PARAGE PROJECT ASSESSING AGRI-ENVIRONMENTAL IMPACTS IN THE FRENCH WEST INDIES AND FRENCH GUIANA

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ABSTRACT

The chief aim of the PARAGE project is to help public institutions and organizations to observe and analyze the impact of farming practices on the natural and urban environment using satellite data in combination with existing data and expertise. The project's 3 pilot sites in French Guiana, Martinique and Guadeloupe have permit to generate map products and geo-indicator derived from satellite data, and to build a Web-based GIS demonstrator to answer the following issue: land clearance monitoring in slash-and-burn farming in French Guiana, soil risk erosion assessment in Martinique and agriculture pressure on protected area evaluation in Guadeloupe.

Index Terms— agriculture, environment, GIS, remote sensing, geo-indicator

1. INTRODUCTION

The PARAGE project funded by the French ministry of agriculture and fisheries is a two-year pilot study involving private firms (Spot Image and SIGbea) and government agencies (CIRAD and IRD). Under French and European land and resource management regulations (the sustainable agriculture contract, Common Agricultural Policy and EU Framework Water Directive), farming institutions need reliable and current spatial information. This information is needed to base decisions on a detailed territorial analysis of utilized agricultural area (UAA), its spatial and temporal dynamics and how it is interacting with urban and natural environments. Processed satellite imagery in combination with existing data and expertise meets this requirement. The PARAGE project focuses on French Guiana, Martinique and Guadeloupe issues.

2. GEOINDICATORS

As defined by GéoTraceAgri [1] and GTIS-CAP [2] projects, a geoindicator is an indicator giving a synthetic vision of a problem in order to better understand it, based on reliable and easily accessible data, responsive to expected changes and understood and accepted by users. It also has to satisfy certain spatial criteria. It must be: **explicitly spatial**, i.e., underpinned by a model explicitly based on geographic coordinates (x, y) and spatial algorithms; or **implicitly spatial**, i.e., underpinned by data tied to geographic objects (e.g., a polygon). For the PARAGE project, geoindicators must also address agri-environmental issues. The original feature of these geoindicators is that they highlight existing spatial relationships between a field and its environment. They were defined after conducting interviews with users in French Guiana and the French West Indies. They are calculated using spatial data from existing databases on the demonstration sites and by exploiting satellite imagery.

3. THREE REGIONS, THREE ISSUES

Methodologies developed cover three specific study areas: French Guiana, Guadeloupe and Martinique. These French overseas territories are governed by the same laws as mainland France but benefit from special provisions—notably fiscal provisions—applying to the European Union's so-called "ultra-peripheral" regions. In each of these regions, study sites were selected and analyzed from an agri-environmental perspective in line with local requirements. From the results of these requirements analysis, useful spatial information was inventoried and project phases were planned through to the production of indicators chosen to describe and analyze farming issues: 1) Martinique: assessment of erosion risks on the Baie du Robert watershed; 2) Guadeloupe: landscape change; 3) French Guiana: monitoring of land clearance by slash-and-burn farming. Two key geoindicators were developed to study these issues: 1) Land-use change indicator implemented in French Guiana, Guadeloupe and Martinique; 2) Erosion sensitivity indicator implemented in Martinique.

4. DATA

SPOT Satellite images used for the PARAGE project are listed in Table 1. They were acquired by the SEAS receiving station operating in French Guiana since February 2006.

MARTINIQUE		GUADELOUPE		FRENCH GUIANA	
2,5 m C	28/08/2006*	2,5 m C	17/08/2006	10 m C	26/11/1999*
	14/11/2006*		20/12/2006	5 m C	10/01/2005*
	25/04/2007*		20/05/2007*	10 m C	26/09/2006*
	31/05/2007*			2,5 m C	05/10/2006*
	29/11/2007*				

Table 1: Satellite imagery used for project (* bundle product)

a) Martinique: Baie du Robert (14-Nov-06)
b) Guadeloupe: Grand-Cul-de-Sac Marin (20-Dec-06)
c) French Guiana: St Laurent- Apatou corridor (05-Oct-06)

Figure 1: Study sites displayed on SPOT 2.5-m natural-color basemap image *(© CNES, 2006 – Distribution Spot Image)*

5. RESULTS

5.1. Erosion sensitivity geoindicator

Issue and Study Site: Soil erosion is a key element for agri-environmental assessment in the 3 regions, i.e.: erosion and water pollution by pesticides, erosion causing hyper-sedimentation of littoral zones, or erosion caused by land clearance for farming. In Martinique, in response to demand from local authorities, the Martinique regional agronomy cluster, Ifremer and the University of Antilles and French Guiana decided study a relatively closed catchment basin with farmland, urban areas and low-density housing in the Baie du Robert (Fig. 1a). The team focused on the chemical pollution and erosion impacts of human activities on both the land and marine environment [3]. The methodology integrates quantitative measurements and field observations (i.e. slope, nature and coverage of soil) and uses an erosion index with several classes [4]. This issue falls within the scope of the EU Framework Water Directive.

