Land-use planning, *Risks*

Geomatic research is carried out to gain further insight into areas utilized by humans and to enhance territorial management and governance. The results have been widely published through visual products such as maps (thematic, 3D, photomaps, etc.), as well as various images and photographs (orthophotomosaics, aerial photographs, satellite images, etc.). This broad range of constantly evolving and ever more accurate, exhaustive and diversified 'images' ('animated maps', web mapping, 'virtual globes') prompts researchers to reflect on choices to be made for stakeholders as a function of the knowledge collected, issues at hand and objectives to fulfil.

Mobilizing spatial information for land-use planning is a co-building and co-responsibility process. The project contributes to building a shared view of territory based on available tools, including: remote sensing, which enables information acquisition on large areas and targets of interest, and; geographic information systems (GIS) and georeferencing of different information layers for spatial correlation of data of various origins. Geoinformation mobilization could be defined as the "implementation of an information process by an individual (or a group of individuals) in order to assess, or communicate on, a social area". This approach thus combines technical and social aspects. The increasing dissemination of these many geographic tools and their use in a range of fields, especially land-use planning and risk management, nevertheless prompts us to re-examine the meaning of some concepts (e.g. 'geoinformation', 'information system', 'complexity', etc.), modifications in knowledge and its use, the status of territory with respect to geomatics (e.g. between real and virtual spaces), etc.

The research examples presented in this chapter highlight the broad range of different territories investigated and scales considered: from a national view, through the prevention of locust outbreaks in Madagascar, to an in-depth characterization of the vulnerability of a region (Ile de France) to accidents associated with dangerous material transport, but also through targeted objectives. The applications presented thus involve the characterization and assessment of territorial modifications (converting agricultural land into housing developments), monitoring the evolution of a phenomenon (coastal erosion), characterizing geological disasters (earthquakes). Integrated studies are also presented. They are aimed at building 'applied' geographic information systems, such as GIS RINAMED on natural hazards in the Mediterranean region, or 'integrated' GIS tools such as the SYSCOLAG project for global coastal zone management. Through their diversity, these studies illustrate the range of issues associated with the use of geoinformation. These problems are hinged on the uncertainty, the level of validity of spatial information used and their impact on associated models, as clearly illustrated by the study on the spatialization of the cost-benefit analysis of flood prevention projects.

Geoinformation enables studies on all topics associated with land-use planning and risks by providing key decisionmaking support elements, while also highlighting new scientific questions that will become research topics of the future.

Jean-Paul Bord (EA GESTER)
& Pierre-Alain Ayral (LGEI)

From Agropolis International thematic directory n° 9 - "Geoinformation and Earth Observation for environment and territories" (February 2010 - 68 p.)

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▲ *Swarm of migratory locusts in Madagascar.*
Crop damage associated with the last major outbreak (1996-2000) led to pesticide spraying of an area of over 4 million ha, thus highlighting the need for an operational warning network.

Spatial analysis to prevent locust outbreaks in Madagascar

The Malagasy migratory locust, *Locusta migratoria capito* Sauss., is able to change phase according to its population density. The solitary and gregarious phases are characterized by specific behaviours with markedly different morphological, physiological and ecological traits. In the solitary phase, these locusts are dispersed and do not threaten crops. They migrate by flying in search of suitable conditions for their development. If such suitable areas are spatially reduced, the locusts form high density groups. They can then, through a few generations, switch to the gregarious phase, where they form hopper bands and swarms that are capable of destroying crops and pastures.

An operational research project carried out by EMPA (CIRAD), in collaboration with the Malagasy National Locust Centre, is aimed at improving locust forecasting and monitoring systems in order to control this plague. This involves combining monthly information on rainfall, habitats and the biology of the locust (density, phase and stage). Spatial data can also be used to delimit potential grouping areas where the high population densities could trigger phase transformation and subsequent outbreaks.

A spatial delimitation of habitats was carried out through an analysis of around 12 high resolution Landsat images. These spatial data on habitats structures are updated monthly with field data: the rainfall levels and biological features of the migratory locust are integrated in a GIS for interpolation over the entire outbreak source area, i.e. 100 000 km². It is thus possible, on a monthly basis, to monitor the evolution of areas suitable for locust grouping and prevent outbreak risks.

Spatial monitoring of pest locusts in Madagascar, and elsewhere, represents extremely targeted research. It requires in-depth field knowledge, effective management of spatial information and long-term partners in concerned countries.

