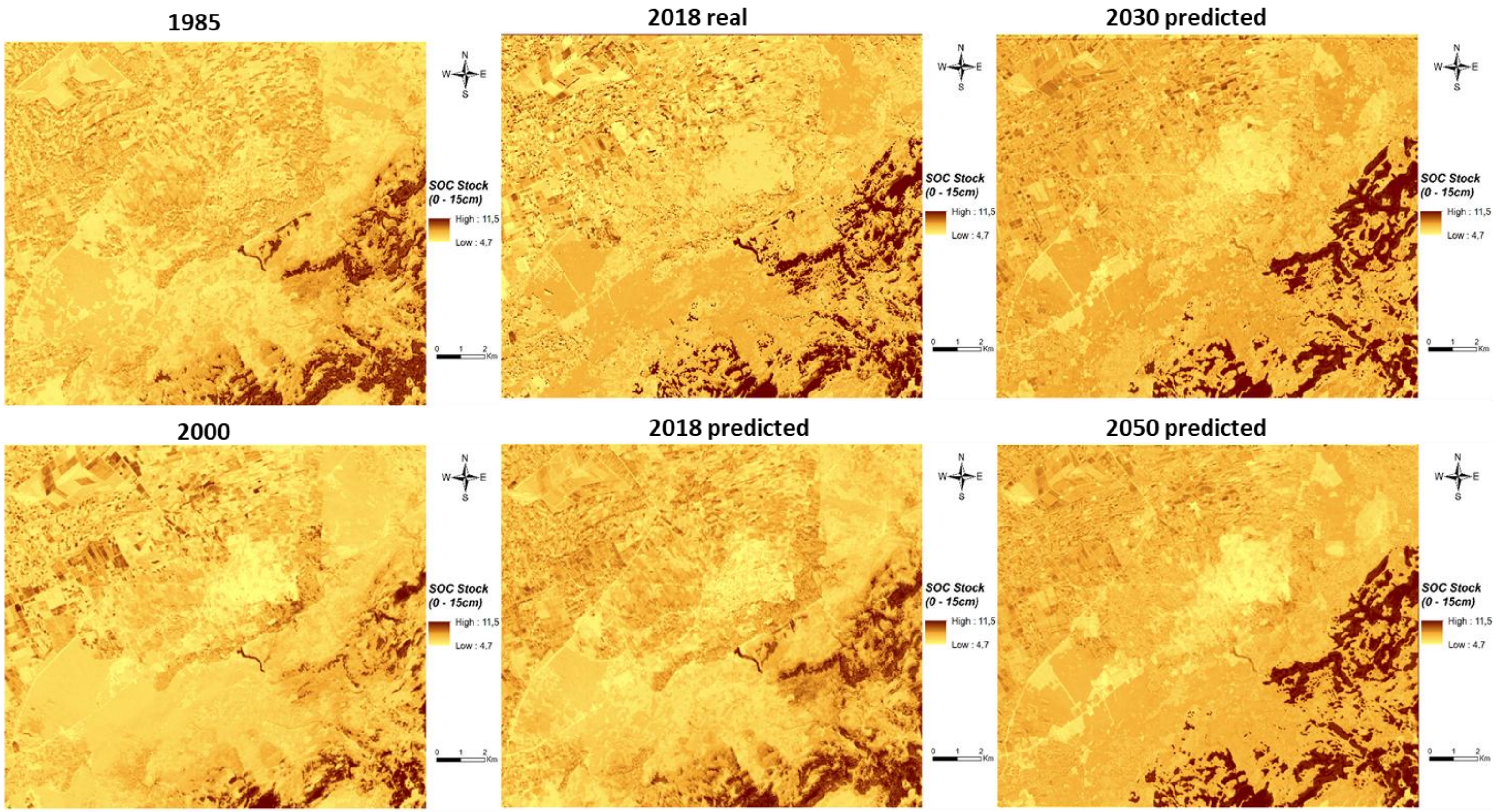
Simulating environmental variables for sustainable planning



Tree Crops Cropland Urban Area Unused Land Forest Cover

Sébatien Gadal, Mounir Oukhattar, Catherine Keller (UM 34 CEREGE), and Ismaguil Hanadé Houmma, UMR 7300 ESPACE

Modeling the Stock of soil organic carbon



Sébatien Gadal, Mounir Oukhattar, Catherine Keller (UM 34 CEREGE), and Ismaguil Hanadé Houmma, UMR 7300 ESPACE