Input data: Input data required for this indicator are:

- Maps derived from satellite imagery: 1) Natural-color satellite image basemap and 2) Land-use map (Fig. 2)
- Additional data: 1) Slope map, 2) Slope length map (or flow accumulation map), 3) Soil map and 4) Hydrological boundaries: catchment basin

Calculation principle and frequency: The erosion sensitivity indicator is calculated by combining four key variables (land use, slope, slope length or flow accumulation, and soil conditions) according to criteria defined by a decision tree [4]. These variables are subdivided into classes to represent the spatial diversity of the catchment area (i.e. 10 land-use/land cover classes: bare ground, impervious surface, wood, sugar cane, etc…).

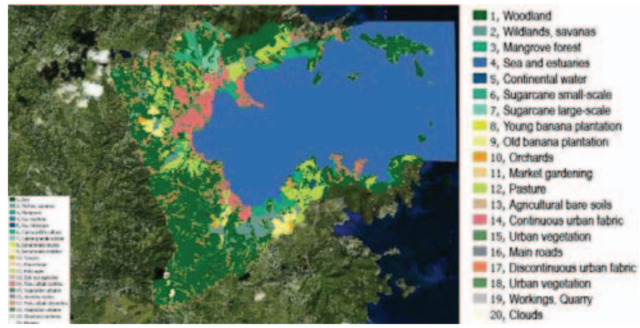
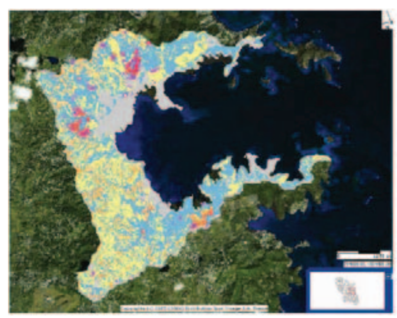


Figure 2: Land-use map of the Baie du Robert derived from SPOT satellite image acquired 14-Nov-2006

Each point in the catchment is thus characterized by a combination of four classes, one per variable. The model then calculates the sensitivity indicator by ranking these combinations depending on whether they are likely to locally reduce or favor soil erosion. Erosion sensitivity is first estimated from raster data (topographic map, aerial photo or satellite image) and results are then displayed in vector form according to the spatial unit (field, municipality, district, catchment area, etc.) chosen by the user. Erosion sensitivity is expressed by six classes from zero to maximum (Table 2). This index can be calculated every six months to track changes in erosion sensitivity

Result and representation: The calculated erosion sensitivity indicator is displayed in the form of an image basemap showing polygons color-coded from 0 to 6 (Fig. 3).



Colour code	Vulnerability index	Vulnerability
	0	Zero
	1	Very low
	2	Low
	3	Medium
	4	Very high
	5	High
	6	Maximum

Table 2: Vulnerability classes (source: Pinte, 2006)

Figure 3: Erosion vulnerability map of the Baie du Robert watershed on SPOT satellite image (14/11/2006)

5.2. Landscape change geoindicator

Issue: Whether in French Guiana, Guadeloupe or Martinique, land is under very strong pressure from human settlement. The geoindicator developed to highlight landscape change is intended to tell us more about land use so to study its dynamics.

- In Guadeloupe, the chief agri-environmental issue is the need to evaluate pressure exerted by farming on protected areas. In recent years, protected areas in Guadeloupe (wetlands, national parks, nature reserves and woodlands) have become increasingly "colonized" by croplands and uncontrolled development of associated housing [5]. There is now a need to obtain reliable regional-scale maps, regularly updated using the same methodology to enable robust comparisons and answer questions like: How fast are littoral wetlands and dry forests receding? How is agriculture evolving in Guadeloupe where farmlands are tightly interwoven with natural and urban areas? Is it developing at the expense of re-farmed idle lands or at the expense of forests? These are key planning questions.