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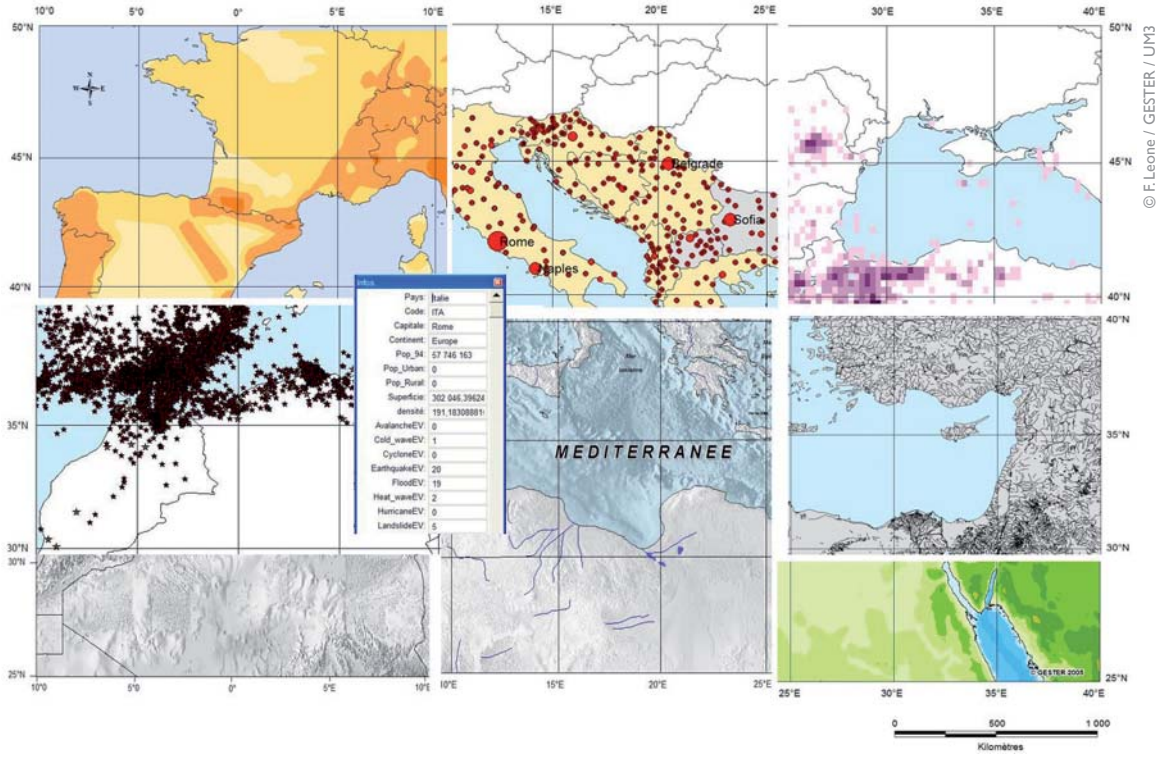
UMR Géosciences Montpellier
(see page 28)

UMR LISAH - Laboratoire d'étude des Interactions Sol – Agrosystème – Hydrosystème
(see page 18)

UMR TETIS - Geoinformation and Earth Observation for Environment and Land Management
(see page 8)

...continued on page 50



▲ *Map mosaic extracted from GIS RINAMED.*

A geographic information system on natural hazards in the Mediterranean region: a tool for territorial analysis, risk evaluation and production of a permanent atlas

This project is part of a European initiative aimed at raising awareness on natural risk prevention in the Mediterranean region (INTERREG RINAMED programme: a European interregional cooperation initiative 'Natural Risks and Hazards in the Mediterranean'). It involves development of an interactive open-ended geoinformation platform (GIS and webmapping) on natural risks and disasters throughout the Mediterranean Basin. This is an exceptionally interesting area because it hosts a broad range of damaging natural phenomena (earthquakes, flash floods, volcanic eruptions, landslides, severe storms, etc.) while benefitting from a number of risk reduction initiatives.

The main difficulties encountered in this project concern the integration, synthesis, homogenization and critical analysis of the many sources of available data, and setting up a network of foreign correspondents. Moreover, the mapping production process requires the development of a graphic production line, a specific graphic charter, and an online interactive digital mapping tool.

