



# P R O G Y S A T

## Regional Cooperation Project:

## Satellite Observation of the Guianas

**(Projet de Coopération Régionale d'Observation des GuYanes par SATellite)**

## *P r o j e c t  D e s c r i p t i o n*

*Project Promotor:*

*IRD – Centre de Guyane*

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# PROGYSAT

## Regional Cooperation Project: Satellite Observation of the Guianas

# - SUMMARY -

# General context

The balanced development of French Guiana is one of the major challenges for the regional government over the next decade. The cross-border zones and coastline – the region's two main development areas – are characterised by very different socio-spatial dynamics.

Demographic projections for the border with Suriname over the coming decade mean that the Mana – Saint Laurent – Apatou zone will become the most populated sub-region in French Guiana ahead of Cayenne Island. To the west, the Maroni River (which marks the border) is a permanent focal point, with trade helping to structure and fertilise inter-community relations. The need for environmental protection intersects, on the one hand, with the space-resource objective of the local populations and the regional demand for growth and development; and, on the other, with the prevention of vector-borne diseases and the integrated management of natural resources.

To the east, opposite its Brazilian neighbour, the Oyapock River shares national parks and protected coastal areas on both sides of the border. The gradual opening of the Oyapock River Bridge means that these zones – where the forest, gold and fish resources are still under (poorly managed) pressure – require further monitoring. Here, too, the regional managers must implement suitable and sustainable public planning and development strategies in the face of the challenges and requirements of the local populations.

More broadly, the environmental issues are similar across the Guiana Shield. With 75% forest cover, French Guiana is under heavy pressure in this natural area. Developing the capacity to monitor and manage the region is likely to favour an integrated strategy based on the sustainable development of the environment.

In this context, the introduction of global monitoring to these areas undergoing change serves as a fundamental contribution to uniting economic visions and environmental constraints as part of sustainable development policies across French Guiana.

# Strengths and positioning

The marked socio-economic disparities on both sides of the border and the spatial continuity of the ecosystems common to the Guiana Shield call for constant cooperation with neighbouring countries to enable measures for preserving natural resources and regional planning initiatives to be designed and deployed effectively. If French Guiana is to develop sustainable environmental and regional management policies, the country must have a regional perspective of the natural or anthropogenic dynamics at work. The satellite imagery and geo-information that are extracted provide the vision and knowledge for implementing thematic applications of common interest on the required spatial and temporal levels. The ability to establish spatial indicators and to share them among the Shield's institutional actors is a key issue for the sub-region's cooperation policy.

The PROGYSAT project proposes an answer to the above challenges. It is built (i) on harnessing the strengths of Earth observation in French Guiana; and (ii) on developing new space-based tools produced by the project for the region's institutional needs.

PROGYSAT intends to provide institutional users of satellite information in French Guiana and the sub-region with recent, essential advances in the sector. It is an area that has evolved considerably over the last five years, driven largely by:

- Creating and operating national platforms dedicated to using and appropriating satellite information for scientific and institutional applications;
- Commissioning new orbital sensors.

In concrete terms, these advances – which have thus far mainly benefited actors in regions of mainland France – now make it possible to access new data and new processing chains; trial new thematic products qualified for temperate regions; exchange information in dedicated forums and arenas; and project new image processing in IT environments that are innovative and operational.

PROGYSAT's activities are aimed at importing some of these new capacities into the Guiana Shield in close connection with local needs and the new national bodies. PROGYSAT is a project linked to facilitating these bodies in the global south: the GeoDEV network run by the Theia Data Centre.

PROGYSAT proposes a work plan that means that useful capacities, tailored to the themes of the Guianas sub-region, will once more be made available to institutional consumers of satellite data and geo-environmental information. These capacities are intended to support their management and scientific missions and objectives.

The project reinforces the international cooperation actions undertaken by SEAS Guyane, whose recovery plan – led by CTG with the support of CNES, UG and IRD – is being examined by French Guiana's European Affairs Centre. PROGYSAT builds on French Guiana's existing strengths as part of a partnership in the field using: (1) new observation and data-processing capabilities; (2) new arrangements for sharing and pooling information; (3) new application chains and products of interest; and (4) a programme dedicated to supporting the Guiana Shield communities that use satellite information applied to regional management, monitoring or surveillance. Based on previous achievements (PO Amazonie), the project aims to re-activate a network within the Guiana Shield dedicated to using Earth observation data for monitoring the state and dynamics of the environment.

# Project objectives

PROGYSAT's main objective is to formalise – and make operational – services for accessing, processing and disseminating geo-information derived from Earth observation. This information is tailored to the missions of institutional communities in the sub-region that are responsible for environmental management.

The ultimate aim is to use space technology to contribute to the integrated management of the natural and regional heritage of French Guiana and neighbouring countries. The planned information-processing chains are based on the methodological advances of the scientific community represented by

the institutions taking part in the project. In concrete terms, this takes the form of applications accessible on the web in the areas of natural resource management and the monitoring of cross-border regional dynamics that are of interest to the regional government.

Working in close collaboration with the regional government – and thanks to the involvement of the University of French Guiana – the French Guiana IRD proposes defined objectives in partnership with Anton de Kom University in Suriname; three partners in Brazil, namely the Federal University of Amapá (UNIFAP), the Amapá Institute of Environmental Research (IEPA) and the National Institute for Space Research (INPE); and the University of French Guiana. This partnership is supplemented by an extensive set of collaborations connected to the thematic actions of the project: the Pasteur Institute, the French Guiana Regional Health Authority, the Health Surveillance Superintendency in Amapa, ONF Guyane, Cayenne Hospital, the Mosquito Control Department, the University of Brasilia, Embrapa, Fiocruz, the University of Amazonas, Pará University, Amazonian Rural University, the French Guiana Forestry Commission and the French Guiana Land and Statistics Commission.

PROGYSAT's proposed area of intervention is divided into two workstreams:

**Workstream 01 – Data and tools for cooperation**

Workstream 01 proposes facilitating and running a regional cooperation programme for acquiring, pre-processing and disseminating satellite data. All these activities will be backed by and supplement the SEAS platform.

The data sets will be acquired for the purpose of regional cooperation and will be exploited from a thematic perspective by the activities in PROGYSAT Workstream 02. The images and geo-information derived from image sets – together with the tools for pre-processing images – will be disseminated as widely as possible among institutional communities in the sub-region that consume satellite information. A web portal compatible with existing IT systems will make it possible to access products and images from the project. A support and training tool will be developed under the supervision of the University of French Guiana: a distance-learning module in remote sensing.

This PROGYSAT workstream will be carried out in close collaboration with the regional government in order to ensure that it is consistent with the authority's policy on regional satellite observation and the orientation of SEAS activities. Support actions designed for the general public will supplement the dissemination of the project's outcomes.

**Workstream 02 – Thematic applications of regional interest**

Downstream of the input from Workstream 01, Workstream 02 supports mixed teams (Brazil and / or Guiana and / or Suriname and / or France) involved in developing or harmonising remote sensing thematic applications. The objectives are to produce environmental and regional geo-indicators qualified by research and intended for institutional users of satellite information in the sub-region. In concrete terms, this work will take the form of a series of mapping products on different themes and / or services for the online processing of satellite data that can be accessed remotely by communities using satellite imagery.

The activities carried out by PROGYSAT will consolidate and enhance the role of satellite information in research, teaching and regional management. This will improve, optimise and supplement public action in terms of monitoring the environment and regions in the areas of interest in the Guianas. Based on this roadmap, PROGYSAT will develop the appropriation and use of remote sensing tools by the institutional communities, thereby promoting applications useful for the management and development of the Amazonian regions. Thanks to SEAS, French Guiana has been able to assimilate and exploit the great potential of satellite information for managing the environment and regions. These operations will be continued and developed via the implementation of PROGYSAT.