-In French Guiana, the main issue is the detection and spatio-temporal monitoring of land cleared for farming or urban development at characteristic study sites. This is a major environmental concern due to farming practices driven by unplanned land occupancy; fear that land clearances will eat increasingly into the forest once roads are built; the huge environmental impacts of illegal gold panning (notably loss of forest and degradation of soils and water); growing human pressure [6] as a result of the large number of migrants coming into the Charvein-Saint-Laurent du Maroni region from neighbouring countries (e.g. Surinam, Brazil).

Whatever the study area, the landscape change indicator is a federating factor for keeping municipalities regularly informed about how their territory is evolving, and an important element of broader evolving land-use issues. An annual status review could be provided to a wide audience in order to highlight changes taking place (e.g., hectares of mangrove or forest lost, UAA reclaimed from dry forest, etc.). This geoindicator is also contributing to implementation and monitoring of sustainable development plans and areas of ecological or floristic interest (ZNIEFF).

Study sites:

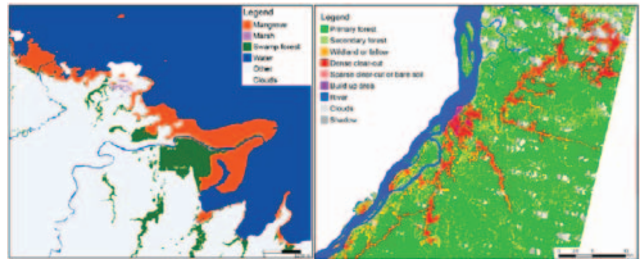
-In Guadeloupe, this broad theme involves as many issues as stakeholders, with very different types of features to be identified and nomenclatures that are difficult to adjust. Due to the diversity of situations encountered, it was decided to cover this theme in different sectors: on Basse-Terre, in the Grand Cul-de-Sac Marin nature reserve (coastal wetlands) and along the Côte sous le Vent (leeward coast, with dry forest and shaded crops) and the Côte au Vent (windward coast, with banana plantations); on Grande-Terre, in Grands-Fonds (cleared land) and in the south-east corner (market gardens). Here, we present the results obtained from the Grand Cul-de-Sac Marin area (Fig. 1b).

- In French Guiana, the indicator was demonstrated in the region of St-Laurent du Maroni and along the Saint-Laurent/Apatou corridor, where a road is currently under construction (Fig. 1c).

Input data: Input data required for this indicator are:

- Map products derived from satellite imagery: 1) Natural-color satellite basemap and 2) Land-cover (fig. 4a) or land-use map (fig. 4b) with dedicated nomenclatures
- Optional additional data: 1) Administrative (municipalities, district, fields, etc.) and protected area boundaries and 2) Historical thematic maps

Calculation principle and frequency: The indicator is calculated by combining multi-temporal land-cover/-use layers [7] [8].



a) Grand Cul-de-Sac Wetland map (20-Dec-06)   b) St-Laurent/Apatou land-use map (26-Sept-06)

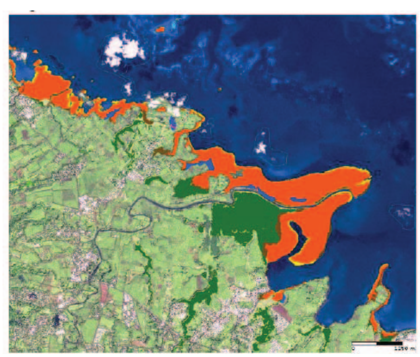
Figure 4: a) Land cover and b) Land-use maps derived from classification of SPOT scenes

These layers may be derived from old maps or remote-sensing data classifications (aerial photos or satellite imagery). They must first be harmonized (i.e. nomenclature standardization) for comparison purposes. A change is indicated when a vector feature (polygon) moves from one class to another between two dates. This index can be calculated once a year to monitor landscape change or more frequently as new land-use maps become available.

Result and representation: The result of the landscape change calculation is displayed in the form of an image basemap (i.e. natural-color satellite image) showing polygons where change of class was noted between two dates. Each change is color-coded (Table 3 for Guadeloupe and Table 4 for French Guiana). This geoindicator also yields a list of changes and their surface area (in hectares).