Integrating environmental risks (flooding) into urban planning and mapping people's exposure

Geo-Eco-Trop., 2017, 41, 3, n.s.: 463-477

GEO - ECO - TROP
http://www.geoecotrop.be
Numéro spécial

Le risque d'inondation de débâcle et le réchauffement climatique à Yakoutsk (Russie)

Break-up flood risk and climatic warming in Yakoutsk (Russia)

Romain ROLLOT[1], Jean-Louis BALLAIS[1], Sébastien GADAL[1,2] & Youri DANILOV[2]

Abstract : The Léna river is the major axis that structures a part of central and oriental Siberia. Real motorway in winter and seaway in summer, it is the only way that allows the goods transportation in quantity.

More than 40 % of the Saka Republic (Yakoutia) inhabitants live along the Léna. It was the main antropisation axis and is the main urbanization axis at the present day.

Its nival regime is characterized by a great excessiveness due to the cold continental climate and opposes low winter flows to enormous spring flows during break-up.

Climatic warming during the end of XXth century causes increase of flow, thickening of permafrost active band and thinning down of superficial ice layer in winter. In spring, melting is earlier in May and daily discharges are lower in June.

There a few change in summer but September and October discharges decrease. In total, even if the mean annual discharge weakly increases, there is no increasing of the peak flow and thus of the flood risk. Exposure of population to flood risks has been considerably increased by the urban growth of Yakoutsk.

Key-words : Léna river, break-up, anthropisation, climatic warming, oriental Siberia.

Résumé : La Léna est l'axe majeur structurant l'espace géographique d'une partie de la Sibérie centrale et orientale. Véritable autoroute en hiver et voie maritime en été, elle constitue la seule voie permettant le transport des marchandises en grande quantité. Plus de 40% des habitants de la République de Saka (Yakoutie) habitent le long de la Léna. Elle fut l'axe principal d'anthropisation et aujourd'hui d'urbanisation.

Son régime nival se caractérise par une forte immodération due au climat froid continental et oppose de faibles débits hivernaux à d'énormes débits printaniers lors de la débâcle.

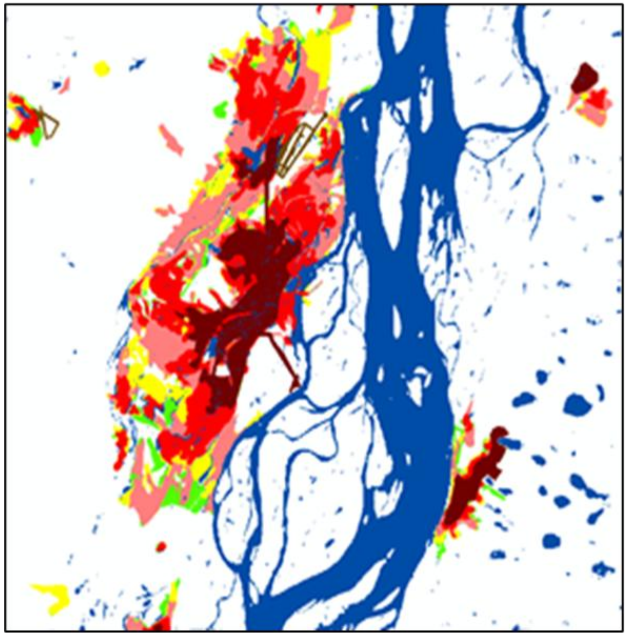
Le réchauffement climatique de la fin du XX^{ème} siècle se marque, en hiver, par l'accroissement du débit, l'épaississement de la couche active du pergélisol, et la diminution de l'épaisseur de la couche de glace superficielle. Au printemps, la fusion est plus précoce en mai et les débits journaliers plus faibles en juin. L'été présente peu de changement alors que les débits de septembre et d'octobre diminuent. Au total, même si le débit annuel moyen augmente légèrement, on n'observe pas d'accroissement du débit de pointe et donc du risque d'inondation. L'exposition des populations aux risques d'inondation s'est considérablement accrue avec la croissance urbaine de la ville d'Yakoutsk

Mots-clés : Léna, débâcle, anthropisation, réchauffement climatique, inondation, Sibérie orientale.