# Key PROGYSAT projected actions

Implementing the 28-month project will be based on a dual operational position:

(1) Feeding into and supporting the structuring of a regional cooperation programme that meets the current needs of users of satellite information in the region. This workstream is proposed under the authority of the regional government, which owns the SEAS platform and prescribes its strategic direction;

(2) Generating and disseminating innovative, reliable thematic tools and products in response to the environmental and regional challenges of the Guiana Shield, as part of a co-construction process initiated with the actors in French Guiana and the sub-region's institutions (scientists and managers).

In this context, the main challenges of PROGYSAT will be to devise application chains that are qualified and calibrated from a scientific point of view, and that are also simple to access for institutional users in the sub-region who need them to fulfil their public service missions.

The project will be implemented and organised according to the following key steps: introducing a space-based environmental observation system; controlling data sets for managing shared reference systems for joint use; and controlling the processes for producing indicators for managing cataloguing tools, referencing and shared diffusion of information. These "observatory"-type tools, when appended to space data infrastructures, will make it possible to devise methodologies for detecting and studying environmental changes using satellite tools, as well as for the production of the expected geo-information.

PROGYSAT's projected actions fall into the following key categories:

- Acquisition of satellite imagery and implementation of satellite information applications in various thematic areas useful for institutional actors in the sub-region;
- Collective definition, between project facilitators and users, of priority application chains to be developed by the project on a region-wide basis of interest in the sub-region;
- Production of satellite imaging processing chains in the themes of interest;
- Production of thematic geo-information qualified by the project stakeholders and pooled at institutional level in the sub-region;

- Promotion and sustainability of outcomes by uploading the tools for producing detailed geo-information using the project's equipment and outputs and / or establishing partnerships with public or private entities working in the field that have been established in French Guiana;
- Inventory of the competences of the different regions regarding the use of space data;
- A training and support plan for target communities (environmental and regional managers / scientists) who are not expert in processing satellite data;
- Implementation of a distance education module in the field of remote sensing in collaboration with the University of French Guiana;
- Development of educational modules and videos on the thematic focuses developed by the project for the general public;
- Introduction of innovative application fields for analysing and assessing the sensibility of natural resources.

The ecological or anthropogenic dynamics of interest will be the focus of application modules aimed at extracting and composing useful information. These application modules form part of the themes that reflect the priority objectives of the PCIA (Interreg Amazon Cooperation Programme).

Four specific applications are proposed:

- Natural resources and renewable energies
- Risk of malaria and arbovirus transmission
- Urbanisation and precarious housing

- Expertise in and characterisation of forest regions

The project will rely on capitalising on the achievements of previous projects regarding the production of knowledge and monitoring the regions and environments in the sub-region, providing scientists and managers of ecosystems and regional dynamics with information that is relevant and up-to-date. The ecological or anthropogenic dynamics of interest will be the focus of application modules intended to extract and compose information useful for cooperative environmental management purposes. The shared aim will be to promote the sustainable development of cross-border regions.

## Instruments of governance and management of activities

The project's overall coordination will ensure that the applications are executed correctly; this will be achieved by proposing and managing the governance instruments required for delivering the project.

A steering committee will be set up and facilitated by the project promotor. It will meet every six months and will consist of the following representatives:

- PCIA management authority
- IRD promotor
- Main partner: University of French Guiana
- Foreign major partners

Where appropriate, a representative of the regional Earth observation policy will sit on the committee to ensure consistency between the project's activities and regional strategies.

To ensure the sound financial and administrative execution, all expenses and accounting follow-up are carried out under the control and responsibility of the promotor (IRD), thereby guaranteeing that the procedures and technical arrangements regarding expenses comply with the PCIA framework. The project coordination team provides for the involvement of permanent administrative staff; the support of the IRD Brasilia representative body and the central services of IRD headquarters; the cooperation of the university's central services; and the collaboration (if necessary) of the technical and administrative services of the partners.

The project will be equipped with a technical coordination unit.

The unit consists of the project promotor, the University of French Guiana, the leader in Suriname (Anton de Kom University), the leader in French Guiana and the leaders in Brazil (Federal University of Amapá, Amapá Institute of Environmental Research and the National Institute of Space Research). The unit is responsible for the daily coordination of the activities of the partner teams that are members of the project. It mainly works remotely and meets regularly (on a monthly basis).

The leaders coordinate with the IRD promotor and the University of French Guiana regarding the following: tracking the progress of work; solving implementation difficulties; developing material for monitoring teams; and devising actions for making the expected products and deliverables available, including conveying their communication and promotion actions.

In parallel with this coordination apparatus, each application has made provision for the joint coordination of its actions between a French manager and a foreign manager. To ensure proper consistency and the good transmission of information, these managers – as well as some team members – are bilingual or trilingual.

# Partnership

The construction phase of the project is very important because it serves as the basis for a successful project. In this phase, the content of the project is defined collectively based on proposals

made by the promotor (IRD) and the main partner in French Guiana (UG) for the foreign partners during the various meetings specifically organised for this purpose. Letters of intent regarding the collaboration from the key partners are formatted, sent and attached to the PCIA approval records.

IRD and UG have scheduled a pre-launch technical meeting with the partners to address and push forward with questions concerning the implementation of the partnership agreements, in the event that the project is accepted. This meeting will also involve the IRD representative body in Brazil, which will be called on to manage expenses on an ad hoc basis.

PROGYSAT is built on a strengthened partnership with Brazil (Amapá), Suriname and French Guiana based on four thematic applications.

In French Guiana the main partner is the University of French Guiana. The project teams will combine on an ad hoc basis according to the themes of the members of the Pasteur Institute of French Guiana, Cayenne Hospital, the Regional Air Quality Office, ONF, the Mosquito Control Department and the Regional Health Authority. They will be able to solicit feedback from institutional actors concerned by the project's themes (CTG, PNRG, DEAL, OHM, etc.).

In Brazil the leaders are: the Federal University of Amapá (UNIFAP), the Amapá Environmental Research Institute (IEPA) and the National Institute of Space Research (INPE). Exchanges will also take place on an ad hoc basis with the following institutions: EMBRAPA Amapá, Amazonas State University, the Health Surveillance Superintendency, Federal University of Brasilia, Amazonas Federal University, Fiocruz, Amazon Rural University and the Federal University of Pará.

INPE will contribute to the activities of Workstream 01 regarding the sharing of satellite imagery pre-processing chains, which the project will make available to institutional communities.

In Suriname the leader is Anton de Kom University. A search will be initiated for a collaboration with the institution responsible for forest management.

In French Guiana the leader is represented by the University of French Guiana. Joining the thematic teams will be: the Forestry Commission (Ministry of Natural Resources), the Commission for

the Regions and Statistics (the president's office) and the Hydrological Resources Department (Ministry of Agriculture).

The applications were selected and constructed by each of the thematic teams with their respective partners. Each operation is jointly supervised by a manager from the project team and a manager from a partner country.

The nature of the activities rolled out by the partners for the work related to the applications is divided into the following categories:

- Presentation of the methods used for data processing;
- Co-definition or co-validation of the final methods used by the project;
- Satellite imagery processing and qualification or validation of geo-environmental information derived from applied image processing;
- Collaboration on the specifications of the remote processing chains that the project will manage;
- Joint supervision of students in the project's areas of activity;
- Organisation of the thematic seminar;
- Contribution to project communications (representative);
- Local project facilitation and participation in project working meetings;
- Feedback on the first outcomes of the project;
- Leaders' participation on governance bodies and bodies for monitoring progress.

The expected contributions are (i) the time spent by staff involved in the project; and (ii) sharing data and methods for processing satellite images.