The first applications derived from the database (GIS RINAMED) concern the production of maps for a future permanent atlas of natural risks and hazards in the Mediterranean Basin (RINAMED Atlas) and the development of composite indicators of risk on the NUTS3 scale (international classification equivalent to the French departmental level) for the Mediterranean Latin Arch (corresponding initiative entitled 'RINAMED indicators').

Current and future projects are focused on the development of an online interactive GIS software tool based on open source technology. It should enable clients, via Internet, to manage information layers, import data, make spatial requests, develop statistical analyses and produce maps. This work should ultimately lead to the development of an open-ended, top notch and efficient tool designed to enhance knowledge and promote geoinformation sharing on natural risks and hazards in the Mediterranean region.

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Main teams

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URP Pastoralism
(see page 38)

US ESPACE - Expertise et SPatialisation des Connaissances en Environnement
(see page 8)

Other teams focused on this topic

FRE MTE - Mutations des Territoires en Europe
(see page 55)

UMR G-EAU - Water Resource Management, Actors and Uses
(see page 43)

UMR LIRMM - Montpellier Laboratory of Informatics, Robotics and Microelectronics
(see page 28)

UPR GREEN - Management of Renewable Resources and Environment
(see page 18)

UR Dynamiques socio-environnementales et gouvernance des ressources
(see page 55)

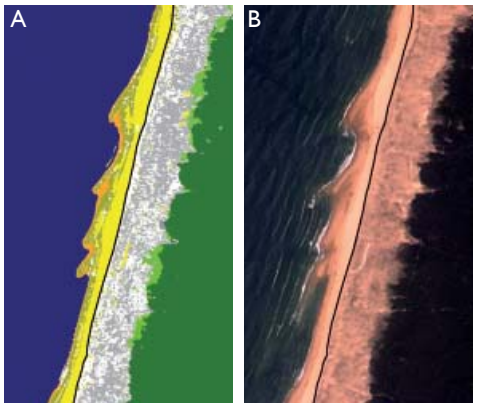
Shoreline and coastal erosion monitoring in Aquitaine region (France) using FORMOSAT-2 imagery

Within the framework of the French *Contrat de Plan État-Région* 2000-2006, the French government, the *Conseil Régional d'Aquitaine*, BRGM and the *Office National des Forêts* collaborated to create the *Observatoire de la Côte Aquitaine*, which aims to provide managers of the coastal zone in the French Aquitaine region with a decision support tool.

The coastal erosion problem is dealt with through remote sensing analysis of the beach-dune system. This study is based on the CNES Kalideos Programme which provides access to satellite data on the Arcachon Basin. The aim is to develop a method for monitoring a number of sedimentary and biological facies that characterize shoreline advances and retreats.

A hybrid method that combines the accuracy of field readings (too expensive to be implemented over the entire 270 km Aquitaine shoreline) and a synoptic view of 14 high-resolution satellite images (FORMOSAT-2) was selected for this monitoring operation. Remote sensing mapping enables regular updates of different facies such as the backshore and foreshore, grey and white dunes, as well as the main limits formed by the shoreline and the dune-forest interface.

A first preparation phase involved georeferenced data verification, and radiometric analysis of scenes. Using an unsupervised classification method, the Aquitaine coast was divided into four different sectors, while taking atmospheric content variations that could impact radiation transfer (e.g. associated with differences in dates, natural variability in substrate colours, etc.) into account.



◀ *Shoreline overlay (black): (A) supervised classification and (B) FORMOSAT image (Hossegor sector).*

The classification results were efficient overall for selected targets (forests, grey and white dunes, foredune, backshore, foreshore). Shoreline detection (5.3 m map accuracy) was further optimized (up to 84.6% success) by using a filter designed to extract the outer contour of objects.

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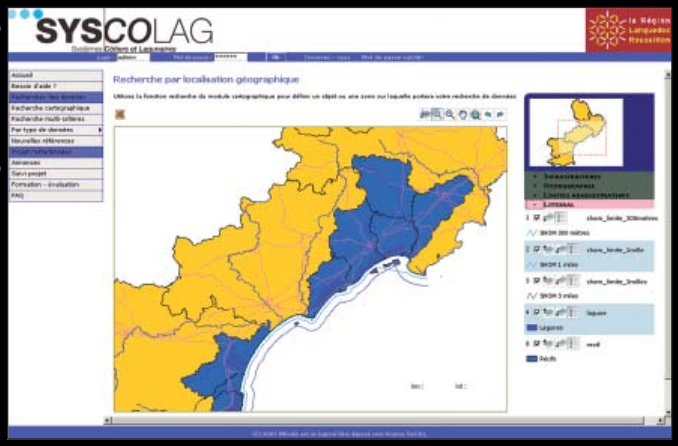
Integrated environment/society approach applied for the management and sustainable development of interface territories: coastal regions and islands