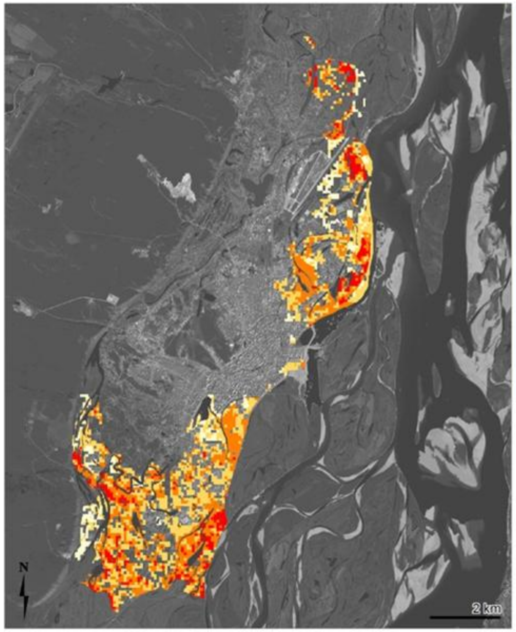
[1] Aix-Marseille Université, CNRS ESPACE UMR 7300, Aix-en-Provence, France. jean-louis.ballais@orange.fr
[2] North Eastern Federal University, Department of Geography, Yakoutsk, Russie

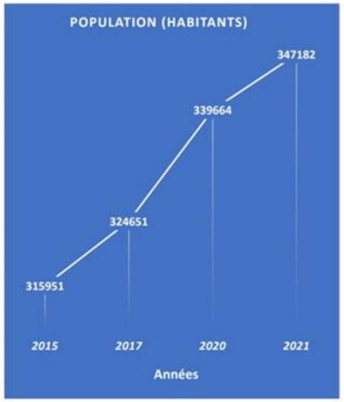
Modelling the Debacle risk exposure of Yakutsk

- Massive urban and demographic expansion of Yakutsk (capital of Sakha Republic, Siberian Arctic) to 355443 inhabitants in 2022.
- Settlements of new inhabitants near risky areas: Permafrost, debacle's flooding.



1990 => 2020





Modelling the vulnerable urban areas of the debacle's flooding
Sébastien Gadal, Romain Rollot, UMR 7300 ESPACE

URBAN VEGETATION MAPPING BY AIRBORNE HYPERSPETRAL IMAGERY; FEASIBILITY AND LIMITATIONS

Ouerghemmi W[1], Gadal S[1], Mozgeris G[2], & Jonikavicius D[2]

[1]Aix-Marseille Univ, CNRS, ESPACE UMR 7300, Univ Nice Sophia Antipolis, Avignon Univ, 13545 Aix-en-Provence, France
[2]Aleksandras Stulginskis University, LT-53361, Akademija, Kaunas r., Lithuania

ABSTRACT

Fast urbanization requires complex management of green spaces inside districts and all around the cities. In this context, the use of high-resolution imagery could give a fast overview of species distribution in the considered study zone, and could even permit species recognition by taking advantage of high spectral resolution (i.e. superspectral/hyperspectral imagery). In this study, we aim to explore the feasibility of eight vegetation species recognition inside Kaunas city (Lithuania). The goal is to determine the potential of metric/centimetric spatial resolution imagery with less than hundred bands and a limited spectral interval (e.g. Vis-NIR), to be able to recognize urban vegetation species. The ground truth samples were also limited for some of the considered species. The method included pre-treatments based on vegetation masking and feature selection using Minimum Noise Fraction (MNF). Support Vector Machine (based classifier) showed encouraging performance over Spectral Angle Mapper (SAM), the accuracies were not notably high in term of statistical analysis (i.e. up to 46% of overall accuracy) but the visual inspection showed coherent distribution of the detected species.

Index Terms— Airborne, hyperspectral, SAM, SVM, MNF, vegetation mapping.

1. INTRODUCTION

Green spaces become key elements nowadays in every modern city insofar as they offer multitudes of social and environmental services; entertainment, physical activity, biodiversity development, urban heat island effects decrease and atmospheric pollution absorption, etc. All these services contribute to the well-being of citizens and to the compensation of the negative effects of urbanization expansion and development.

Remote sensing data is an important tool and approach for urban planners, urban architects and municipalities to manage, characterize and monitor the green spaces over large areas. Multiband imagery combined to high spatial resolution could also offer a detection by vegetation species. One could divide the existing methods in terms of vegetation species mapping into two groups 1) pixels based approaches, and 2) objects based approaches.