# WORKSTREAM 01

# Data and tools for Earth observation regional cooperation

As part of the regional cooperation led by the PCIA, this workstream of the PROGYSAT project is designed to take responsibility for acquiring, supplying and pre-processing satellite imagery sets in the sub-region. These are intended to be shared and for institutional and scientific work on knowledge, monitoring and management of the environment and regions.

This workstream will also focus on implementing tools for processing regional data. It will make it possible to use transferable and poolable solutions within the framework of partnerships to meet the needs of PROGYSAT and the specific requests from the PCIA itself or from the CTG as part of its regional cooperation policy.

These tools will be compatible and integrable with the SEAS Guyane platform.

Workstream 01 also plans to implement promotional and training actions: satellite environmental monitoring techniques and tools for students and professionals; publicising the outcomes for the general public; and raising awareness about the importance of space data in environmental management aimed at schools.

## 1.1 Building regional capacities in Earth observation

Satellite imagery in the Guianas, by its very nature, generates and fosters regional cooperation in the fields of environmental and regional management applications, given the spatial continuity of the ecological or regional dynamics that it expresses. Satellite imagery is used to support and develop the activities of institutions responsible for regional knowledge and management. It opens up fields of investigation and scientific studies that are closely connected to the current major environmental challenges that the sub-region is facing. Its use is recommended by all the international institutions in charge of the global monitoring of the environment and monitoring the indicators of the Sustainable Development Goals (UN SDGs).

Against this background, PROGYSAT aims to consolidate the use of space data in the regions of interest in French Guiana or beyond in the Amazon region, starting from French Guiana and by promoting its achievements in the field. To this end, actions for supplying useful satellite data and commissioning pre-processing chains for the selected image sets, built with the project partners, will be initiated in Workstream 01.

Workstream 01 plans to acquire and provide the institutional users of satellite information with images that are programmed on demand, as well as updated image sets in routine mode for the different regions in the Guianas: Spot 6/7, Pléiades, Sentinel 1 and 2, Landsat 8 and Spot World Heritage. This data will be acquired through the SEAS Guyane platform and / or newly-created national platforms. Spot 6/7 or Pléiades data will be obtained through the procurement mechanism set up by SEAS and through national institutional arrangements.

Workstream 01 of PROGYSAT plans to communalise and operate pre-processing tools to facilitate the thematic exploitation of the image sets: geometric corrections and orthorectification, atmospheric corrections, data calibration, imaging assembly and radiometric homogenisation. Based on the data of interest that PROGYSAT will make available, derivative products will be produced and distributed directly by the project. Where appropriate, processing chains will be made available and activated remotely by the users themselves

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The features that PROGYSAT intends to implement and operate in French Guiana will be assigned to SEAS. In order to ensure consistency with the national scene, PROGYSAT will mobilise the GeoDEV actors, the THEIA – GEOSUD facilitation network dedicated to the global south. The network founded by CNES, CIRAD and IRD aims to support skills centres with remote sensing such as SEAS. PROGYSAT has been targeted as a project of priority interest for facilitating the transfer of skills, methodologies and tools from Theia and GEOSUD.

The PROGYSAT project meets the stated aim of streamlining the supply of images formulated by the actors in French Guiana involved in projects that mobilise satellite information or in cooperation projects in the sub-region that require the use of Earth observation imagery. This investment in the supply of useful imagery and introducing processing tools will build French Guiana's ability to position itself as a preferred player for acquiring and disseminating data of high to very high resolution across the entire sub-region. This will, in turn, pave the way for strong partnerships in regional cooperation regarding the use of space data for the expertise and management of natural resources in the Amazon. In the same vein, the partnership that will be established under Workstream 01 with the National Institute of Space Research of Brazil (INPE) will open up possibilities for enhancing the imaging catalogue that will be made available. It will also make it possible to study the potential for methodological and technical exchanges with INPE concerning the sharing of pre-processing tools for the mobilised imaging. Finally, it will explore the possibility of supporting technical cooperation with SEAS Guyane based on the Brazilian Earth observation satellite CBERS4 for the acquisition and wider use of its data in the Guianas.

**Summary of expected outcomes** Workstream 1.1

• Mobilisation and implementation of a network of scientific and institutional actors and users leading cooperation programmes and public entities in French Guiana, the Guianas, Suriname, Amapá, Pará and Amazonas using space data;

• Strengthening a data infrastructure consistent with the SEAS platform for hosting, processing, storing and archiving new data;

• Implementation of tools and procedures for handling and pre-processing images dedicated to regional cooperation;

• Hosting Workstream 02 processing chains (application purpose) useful to partners in the sub-region.

## 1.2 Powering a satellite information and service system dedicated to cooperation

This action area meets the need to pool and streamline tools for accessing data, products and features useful to partners. The intention to provide a single platform to all the communities in the Guiana Shield that use satellite information is a major development that responds to a need for simplification in the regional cooperation component proposed by the project.

To this end, the project will revisit and integrate the GUYAMAPA cross-border environmental geo-information portal (2012-2014, PO Amazonie / CTG / CNES / IRD / INPE and partners) into the new portal. In this shared environment, the PROGYSAT portal will make the vast mass of already-existing digital data available and will present the new information derived from the project. New features will be implemented for searching for, sharing, analysing and visualising the information offered to institutional players.

This development will promote the products and added value of French Guiana in the area at regional level. The portal will provide major information and organisational material for actors in French Guiana engaged in cooperation actions with the Guiana Shield partners. It will promote the regional convergence of methodologies developed in image processing applied to the management of the environment and cross-border regions.

**Summary of expected outcomes Workstream 1.2**

• Pooling resources and tools; simplification of access points to regional space-based observation resources for actors and partners in the sub-region;

• Web portal access to products derived from the project, with the possibility of interface access to the SEAS Guyane catalogue;

• Provision of new features and additional new thematic products developed in cooperation by the project in a dedicated data infrastructure and services tool;

• Promotion of images, environmental geo-information, processing chains and know-how derived from the project;

• On-going additional routine services for satellite environmental monitoring useful to partner communities in the sub-region.

## 1.3 Training and e-learning material for satellite observation of the cross-border environment

The project is mainly built on a university partnership that is a vehicle for thematic and scientific actions. The University of French Guiana and its committed staff will carry out research that is key to understanding and monitoring the environments of the Guianas, which Workstream 02 is intended to organise. The university will also make a significant contribution to supporting distance-learning tools designed for institutional partners in the sub-region.

Integrating the University of French Guiana (UG) into its Amazonian environment will be facilitated and boosted by the implementation of the project. UG is a member of the SEAS steering committee: its deep interest in the scientific and educational fields of Earth observation and its applications will be reaffirmed across the Guiana Shield.

This outlook is also apparent in Central Africa as part of the on-going cooperation actions with the Agence Gabonaise d'Etudes et d'Observations Spatiales (AGEOS), which has a similar arrangement to

SEAS. As part of UG's investment in PROGYSAT and in SEAS, it could extend to the West Indies in the form of a collaboration with Haiti, entered into with CNES and IRD as part of discussions on setting up a remote sensing skills centre.

UG's commitment to PROGYSAT also includes starting preparations for the master's degree, with the course on using space data scheduled to begin in September 2018.

In practical terms, the planned actions are designed to develop, build and put online distance learning and training tools (EAD remote sensing module). These tools will be implemented by the project using resources that it will make available to the university and thanks to the university's own capacities.

This will build on SEAS's current and future capabilities and on the regional cooperation application work organised by Workstream 02 in support of the platform. In this context, it will be possible to exploit, adapt or transfer tools from partner schemes in mainland France (Theia and GEOSUD) with the logistic and financial support of PROGYSAT.