▲ *Environmental information research site in Languedoc-Roussillon region (France) for the SYSCOLAG programme based on the MDweb tool.*

The most complex ecosystems and sociosystems are generally located at the interface between different environments. In coastal areas, land-sea contact points attract human populations and economic activities, with a concomitant increase in land use disputes. On islands, the landscape diversity, small area and isolation generate atypical ecosystem and sociosystem organizations.

In this setting, sustainable development cannot be managed through a sectoral approach–activity by activity–but rather through an integrated territorial management approach. There are thus two angles to the research:

- developing and validating knowledge integration and management tools, such as the MDWeb tool for the management of metadata tailored to the needs of the *SYStèmes CÔtiers et LAGunaires du Languedoc-Roussillon* (SYSCOLAG) project by the ESPACE, LIRMM and TETIS research teams and regional stakeholders, i.e. the *Centre d'Études et de promotion des Activités lagunaires et Maritimes du Roussillon* (CEPRALMAR in Languedoc-Roussillon, France);

- proposing each of the three main types of territorial stakeholders, i.e. public authorities, economic decisionmakers and users, a description of the dynamics and dysfunctions of this system, while specifying their respective responsibilities in order to boost their awareness on the problems and encourage them to jointly come up with solutions.

The research unit ESPACE (IRD) has thus developed three methodological modules focused respectively on:
- modelling the impact of catchment dynamics on coastal areas;
- analysis of spatial and temporal agreements and disagreements in administrative territories with respect to institutional integration of public policies;
- assessment of the socioeconomic value of ecosystems.

All of these initiatives involve sharing, analysis and joint management of spatial information on territories, while contributing to enhanced governance of coastal areas and islands.

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Spatial imagery as a tool for research
on geological hazards and their prevention

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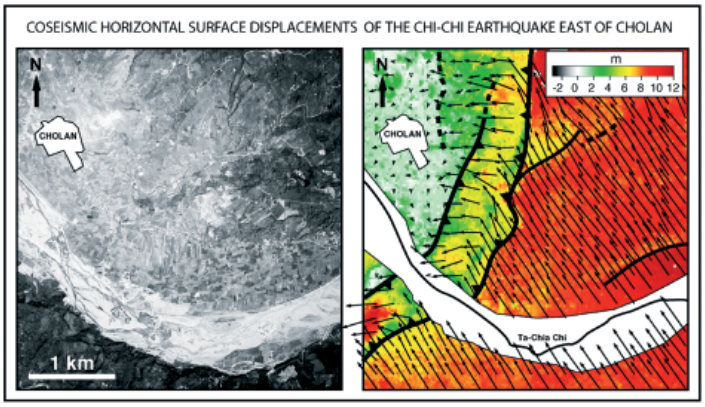

▲ *Measurement–by correlation of orthorectified aerial images–of ground displacements induced by an earthquake in Taiwan (1999): in red, displacements of as much as 10 m.*

Of all the different categories of geological hazards, earthquakes have the greatest societal impact, with heavy human casualties. In the last 5 years, the only major earthquakes (Iran in 2003, Sumatra and Pakistan in 2005, Indonesia in 2006, China in 2008) claimed almost 500 000 victims (source: United States Geological Survey).

Satellite imaging is very useful for gaining insight into the mechanisms that control these geological phenomena, while also being an efficient means of obtaining quantitative measurements.

A new imagery method that was developed by the French Commission for Atomic Energy (CEA) and recently implemented by *Géosciences Montpellier* provides a way to supplement GPS point measurements and field observations following earthquakes. This technique, which is based on the correlation of high resolution optical satellite images (e.g. Ikonos, QuickBird or SPOT5) acquired before and after an earthquake, enables operators to identify faults where displacements have occurred and to accurately measure the horizontal constituents of land deformations over a broad region around the earthquake epicentre. These data are essential for understanding the behaviour of seismic faults and assessing associated hazards and risks.