- In the Grand Cul-de-Sac Marin area (Guadeloupe), the indicator was calculated from several maps: 1995 wetlands map (ONF), 1989 wetlands map (DGRST), 2006 coastal wetlands map (from processed SPOT satellite image of 20-Dec-06). Fig. 5 shows the combined result from the 1995 and 2006 wetlands maps.

- In French Guiana, the landscape change geoindicator was calculated for the Saint-Laurent/Apatou area from the 1999 and 2006 land-cover maps (derived respectively from processed SPOT satellite images of 26-Nov-99 and 26-Sept-06). Fig. 6 shows the result of these combined layers.



Colour code	Landscape change
	Mangrove gained
	Marsh gained
	Marshland forest gained
	Mangrove stable
	Marsh stable
	Marshland forest stable
	Mangrove lost
	Marsh lost
	Marshland forest lost
	Other change

Table 3: Colour-coded landscape change geoindicator in Guadeloupe

Figure 5: Landscape change geoindicator applied to Grand Cul-de-Sac Marin area (Guadeloupe) between 1995 and 2006

Colour code	Landscape change
	Built up
	Stable slash and burn
	Refarmed
	Cleared
	Fallow/idle
	Forest regrowth
	Unchanged
	Not given

Table 4: Colour-coded landscape change geo-indicator in French Guiana

Figure 6: Landscape change geoindicator applied to the St Laurent/Apatou corridor (French Guiana) between 1999 & 2006

6. PARAGE DEMONSTRATOR

To implement these geoindicators, a Web-based GIS demonstrator was also specified and developed. This demonstrator aims to highlight results from processed satellite imagery and show the dynamic nature of the geoindicators. It is a data viewing and distribution tool geared toward supporting dialogue and exchange of information between stakeholders (Fig. 8).

The demonstrator is hosted on a Web data and applications server supporting international OGC WFS/WMS specifications. It is therefore totally interoperable with other Web-based GIS systems.

The PARAGE demonstrator lets users:

- Build up geographic databases shared across departments or agencies (geo-referenced data such as satellite images, maps or other features network). This database also contains geospatial layers produced by the participating agencies, which each have individual access rights. This single database can be viewed with an Internet browser for broad sharing of geospatial information.
- Browse commentaries of specific areas of interest.

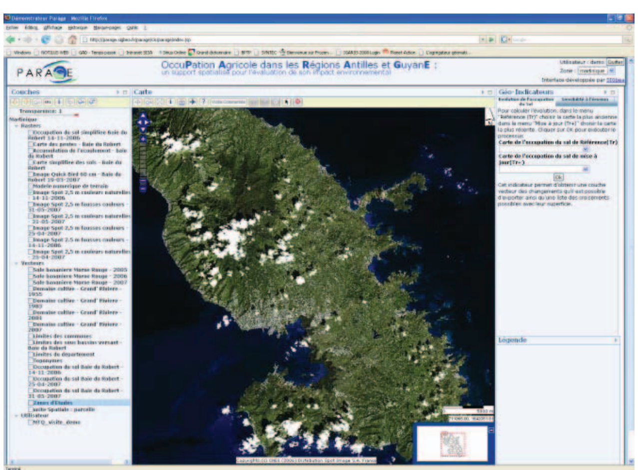


Figure 8: PARAGE GIS demonstrator interface

- Compile 3D data layers and view them in Google Earth for easier communication of environmental issues.
- Prepare page layouts on line using a print module to choose map layers and customize texts and logos for example. Pages are generated in print-ready, distribution-ready PDF format.
- Calculate geoindicators on-line for their area of interest at time intervals suited to the specific issue they are studying. Results either remain in the private domain or are published and therefore accessible to other users.

7. CONCLUSION AND OUTLOOK

Working in close partnership with local stakeholders, the PARAGE project has successfully developed map products and geoindicators to meet their needs, notably for monitoring changing land use - across a range of agri-environmental contexts (mangrove, market gardens, low-density housing, primary forest, etc.) - and soil erosion vulnerability. However, the project was not able to achieve completely standardized products in the time available. The GIS demonstrator has elicited very positive feedback from the vast majority of users. In particular, they liked the fact that it is built around lightweight, open-source Web technologies; allows sharing of geospatial information between all users; meets the needs of both engineers and the lay public. It nevertheless remains a demonstration tool, so further work is needed to develop a truly operational Web GIS solution. The future developments the PARAGE consortium wishes to pursue as a continuation of this project will focus on extending work done on test zones to larger territories, and on improving the demonstrator and its interface.

8. REFERENCES

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