**Summary of expected outcomes Workstream 1.3**

- Identification of university capacities for using space data
- Potential for pooling teaching and exchanges between universities on environmental management via satellite observation
- Creation of e-learning material dedicated to observing the Amazonian region and satellite monitoring of the environment
- Bi-national training sessions on themes from Workstream 2
- International training sessions on using the service's infrastructure and the internationalisation of the portal
- The introduction of a distance-learning component
- Popularising approaches to environmental management through the use of space data

## 1.4 Summary of activities and projected outcomes

### 1. User network

Set up and facilitate a network of scientific and institutional actors and users leading cooperation programmes with public bodies in French Guiana, the Guianas, Suriname, Amapá, Pará and Amazonas;

### 2. Satellite data

Capture and acquire (according to expressed needs) satellite imagery sets dedicated to regional cooperation in the form of partnerships, and which are accessible to all institutional actors in French Guiana and foreign institutional actors involved in the project;

### 3. Tools and applications

On the basis of previous achievements, strengthen a data and services infrastructure specific to satellite imagery and applications for the purposes of cooperation. This tool will be consistent with the recommendations of the CTG in this area. It will be dedicated to hosting, storing, handling and archiving data, processing chains and thematic products proposed by the project. It will be an entirely autonomous tool that may form a part of the SEAS platform as it develops in the future;

### 4 Routine services

Automation work and provision of pre-processing data, information useful for monitoring the environment and regions; and international training sessions on the use of service infrastructure;

## 5. Training

Creation of online e-learning material dedicated to satellite observation of the Guianas and monitoring the environment;

## 6. Access and dissemination

Via the web, a simplified access point for project resources for actors in French Guiana and partners in the sub-region: a portal with new features for the project and its users, with the addition of new thematic products developed in cooperation by the project in the context of Workstream 02. Prefiguration of a "SEAS Cooperation" portal as part of its future development;

## 7. Communication and promotion of activities

Communication project regarding the partnership, image resources, geo-information produced, processing and know-how chains made available as well as educational tools; activities entrusted by professionals in the project's sector.

# WORKSTREAM 02

# Thematic applications and satellite information products of regional interest

## 2.1 General objectives

The Programme de Coopération Interreg Amazonie (PCIA – Interreg Amazon Cooperation Programme) is an extension of PO Amazonie (Programme Opérationnel de Coopération Territoriale Interreg Amazonie – Interreg Amazon Regional Cooperation Operational Programme). It ensures there is continuity in the investments made by French Guiana's in cooperation projects in the sub-region, reinforcing the country's international position.

The PROGYSAT project mainly targets priority Workstreams 3 and 4 of the PCIA: protecting and promoting the exceptional biodiversity and natural and cultural heritage in the cooperation zone; environmental preservation and protection and encouraging the balanced use of natural resources; and providing improved protection, management and promotion of the exceptional biodiversity in the cross-border cooperation zone.

The purpose is to disseminate environmental and regional geo-information – qualified and validated by the scientific community – that is valuable to institutions on both sides of the border for their missions concerning the expertise, management and promotion of cross-border and trans-national natural heritage.

To this end – and in line with the specific PCIA objectives and based on the actions of Workstream 01 – the project aims to put into operation or harmonise satellite imagery applications among teams in the sub-region.

There are four specific applications:

- Water resources, sensitivity and changes
- Risks of malaria and arbovirus transmission
- Pollution, urbanisation and precarious housing
- Expertise and characterisation of forest regions

These different applications slot into the project equally in the two parts of the PCIA: the cross-border component (Suriname – French Guiana – Amapá) and the trans-national component (with Pará, Amazonas and French Guiana).

## 2.2 Specific objectives

With Workstreams 01 and 02, PROGYSAT offers a coherent set of objectives for promoting cooperation in environmental monitoring using space data.

- Implementing tools and resources for a cross-border satellite observatory pending the re-activation of the regional SEAS platform;
- Producing geo-environmental indicators characterising natural resources and regional dynamics in French Guiana;
- Deploying application services accessible to all knowledge and management actors in the region's natural heritage;
- Supporting users by creating an e-learning medium dedicated to satellite observation of the Amazonian region and environmental monitoring;
- Actions and tools for communicating and promoting French Guiana's know-how in the field and achievements of the project, directed especially at the general public and schools.

This project is not a basic research project. Nevertheless, the development of the four proposed applications will require implementing trials on the ground and will be the subject of research action to develop the expected services.

The context for carrying out the project and its expected results must answer the needs of the actors in the region and result in local benefits. This means that, for each of the four applications, it will be necessary to define the anticipated uses and useful indicators that will ultimately be made available within the infrastructure delivered by the project. These must be defined jointly with the targeted institutional users.

For this purpose, each of the proposed applications will be co-led within the partnership between actors from French Guiana and actors from the foreign institutions involved. The applications will produce shared geo-information. The teams approved by the project will define the geographical perimeters and the final content of the thematic products generated. Each team will undertake to harmonise the reference data valuable for constructing the expected applications; the different partners will validate the suitability of the indicators produced in collaboration with the key managers in their regions.

## 2.3 Activities and projected outcomes

Transversal activities for the thematic applications in Workstream 2:

- Pool and promote the existing knowledge bases; produce common environmental indicators / geo-information harmonised at the level of cross-border or trans-national regions;

- Expand the project catalogue designed to disseminate the results with the new geo-environmental information produced, the aim being to improve and share knowledge, understanding and management of the natural heritage;

- Develop routine or one-off environmental or regional monitoring services based on the proposed applications and linked to knowledge models derived from the scientific research;

- Promote and communicate the project's activities and outcomes, particularly in academic courses and training programmes;

- Contribute to the content of remote educational modules for students studying satellite Earth observation applied to the monitoring of Amazonian environments.

During the execution of the project, the implementation of the thematic applications will also include organising various seminars, whose expected outcomes will be:

- Designing and producing geo-environmental products and related data-processing chains;
- Fulfilling the expectations and needs of public actors;
- Educational workshops on the specifications of the distance-learning content.

For each of the applications generically, the planned activities and deliverables may be categorised as follows:

## 1. Knowledge production

Environmental or regional geo-information based on the seven thematic applications of interest to the scientific or institutional actors in the sub-region;

## 2. Provision of tools

A range of data-processing chains accessible to institutions responsible for the knowledge, management and monitoring of the environment or regions;

## 3. Academic or professional training

Supervising student work, training in the products and tools for students and institutional actors in the sub-region, French Guiana, Suriname and Brazil;

## 4. Communication and feedback

Communication material and conferences on the project's progress and thematic results.

# Fields of application

## Water resources, sensitivity and changes

## 3.1 Water resources in the cross-border region between French Guiana and Suriname: sensitivity and changes

### 3.1.1 Context

The Guiana Shield – and, more specifically, the cross-border region from north to south Suriname – is characterised by dense tropical forest and high biodiversity; an exceptional hydrological network that provides significant water resources; and extensive amounts of minerals. A large population lives in this cross-border zone, mainly on the banks of the river border, since it is reliant on the water for its daily business. Agriculture, mining and timber are the main activities undertaken by the communities living in the study area. These resources, however, are threatened by a range of internal and external factors, which may be exacerbated by climate change.

This study aims to compile a database on the study region that is as exhaustive as possible. One component will gather data that is accessible via remote sensing: measuring the level of lakes and rivers using spatial altimetry and solar radiation; estimating rainfall and evapotranspiration; producing land occupation maps; and identifying the colour of the water. French Guiana's Espace-Dev teams are specialists in water cycle indicators obtained by remote-sensing for solar radiation (with three doctorates and several publications between them), rainfall (one doctorate and articles published), and water levels in lakes and rivers the results. This is thanks to the results obtained during the Guyamapa programme on Amapá as well as many published works. In addition, the Guyamapa project developed a mapping methodology for land occupation that can be used for water cycle modelling. For the cross-border region, this database will also include socio-economic data.