Landslides are another major source of risk for inhabitants and infrastructures. They have a key role in the evolution of the topography of mountain ranges. Remote sensing techniques facilitate global monitoring of hazard zones while not being hampered by any field constraints. Radar interferometry (InSAR) is advantageous for quantifying, with centimetre accuracy, a landslide that has taken place between two image acquisitions. It enables the operator to accurately determine the spatial distribution of the surface deformation. Moreover, the temporal evolution of landslide activity can be studied to analyse the impact of tectonic or climatic forcings that could induce catastrophic landslides.

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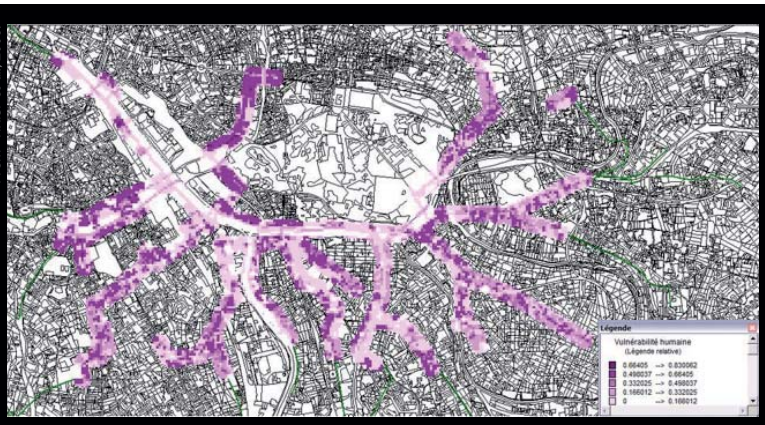
Evaluation of the vulnerability to risks associated with the transport of dangerous goods

It is essential to understand and prevent hazardous events so as to ensure the safety of inhabitants in the concerned area. Methodological risk characterization research involves quantification of hazard sources and also on taking into account–in an organized and formal way–the stakes (people, goods and environment) and their vulnerability, and finally on aggregating all of this information to assess risk levels.

An analysis of risks associated with hydrocarbon transport throughout the Ile de France (IdF) territory focused on modifications in risk levels induced by shifting hydrocarbon depots from the *petite couronne* area (four departments adjacent to Paris) to the *grande couronne* area (four departments on the periphery of IdF).

The number of kilometres travelled to deliver fuels to Paris has increased substantially, but it is also crucial to quantify the associated risks. The risk 'level' is defined as a function that combines a hazard potential variable (quantified by a probabilistic and deterministic approach) generated by the source (hydrocarbon transport) and a variable of the vulnerability of stakes in a concerned area. The method was implemented with GIS software to map the risk relative to hydrocarbon transport in IdF.

From Tixier *et al.*, 2006.



▲ *Example of a human vulnerability map.*

Three categories of mapping information were obtained:
- mapping the hazard potential of hydrocarbon transport;
- mapping the vulnerability within a territory (human, natural, material stakes);
- and finally mapping the risk level relative to a hydrocarbon depot and associated hydrocarbon transport involved in the depot shift.

Based on all of this information, an analysis can be conducted on the risk of shifting a hydrocarbon depot and to predict the impact of a given scenario.

This project was funded by the French *Direction Générale de l'Énergie et des Matières Premières* (Ministry of Economy, Finance and Employment) and supported by the 'crisis management preparation' service of the *Direction Régionale de l'Équipement d'IdF/Service Sécurité Défense* (Ministry of Equipment).

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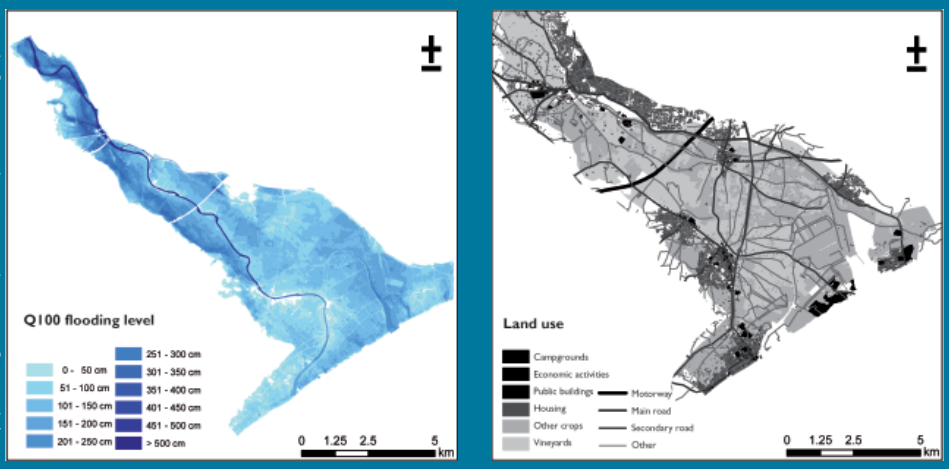
Mapping economic indicators and uncertainties for flood prevention projects