The first group is mainly based on the use of spectral/radiometric features of multiband imagery. In general, these methods are based on a supervised classification preceded by a pre-treatment step commonly using filters or feature selection procedure (e.g. Minimum Noise Fraction (MNF), Principal Component Analysis (PCA)). The classification is applied then on pre-treated data in the initial space, or in the transformed space, or both (i.e. spectral bands and neo-channels) (e.g. [1],[2],[3]).

Second group of methods consider the trees as an object, starting from there, spectral and spatial features (i.e. texture, shape) are calculated over the detected objects, and finally the objects are classified. The first step involves delineating the objects manually (e.g. [4],[5],[6]) or using segmentation algorithms (e.g. [7],[8]), the second step consists in classifying these objects by parametrical statistical classifiers (e.g. Linear Discriminant Analysis) or machine learning classifiers. With the emergence of very high spatial resolution imagery, several studies reported the usefulness of objects-based approaches over pixel-based ones (e.g. [9],[5],[8]), nevertheless, object-based methods could be time consuming especially when applying a manual delineation of trees crown, and the automatic segmentation techniques brings a lot of confusions.

In this study, we tested a pixel-based approach using two classifiers: (1) a distance based one, (2) and a machine learning one, the potential of using feature selection was assessed at the pre-treatment level. The goal is to assess the feasibility of vegetation species identification using superspectral/hyperspectral Vis-NIR imagery and to compare our results with the ones of similar studies in the field of vegetation mapping.

2. DATA AND STUDY ZONE

Two airborne multiband images were acquired over Kaunas city (Lithuania) in July 2015 and September 2016 by hyperspectral Vis-NIR sensor RIKOLA (SENOP OPTRONICS). The sensor was installed on a manned ultra-light aircraft and was characterized by a spectral range of 500-900nm. In the first campaign, 16 spectral bands were recorded, while the number of bands was increased up to 64 in the second campaign, the ground sample distance (GSD) was of 0.7m and 0.5m respectively, the first image was then resampled to 0.5m.

URBAN VEGETATION MAPPING USING HYPERSPECTRAL IMAGERY AND SPECTRAL LIBRARY

Walid Ouerghemmi[1], Sébastien Gadal[1], Gintautas Mozgeris[2]

[1]Aix-Marseille Univ, CNRS, ESPACE UMR 7300, Univ Nice Sophia Antipolis, Avignon Univ, 13545 Aix-en-Provence, France
[2]Aleksandras Stulginskis University, LT-53361, Kaunas r., Lithuania

ABSTRACT

The development and expansion of urbanized areas around the cities, brings new challenging issues about the organization, the monitoring, and the distribution of green spaces within the cities (e.g. grass, trees, shrubs, etc.). Indeed, these spaces brings better life quality for population and preserve biodiversity. This study, aims to 1) investigate the feasibility of urban vegetation mapping by species using multiband imagery and spectral libraries and to 2) determine at what scale the mapping is reliable (e.g. trees scale, group of trees scale, high/short vegetation scale).

Index Terms— Hyperspectral, spectral library, band selection, regularization, vegetation mapping.

1. INTRODUCTION

Urban vegetation study is a key feature in landscape monitoring; it serves as an ecological regulator, and provides many ecosystem services. The preservation and management of the green spaces requires an accurate mapping, which is carried by field inspection, aerial photography interpretation, and other time and money-consuming methods. The existing solutions of urban vegetation inventories may be significantly improved by introducing more advanced remote sensing techniques without notable increase of costs. Vegetation mapping and monitoring in urban context by remote sensing, remains nevertheless, a challenging issue, insofar as the vegetation spectral response is sensitive to chlorophyll content at the plant level, which increase spectral variability regarding individual species. Many misclassifications between species could be therefore expected depending on the seasonality, data spectral/spatial resolution (e.g. [1], [2]). The goal is to provide reliable vegetation maps that could serve as basis for urban planners, municipalities, and decision makers.

Many existing studies assessed the feasibility of vegetation mapping using remote sensing data (e.g. [3],[4],[5]), however, most of these studies concentrate on specific vegetation families. Few studies addressed the separability issues between species or group of species were, and the spectral correlations issues management.

This study further elaborates on the existing vegetation mapping methods, aiming to propose an original approach, which includes a three steps procedure; 1) a classification step by spectral library, 2) a band selection step for spectral correlation compensation, and 3) a regularization step, which is applied over the classification map to smooth the rendering.