## General aims and objectives

Assess the water resources of the Guiana Shield and analyse the factors influencing the sensitivity of these resources in the Suriname – French Guiana cross-border region.

1. Compile all the data obtained by the various studies cited in the Guiana Shield in the project information system; supplement it for the data derived from space-based observation across the entire Guiana Shield; and compile the socio-economic data for the Suriname – French Guiana cross-border region.

2. Analyse the spatio-temporal changes in water resources in the cross-border zone and produce indicators and maps.

3. Analyse the impact of changes on communities in the cross-border region.

4. Strengthen the training of students for characterising natural resources: master's students on the sustainable management of natural resources programme at the University of Suriname will visit research institutes in French Guiana to gain a wider understanding of the studies and research carried out on natural resources. Following this visit, a handful of students will be selected every year to undertake part of their master's thesis in French Guiana.

## 3.1.2 Methods and activities

Basic data needs to be compiled to meet objectives 2 and 3. The database will be created from in-situ observations, satellites, maps and reports: observed climatic data (e.g. precipitation, temperature, SST) supplemented by simulated data (re-analysis data of global models); hydrological data (e.g. sea and river water levels, river spills, groundwater data); socio-economic data (e.g. population, land prices, legislation); geological and pedological maps, land use and occupation, maps of protected areas. This goal is preliminary to objectives 2 and 3.

Change indicators will be produced from analysing time series: for changes due to the climate, different parametric and non-parametric statistical tests will be used (McCuen, 2003; Mamdouh et al., 1993; WMO, 1988) on meteorological and hydrological records. The statistical models employed in this research will be: MSExcel (data analysis) and KNMI Climate Explorer (http://climexp.knmi.NI/); changes in land use and occupation will be based on Landsat records available for the last three decades. Simulations using the Brazilian MGB-IPH model will be conducted to try to distinguish the impact on flows linked to climate change (external factors) and changes in land use and infrastructure (internal factors). MGB-IPH is a rain-flow distributed model suitable for the large-scale modelling of low instrumented or ungauged basins. It accepts as input a large amount of data from space-based observation. The model parameters are soil type, land occupation, geology and vegetation. This model is widely used and has been applied in several studies conducted by the team in the Amazon Basin.

Analysing the impact of the changes identified on the communities in the cross-border region will be based on consultations with stakeholders (from the local populations) via surveys in order to collect the necessary information. Perceptions of change will be compared with data (objective 1) and the change indicators produced (objective 2).

### 3.1.3 Expected outcomes

- The physical characteristics of the study area as well as the current uses of the following resources: land, water, forest (timber), energy, mineral resources and agriculture will be described.

- Basic analysis of past trends and indicators of change

- Description and analysis of other factors influencing natural resources in the cross-border zone

- The perception of changes and impacts on populations in the cross-border region

### 3.1.4 Team and partners

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# Risks of transmission of malaria and arboviruses

## 3.2 Mapping the risk of mosquito-borne diseases in the cross-border context of French Guiana – Amapá

### (RiscoTrans)

| Summary | Resumo |
|---|---|
| **Leader:** Emmanuel Roux (IRD / ESPACE-DEV) and Margarete Gomes (SVS-AP) | **Coordinador-a:** Emmanuel Roux (IRD/ESPACE-DEV) e Margarete Gomes (SVS-AP) |
| **Health issues:** Malaria and arboviruses transmitted by *Aedes* mosquitoes (dengue, chikungunya, Zika, etc.) | **Questões de saúde:** Malária e arbovírus transmitidos por mosquitos *Aedes* (dengue, chikungunya, Zika,...) |
| **Study areas: French Guiana and Amapá** | **Áreas de estudo: Guiana Francesa e Amapá** |
| **Objectives**<br>Spatialisation and updating of the risk of the transmission of vector-borne diseases (malaria and arboviruses transmitted by *Aedes* mosquitoes) | **Objectives**<br>Espacialisação e atualização de um risco de transmissão das doenças vetoriais (malária e arboviruses transmitidas por mosquitos do gênero *Aedes*) |
| **Method**<br>• Inventory, production, dissemination and updating of spatialised and multi-thematic information layers that are consistent spatially and temporally; | **Method**<br>• Censo, produção, disseminação e atualização de camadas de informação espacializadas e multitemáticas, coerentes espacialmente e temporalmente; |

| | |
|---|---|
| • Construction of conceptual models for the malaria risk and *Aedes*-transmissible diseases;<br>• Mapping the risk of transmission | • Construção de modelos conceituais do risco de malária e doenças transmissíveis pelo *Aedes*;<br>• Mapeamento do risco de transmissão |
| **Expected outcomes**<br>Scientific publications, databases, data papers, knowledge and risk maps | **Resultados esperados**<br>Publicações científicas, bases de dados, "data papers", conhecimentos, mapas de risco |
| **Proposed partnerships**: Brazil: SVS-AP, IEPA, UNIFAP, Fiocruz, UnB; French Guiana / France: IRD / ESPACE-DEV, ARS-French Guiana, IPG, CTG, CHAR / CDPS, IRD / MIVEGEC, Univ. Artois | **Parceria prevista:** Brasil: SVS-AP, IEPA, UNIFAP, Fiocruz, UnB; French Guiana / France: IRD/ESPACE-DEV, ARS-Guyane, IPG, CTG, CHAR/CDPS, IRD / MIVEGEC, Univ. d'Artois |

### 3.2.1 General context and key issues

Vector-borne diseases such as malaria and arboviruses transmitted by mosquitoes of the genus *Aedes* (dengue, Zika, chikungunya, etc.) are a major public health problem in countries in the Amazonian biome and the Guiana Shield in particular. However, the epidemiological situations, expertise and priorities for action differ significantly from one disease to another. While malaria is in the process of being pre-eliminated or even eliminated entirely, dengue has an endemic-epidemic profile with recurrent epidemics. Chikungunya and the Zika virus have appeared recently, in 2014 and 2016 respectively.

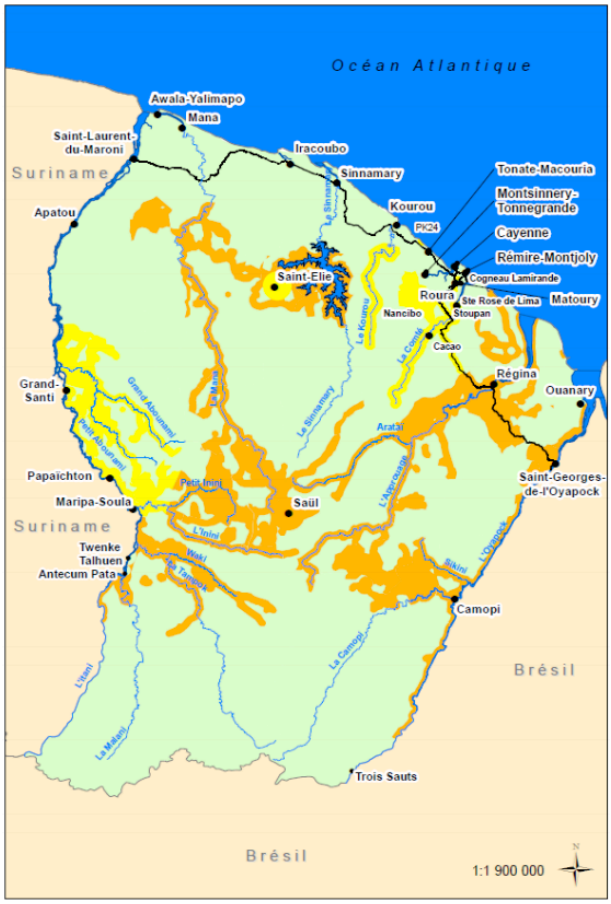



**Figure 1:** Map of malaria risk in French Guiana – 2018: Green: no transmission during the previous year; Yellow: low risk – Cases exist but no transmission in villages; Orange: high risk – malaria transmission in the area. **Sources:** French Guiana Regional Government Mosquito Control and Health Affairs Department – ARS de Guyane – CNR Paludisme, Endemic Areas Centre – French Guiana Army – Off-Site Prevention and Care Centres (CDPSs) of Andrée Rosemon Hospital – Medical biology laboratories in the town and hospitals – Santé Publique France's French

Guiana Regional Prevention Unit (Cire); **Validated by:** Expert Committee on Epidemic Diseases, March 16, 2018; **Carried out by:** ARS Guyane in collaboration with the Pasteur Institute of French Guiana and the French Guiana / SpFrance Cire.