▲ *Example of hazard and land-use maps for economic analysis of flood risk (Orb, France).*

Cost-benefit analysis (CBA) is a public policy assessment method based on comparison of expected policy drawbacks and advantages. In the framework of flood prevention projects, the advantages are estimated on the basis of damage avoided via these projects. Spatial data is involved in calculating this damage: flood maps for a range of different flooding intensities (derived through a combination of hydrological, hydraulic and topographical models), and land-use maps. These data are correlated on the basis of vulnerability functions determined for each type of stake. Several research issues associated with the spatial dimension of CBA emerge through its implementation.

First, methods should be developed that take spatial relationships between systems into account for economic modelling of stake vulnerability. Stakes are often considered as elementary and independent spatial entities (e.g. a cooperative, farm) whereas the damage suffered by a stake also depends on the relationships with other stakes, e.g. an agricultural cooperative located beyond a flood zone is concerned because of the damage suffered by member farmers who live in a flood zone. Secondly, a sensitivity analysis is required to validate the approach. It should take the errors propagated during coupling of different models into account and enable identification of key CBA data. The imprecision of a digital field model, for instance, will be ramified in the measurement of the efficiency of certain local protections, e.g. temporary protective embankments.

A spatialized CBA can be conducted to generate a cartographic representation of different intermediate and final results: flood damage map; map summarizing damage for a flood range; map of damage avoided for a studied project. The extent of flood exposure of a territory can thus be qualified. In the last step in which the produced maps are correlated, it is essential to assess the accuracy of the maps used and produced, as well as their legends and the spatial scale of the analysis.

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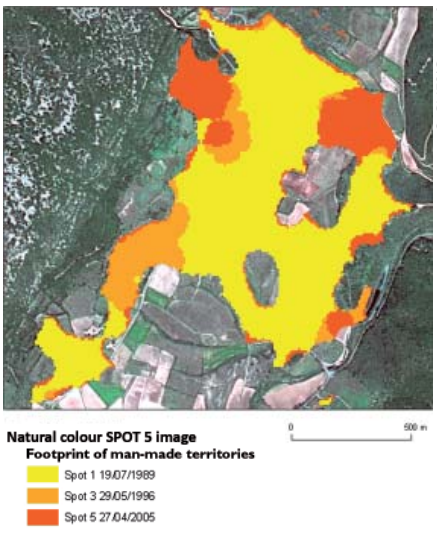
A method for evaluating farmland consumption via urban expansion

Periurban development, housing development in rural areas and the expansion of transportation and tourism infrastructures generally occur to the detriment of farmland. This land is systematically taken over and utilized as a result of local patterns (population growth, economic issues, introduction of infrastructures and real estate at the expense of a few hectares of farmland) and landowners' interests.

This trend of farmland consumption to benefit urbanization is considered marginal on a local scale, but it is a concern on regional and especially national scales when multiplied by the number of towns and cumulated over time. The risk is that this extinction of farmland could be irreversible. Indeed, it would be difficult and expensive (or even impossible or economically unrealistic) to try to reconvert this land back into fields for crop production. In the current international setting of food production and farm product and foodstuff trade, it is thus a strategically important heritage component that is being consumed for immediate economic profit, without regarding the medium- and long-term social utility.



▲ *Footprint of man-made territories, town of Vailhauques (Hérault, France).*

In 2008, the joint research unit (UMR) TETIS, in partnership with UMR LISAH, developed, in a pilot area in Languedoc-Roussillon region (France), a method for quantification and qualification of the spatial and temporal dynamics of farmland consumption by housing developments. This method, which was designed for potential application throughout France, is based on the use of satellite images acquired over the last 20 years, recent land-use databases, and a soil mapping inventory.

The method is being applied in 2009-2010 for validation and to generate objective results on farmland consumption patterns in this region since 1989. A national farmland conservation strategy could ultimately be applied, in line with recognized strategies for the conservation of natural areas and aquatic environments.

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