2. MATERIALS AND METHOD

2.1. Airborne hyperspectral imagery and study zone

For this study, two airborne multiband images were used. The images were acquired using a Vis-NIR sensor (RIKOLA, SENOP OPTRONICS) operating in the spectral range of 500-900nm over the city of Kaunas (Lithuania). For the first campaign in July 2015, the sensor was configured to produce 16 bands for each frame image, a photogrammetrically processed mosaic of size 3189×3292 pixels was used for this study, and the corresponding ground sample distance (GSD) was of 0.7m. For the second campaign in September 2016, the sensor was configured to produce 64 bands for each frame; a mosaic of size 4000×1900 pixels was used for this study. The radiometric calibration was carried using the sensor software, the atmospheric correction was carried using the MODTRAN radiative transfer model [6].

Kaunas city is characterized by a high species diversity with up to 96 tree species, 49 shrubs and 2 vines [7]. For this study, we have focused on the city center zone, the mapping considered urban vegetation of residential gardens, public parks, city trees. The vegetation species were defined using a 2 levels hierarchy, the first level concerns grass (e.g. short vegetation), deciduous trees, and coniferous trees. The second level, which is a finer level, concerns 10 species of deciduous and coniferous trees in addition to grass.

2.2. Urban spectral library

The spectral library includes 50 common urban objects that were collected over the city of Kaunas [8]; the objects include manmade, vegetation and bare soil materials. The measurements were done in laboratory using Themis-Vision VNIR400H sensor. The spectral interval varies from 400 nm to 1000 nm with 1024 narrow bands; the spectral resolution is equal to 0.6 nm. Ten trees species and a short vegetation sample were extracted from the library as follow; 6 deciduous trees including Horse chestnut, European beech, Linden, Maple, Mountain ash, Oak, 4 coniferous trees including Norway spruce, Lime glow, Scots pine, Arborvitae, and 1 green short grass/lawn specie, used in public parks and football field in Kaunas. The ground truth polygons were extracted from a tree inventory of 2012 [9].

2.3. Mapping method

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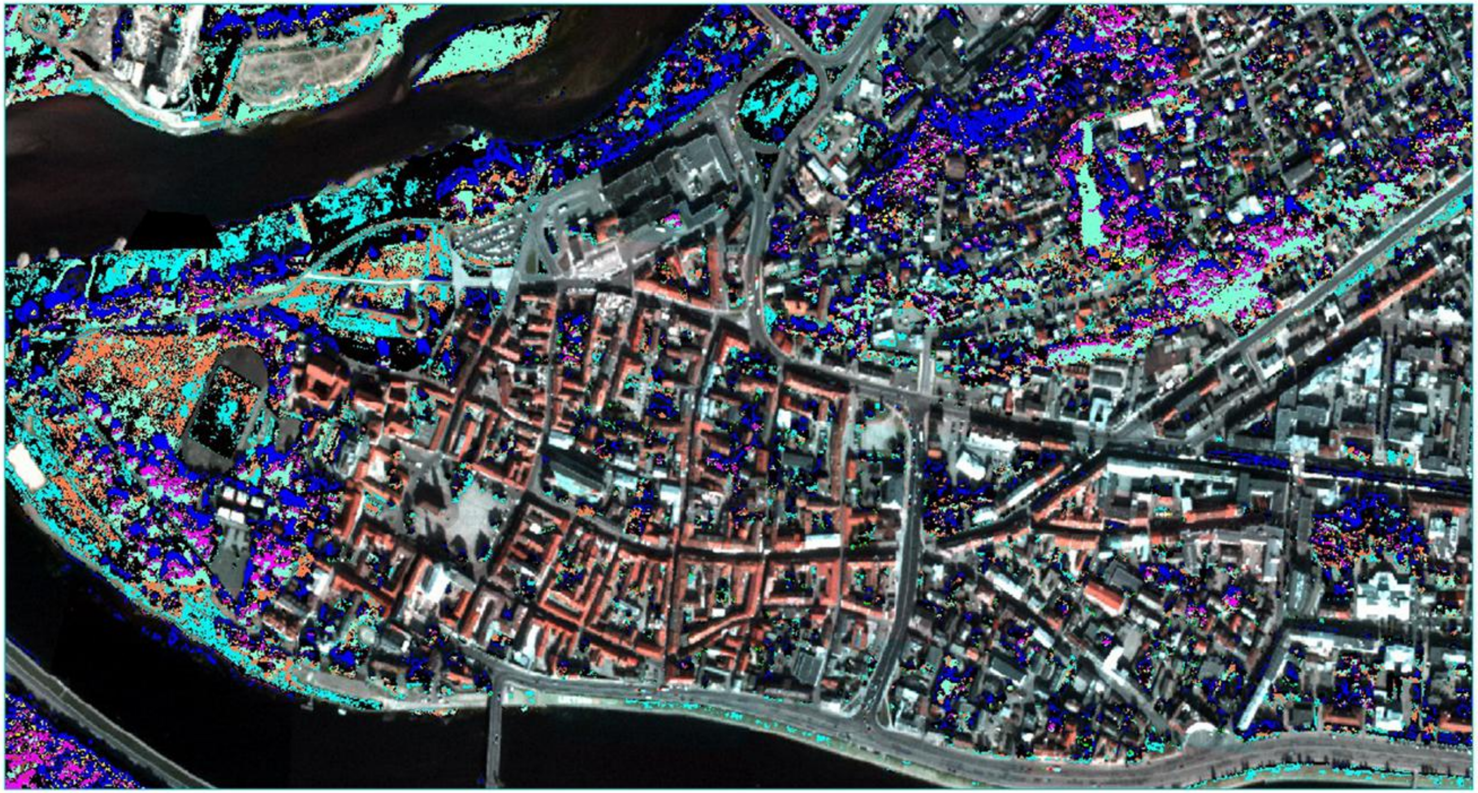
Recognition of urban vegetation by hyperspectral airborne VNIR sensors