**This map, produced by experts, has a strong subjectivity that the RiscoTrans project will help to reduce, at least as regards the border municipalities with Brazil.**

Cooperation between French Guiana and Brazil on cross-border malaria has grown since 2012, with the specific goal of building a cross-border malaria observatory designed to integrate, harmonise and disseminate data and knowledge on the disease from an epidemiological, entomological, environmental and socio-demographic perspective (see https://climaesaude.icict.fiocruz.br/fr/amapa-guyana-francaise; Roux et al., 2014; Barcellos et al., 2016).

In particular, a prototype of an automatic system for integrating, harmonising and visualising malaria epidemiological data on the French Guiana – Brazilian border has been developed. It demonstrates the feasibility of cross-border surveillance and the value of such monitoring for understanding spatial and temporal dynamics and disease control and elimination.

From the perspective of entomology, a spatialised database on *anopheles* captures in French Guiana and the municipality of Oiapoque was constructed as part of Yi Moua's (Moua, 2017) thesis. This made it possible to predict the habitat quality of the main malaria vector in the Amazonian region, *Anopheles darlingi*, across French Guiana (Moua et al., 2017).

The work carried out as part of the OSE-Guyamapá (PO Amazonie – FEDER Guyane), GAPAM-Sentinela (Guyamazon) and TélePal (CNES / TOSCA) projects has helped define a landscape hazard index for constructing the risk of exposure to *An. Darlingi* (Li et al., 2016, 2017), as well as a land use and occupation map identifying the wetlands in the cross-border zone – possible breeding sites of *An darlingi* – by combining radar and optical satellite imagery (Catry et al., 2018).

Partner teams have also studied the cross-border flows of people qualitatively and quantitatively irrespective of the purpose of their journey.

In view of the progress that has been made, a better awareness of the different aspects of malaria is now conceivable with the aim of estimating the integrated risk of the transmission of the disease. Work of this nature must be based on a detailed conceptual model of risk: this may be adapted to the realities of vector-borne diseases and go beyond the simple product of a natural hazard (often reduced to the presence and density of vectors) and human vulnerability (often limited to the presence of human settlements).

However, bilateral research work must be undertaken in order to ensure there is compliance between the different layers of information (geographic footprints, periods, and spatial and temporal resolutions). In addition, these layers must be updated and adapted to environmental and socio-demographic changes in the region.

Furthermore, the experience accumulated on malaria by the partner teams should make it possible to study other diseases, in particular arboviruses transmitted by mosquitoes of the genus *Aedes* (*Ae. Aegypti* more particularly) – in other words dengue, chikungunya and Zika virus.

### 3.2.2 Objectives and challenges

The project's main objective is the spatialisation of the risk of transmission of vector-borne diseases (malaria and arboviruses transmitted by mosquitoes of the genus *Aedes*) at a frequency to be determined in line with the needs and constraints involved in obtaining or producing data.

Specific objectives:

- To make operational the automatic system for integrating, harmonising and visualising epidemiological data on cross-border malaria on the French Guiana – Brazilian border;
- To disseminate and update the space information and indicators produced in the cross-border zone: entomological indicators and habitat quality, land occupation and use, the "dangerousness of the landscape" indicator, cross-border mobility, etc. in order to facilitate the construction of indicators, assess the relative impact of risk factors and implement the conceptual risk model (see below);

- To build a conceptual model of the risk of transmission of *Aedes*-transmitted malaria and arboviruses in the study area;
- To help objectivise and extend to the *município* of Oiapoque the malaria transmission risk map produced by all health actors in French Guiana (https://www.guyane.ars.sante.fr/system/files/2018-09/paludisme%20Carte%20du%20risque%20en%20Guyane%20-%202018.pdf);
- To help better identify and describe the seasonality of the risk of malaria transmission in the French Guiana – Brazil cross-border zone;
- To contribute to the spatialisation of the risk of transmission of arboviruses transmitted by *Aedes* (*Aegypti*) – dengue, chikungunya and Zika – in the urban zones of Cayenne Island and Saint Georges de l'Oyapock (French Guiana), Oiapoque and Macapá (Macapá, Brazil).

The main challenge is to help improve the targeting of prevention and control actions, and thus to contribute to the elimination of malaria in the region (2015 – 2018 malaria control plan in French Guiana and the plan for eliminating malaria in Brazil by 2030, Sustainable Development Goal 3.3 for eliminating malaria by 2030) as well as to contribute to the surveillance and prevention of the emergence of arboviruses.

### 3.2.3 Study areas

The study areas differ depending on the health problem that is under review: malaria will be examined in the French Guiana – Brazil cross-border zone, consisting of the border communes of French Guiana (Ouanary, Saint Georges de l'Oyapock and Camopi) and Brazil (Oiapoque); arboviruses transmitted by *Aedes* will be studied in the urban zones of Cayenne Island and Saint Georges de l'Oyapock (French Guiana), Oiapoque and Macapá (Macapá, Brazil).

The interactions between urban and "natural" environments, consisting of areas where both "rural" diseases such as malaria circulate together with "urban" diseases such as arboviruses transmitted by *Aedes* (especially in Saint Georges de l'Oyapock and Oiapoque), will be the particular focus of the project team.

## 3.2.4 Methods

The methodology is based on three main workstreams:

- Undertaking the census, production, diffusion and development of the conditions for updating spatialised and multi-thematic information layers that are consistent spatially and temporally;
- Constructing conceptual models of the risk of malaria and diseases transmissible by *Aedes* mosquitoes (*Ae. aegypti* more precisely);
- Mapping the risk of transmission.

The specific actions associated with these three workstreams are detailed below.

#### 3.2.4.1. Multi-thematic space data

### *a) Characterisation of the region*

This action aims to describe the potential habitats of the vectors through environmental variables (land use, human footprint, geo-morphological units and landscapes, etc.) and climatic variables (precipitation, temperature, humidity, sunshine, etc.). It also aims to identify and characterise different levels of vulnerability among the human populations. It is divided into the two spatial zones described above:

- *The French Guiana – Brazil cross-border zone (Anopheles mosquitoes, malaria)*

  Two of the layers of information that have led to the spatialisation of the quality of the ecological habitat of *An. Darlingi* in French Guiana cover the entire study area: the mapping of forest landscapes produced by CIRAD (Gond et al., 2011) covering the Guiana Shield; the SRTM digital elevation model produced worldwide by NASA; the human footprint map, produced in French Guiana by Thoisy et al. (2010), which has an equivalent on a global scale (although less detailed) with the mapping of the Global Human Footprint distributed by NASA's Socioeconomic Data and Applications Centre (SEDAC). Other layers can be easily obtained from the competent Brazilian bodies (the road network) although some are, for the moment, specific to French Guiana (land forms and geo-morphological landscapes, Guitet et al. 2013, which is being worked

on in Amapá as part of the BIOMAP project; Guyamazon 2015-2017). The project will lead to the completion of this inventory of the available information layers, produce the missing information and posit the hypotheses necessary for developing risk models on the scale of the study area.