LEGENDE

- Unclassified
- azuolas paprastasis
- berzas karpotasis
- eglé paprastoji
- gluosnis trapusis
- kastonas paprastasis
- klevas paprastasis
- klevas uosialapis
- liepa mazalape
- peulouse
- pusis kalniné
- robinija baltaziede
- tuja vakariné
- uosis paprastasis

Sébastien Gadal, Walid Ouerghemmi, Romain Barlatier, UMR 7300 ESPACE

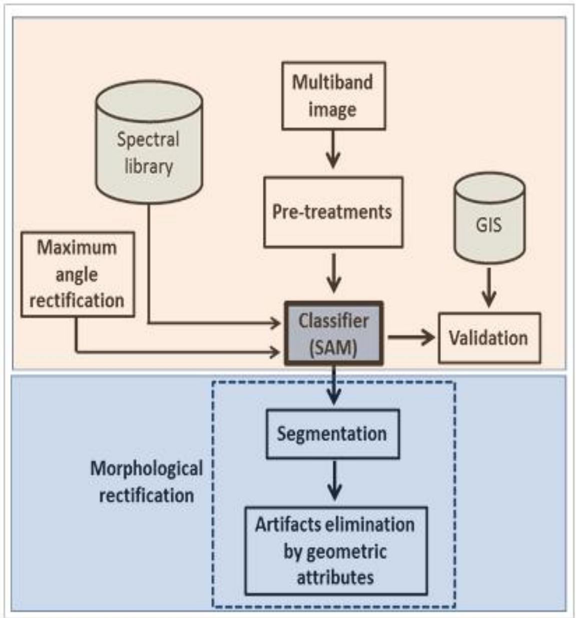
A Spectral Database for the Recognition of Urban Objects in Kaunas City: Performance and Morphometric Issues

ADVANCED CONSTRUCTION AND ARCHITECTURE 2020
Raw Materials and Circular Economy in the Built Environment
September 23-25, 2020, Kaunas, Lithuania
Kaunas University of Technology

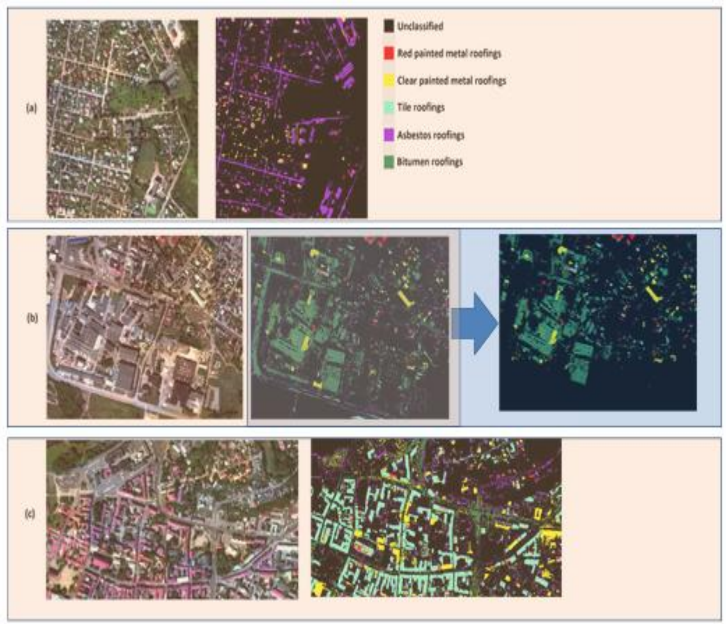
Sébastien Gadal[1,2], Gintautas Mozgeris[3], Donatas Jonikavicius[3], Jurate Kamicaityte[4], Walid Ouerghemmi[1]

[1]Aix-Marseille Université, CNRS ESPACE UMR 7300, [2]North Eastern Federal University, [3]Vytautas Magnus University, [4]Kaunas University of Technology, sebastien.gadal@univ-amu.fr

- *The diversity of urban materials of Kaunas city, contemporary and historical urban structures, urban planning peculiarities and spatial complexity characteristic to post-Soviet Baltic cities permitted the development of a "broad spectrum" object-oriented spectral database made with a Themis Vision hyperspectral Vis-NIR sensor in laboratory on some common roofing's materials.*



Urban objects classification by spectral library and morphological rectification of multiband image.



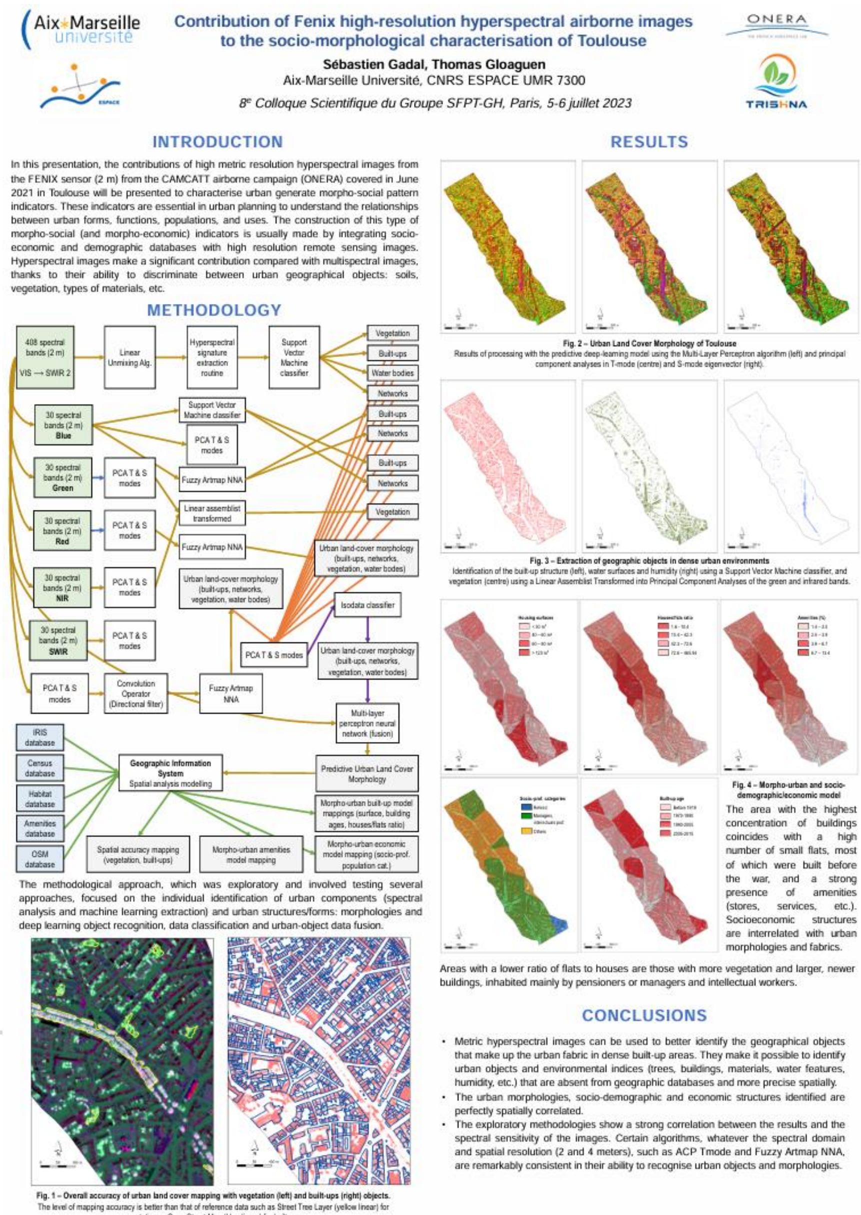
Spectral classification by spectral library of (a) residential zone, (b) industrial zone, and (c) historical center of Kaunas city.