The aim will also include accessing more detailed information on land use and occupation, in particular identifying areas of water covered by vegetation (especially flooded forests) and their spatio-temporal dynamics, based on the approach devised by Catry et al. (2018), combining radar and optical satellite images to overcome the presence of clouds and vegetation cover.

The possibility and suitability of exploiting temporal series of solar irradiation maps (Albarelo et al., 2015) – in connection with the natural resources component of the PROGYSAT project – and rainfall (Ringard et al., 2015) will also be explored.

Knowledge will be derived from the combination of previous information layers, in particular the spatial distribution of the habitat quality of *Anopheles*, based on the methodologies proposed and developed by Moua et al. (2017);

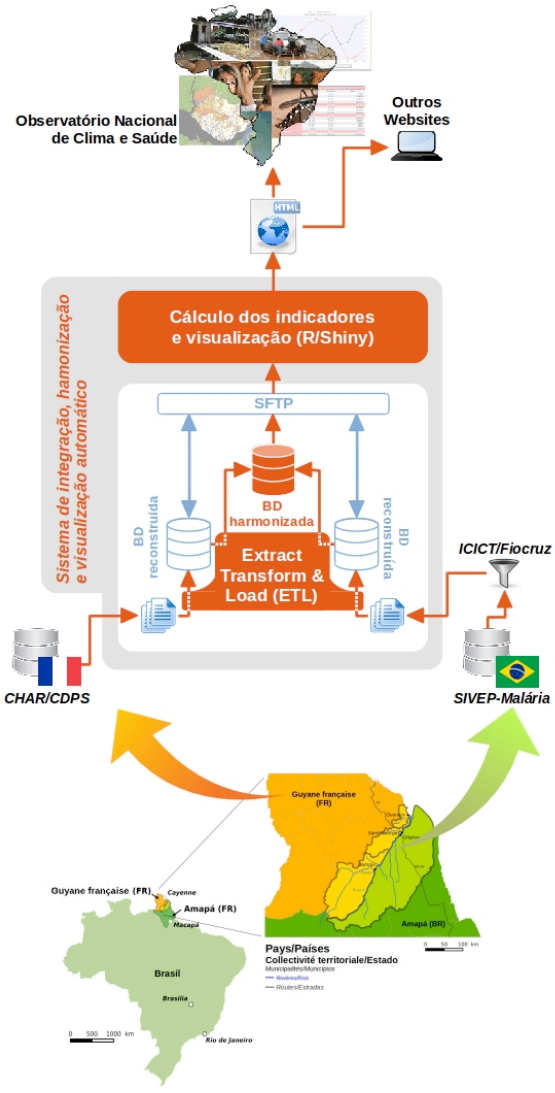
- *Urban zones (Aedes mosquitoes, arboviruses)*

Urban landscapes that favour the proliferation of *Aedes* mosquitoes, as well as the various levels of vulnerability of human populations, will be identified and characterised using remote sensing with very high spatial resolution. This work will build on the results of previous projects, in particular DETECT (CNES / TOSCA) that linked urban characterisation data with entomological indicators in Matoury (French Guiana) and APUREZA (CNES / TOSCA), together with the ADEUSA (Urban) workstream of the current PROGYSAT project, aiming to study the dynamic extension of the urban footprint and the urban landscapes via remote sensing.

### *(b) Integrating and harmonising epidemiological and entomological data*

**Vectors:** the inventory of sites where *Anopheles* is present in French Guiana, carried out as part of Yi Moua's doctorate (Moua, 2017), will be supplemented following the collections carried out by the Pasteur Institute of French Guiana (IPG) in the Trois Palétuvier region in 2017 together with, on the Brazilian side, a literature review and census of existing data, conducted in partnership with the Amapá medical entomology teams. It will be published in open databases (in particular the Global Biodiversity Information Database, GBIF) alongside a data paper.

**Figure 2:** Data flows and technologies planned for the integration, harmonisation and visualisation system for cross-border malaria data between French Guiana and Brazil (Roux et al., 2018)



Census work will be carried out for the sites where *Aedes aegypti* mosquitoes are present and, if possible, their densities and insecticide resistance status in the towns of Cayenne / Matoury, Saint Georges de l'Oyapock, Oiapoque and Macapá, thanks to joint work, capturing and analysis carried out by IPG (Isabelle Dusfour) and the Oswaldo Cruz Foundation (Ademir Martins).

Ideally, a census of vector control actions (spraying, use of larvicides, distribution of impregnated mosquito nets) will be performed to enable studies on the impact of these actions and their integration into risk models.

- **Epidemiology:** the integration, harmonisation and visualisation system of cross-border malaria (see Figure 3) will provide data on the distribution of the disease. The project will improve the system by geo-coding missing Brazilian localities and calculating and spatialising incidence rates.

  The project team will also work on adapting the previous system in order to integrate, harmonise and visualise cross-border epidemiological data on arboviruses transmitted by *Aedes*.

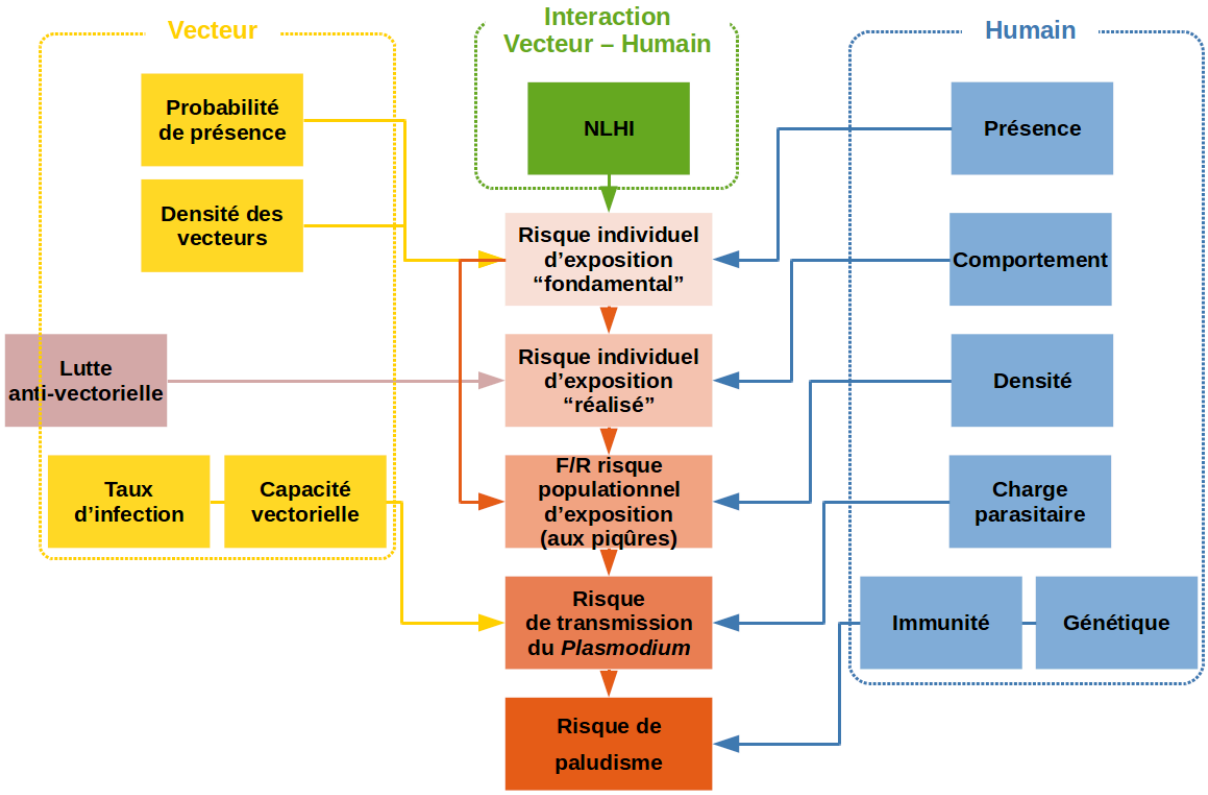
### *c) Dissemination*

The project will contribute to efforts to disseminate baseline data and indicators. This work will be shared by the PROGYSAT project, the Brazilian Climate and Health Observatory and the Theia Data Centre under the remit of the Centre d'Expertise Scientifique (CES: Scientific Expertise Centre) for Infectious Diseases (http://www.theia-land.fr/fr/themes/santé) through the associated data infrastructures.