Key conclusions:

- *The results obtained on the recognition and characterization of urban materials and buildings are substantial.*
- *The performance of the recognition of built-up areas is improved with the use of the morphometric urban object database.*
- *Using the urban objects spectral library in another city is possible after adaptation of the morphological rules to the specific city's structures.*

ANR Hyperspectral Imagery Applied to Environmental Planning & CNES TOSCA AICMEE

Recognition of the socio-morphological structures of urban populations (Toulouse) using hyperspectral remote sensing and INSEE IRIS (Census of population)



Contribution of Fenix high-resolution hyperspectral airborne images to the socio-morphological characterisation of Toulouse

Sébastien Gadal, Thomas Gloaguen
Aix-Marseille Université, CNRS ESPACE UMR 7300

8e Colloque Scientifique du Groupe SFPT-GH, Paris, 5-6 juillet 2023

INTRODUCTION

In this presentation, the contributions of high metric resolution hyperspectral images from the FENIX sensor (2 m) from the CAMCATT airborne campaign (ONERA) covered in June 2021 in Toulouse will be presented to characterise urban generate morpho-social pattern indicators. These indicators are essential in urban planning to understand the relationships between urban forms, functions, populations, and uses. The construction of this type of morpho-social (and morpho-economic) indicators is usually made by integrating socio-economic and demographic databases with high resolution remote sensing images. Hyperspectral images make a significant contribution compared with multispectral images, thanks to their ability to discriminate between urban geographical objects: soils, vegetation, types of materials, etc.

METHODOLOGY

The methodological approach, which was exploratory and involved testing several approaches, focused on the individual identification of urban components (spectral analysis and machine learning extraction) and urban structures/forms: morphologies and deep learning object recognition, data classification and urban-object data fusion.

Fig. 1 – Overall accuracy of urban land cover mapping with vegetation (left) and built-ups (right) objects.
The level of mapping accuracy is better than that of reference data such as Street Tree Layer (yellow linear) for vegetation or Open Street Map (blue linear) for built-ups.

RESULTS

Fig. 2 – Urban Land Cover Morphology of Toulouse
Results of processing with the predictive deep-learning model using the Multi-Layer Perceptron algorithm (left) and principal component analyses in T-mode (centre) and S-mode eigenvector (right).

Fig. 3 – Extraction of geographic objects in dense urban environments
Identification of the built-up structure (left), water surfaces and humidity (right) using a Support Vector Machine classifier, and vegetation (centre) using a Linear Assemblist Transformed into Principal Component Analyses of the green and infrared bands.

Fig. 4 – Morpho-urban and socio-demographic/economic model

The area with the highest concentration of buildings coincides with a high number of small flats, most of which were built before the war, and a strong presence of amenities (stores, services, etc.). Socioeconomic structures are interrelated with urban morphologies and fabrics.

Areas with a lower ratio of flats to houses are those with more vegetation and larger, newer buildings, inhabited mainly by pensioners or managers and intellectual workers.

CONCLUSIONS

- Metric hyperspectral images can be used to better identify the geographical objects that make up the urban fabric in dense built-up areas. They make it possible to identify urban objects and environmental indices (trees, buildings, materials, water features, humidity, etc.) that are absent from geographic databases and more precise spatially.
- The urban morphologies, socio-demographic and economic structures identified are perfectly spatially correlated.
- The exploratory methodologies show a strong correlation between the results and the spectral sensitivity of the images. Certain algorithms, whatever the spectral domain and spatial resolution (2 and 4 meters), such as ACP Tmode and Fuzzy Artmap NNA, are remarkably consistent in their ability to recognise urban objects and morphologies.

Thank you for your attention!