#### 3.2.4.2. Conceptual risk models

The conceptual model for malaria risk shown in Figure 3 will be discussed and revised to provide a valid model for both the scientific community and health actors. The project team will draw on the literature, its own expertise and the risk-building model used by health actors in French Guiana that produced the risk map in Figure 1.

*The construction approach is iterative, resulting from a constant to-ing and fro-ing between data collection / production and model construction in order to ensure the operationality of the conceptual model.*




*Vector* | *Vector – human interaction* | *Human*

*Probability of presence* | *NLHI* | *Presence*

*Density of vectors* | *"Fundamental" individual exposure risk* | *Behaviour*

*Anti-vector control* | *"Actual" individual exposure risk* | *Density*

*Rate of infection* | *Vector capacity* | *F/R population exposure risk (to bites)* | *Parasitic load*

*Risk of plasmodium transmission* | *Immunity Genetic*

*Risk of malaria*

**Figure 3:** A proposed model for constructing the risk of malaria transmission (Roux et al., 2017)

The same methodological approach will be used to propose a risk model for arboviruses transmitted by *Aedes*.

#### 3.2.4.3. Risk mapping

The proposed risk models will be implemented and spatialised by combining the available information layers, based on the knowledge of health actors and objective approaches that exploit epidemiological data and methods of learning, statistical regression and model selection.

The results will be validated by the health actors, relying on the available cross-border epidemiological data.

## 3.2.5 Expected outcomes and optimisation of results

The expected outcomes are:

- Basic information layers for a multi-thematic and up-to-date characterisation of the cross-border region between French Guiana and Brazil and the urban zones of Cayenne Island, Saint Georges, Oiapoque and Macapá;
- The provision of previous layers of information through data infrastructures;
- Conceptual models of the transmission risk for *Aedes*-transmitted malaria and arboviruses;
- Updated risk maps associated with previous diseases.

These results will be promoted through:

- Scientific publications in peer-reviewed journals (*International Journal of Health Geographics, Geospatial Health, Malaria Journal, Journal of Medical Entomology*, etc.);
- Data papers;
- Dissemination of data using open databases (GBIF, VectoBase) and existing data infrastructures and / or infrastructures developed as part of the project.

### 3.2.6. Partnership

**Table 1:** Partner organisations and participants in the RiscoTrans workstream ***(NB: Some of the individuals listed below have not yet given their formal agreement to participate in the project)***

| **Amapá, Brazil** | **French Guiana, France** |
|---|---|
| **Superintendência da Vigilância and Saudan do estado do Amapá (SVS-AP):**<br>• Margarete Gomes *(coordinator)*<br>**Instituto de Pesquisas Científicas and Tecnológicas do Estado do Amapá (IEPA)**<br>• Allan Kardec Galardo<br>**Universidade Federal do Amapá, Oiapoque campus (UNIFAP-Oiapoque)**<br>• Anapaula Mendes<br>• Edcarlos Vasconselos<br>**Fiocruz**<br>• Christovam Barcellos<br>• Ademir Martins<br>**UnB**<br>• Helen Gurgel | **IRD / SPACE-DEV**<br>• Emmanuel Roux *(coordinator)*<br>• Nadine Dessay (link with the ADEUSA workstream )<br>• Thibault Catry<br>• Renaud Marti<br>**Pasteur Institute of French Guiana (IPG)**<br>• Isabelle Dusfour<br>• Claude Flamand<br>**Cayenne Hospital, department at the Off-Site Prevention and Care Centres (CDPSs)**<br>• Emilie Mosnier<br>**French Guiana Regional Health Authority (ARS Guyane)**<br>• Alice Sanna<br>**French Guiana Regional Government Mosquito Control Department**<br>Sandrine Chantilly<br>• Arise Chocho<br>• Johanna Restrepo |

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| | **IRD / MIVEGEC**<br>• Vincent Corbel<br>**University of Artois, Discontinuités Laboratory**<br>• Valérie Morel |

# Pollution, urbanisation and precarious habitats

## 3.3 Protecting the landscape in the Amazonian environment by studying compliance with pollution standards and monitoring anthropogenic and natural pollutants

### 3.3.1 Introduction

Reducing environmental nuisance requires knowledge about and control of the pollutants in our environment. In 2000 Santé Publique France estimated that there were 40,000 deaths in France related to pollution.

Taking into account previous achievements based on collaborative projects with French Guiana's regional air observatory – Atmo Guyane (part of the France Atmo network) – and the research context in French Guiana, this thematic area of application is divided into three inter-dependent groups:

- Verification of the legal framework of French – Surinamese and French – Brazilian safety measures and pollution standards (water and air; see Appendix 2), knowledge of and compliance with the limit values by the population.

- Impact and monitoring of the pollution of anthropogenic and / or natural fine particles (NOx aerosols, etc.) related to landscape development and change around border areas (French Guiana / Brazil and French Guiana / Suriname).

- Biomass characterisation (French Guiana / Brazil and French Guiana / Suriname) using satellite images and remote sensing and modelling tools.

The project partners in French Guiana are Atmo Guyane (Kathy Panechou-Pulcherie) and the University of French Guiana (Marie-Line Gobinddass, Mabiane Franca, Rosuel Lima-Pereira, Abdennebi Omrane). The partner in Suriname is Anton de Kom University (Paul Ouboter), and the partners in Brazil are the Amapá Federal University (Maria de Jesus Ferreira César de Albuquerque), Brazilian Agricultural Research Corporation – Embrapa (Eleneide DoffSotta), Francisco Paulo Marques Lopes, university professor at the Federal University of Pará (UFPA), Faculty of Mathematics of Belem, Campus Universitario do Guama and Cristina Lúcia Dias Vaz, associate professor at the Federal University of Pará (UFPA), Faculty of Mathematics of Belem, Campus Universitario do Guama.

## 3.3.2 Objectives and methodology of the legal framework for environmental standards

### 3.3.2.1 Environmental standards

The environment is a set of physical, chemical and biological factors that allows life to grow in all its forms. Since the 1960s, the legal aspect raised by political movements must be added to the environment. Environment are gaining in importance thanks to the process linked to globalisation. Environmental organisations such as Greenpeace and Friends of the Earth have subsequently been created. In the environmental system, pollution alters life by harming the health and survival of humans and other species. Moreover, environmental preservation is everyone's responsibility because it guarantees the survival of living beings on our planet. Even if environmental legislation is not respected in its entirety, it is nevertheless a guarantee for the preservation of this "heritage of humanity".

In short, environmental standards have finally been set with the aim of preserving people's health and safeguarding their environment. These are based on "desirable preservation criteria" and are an important objective in the regulations of the authorities. They are the result of decisions directed towards implementing measures designed to preserve, to a certain degree, the air, water and soil and to protect against noise pollution. However, it should be noted that they do not represent only minimum levels for preserving the health of individuals: they are desirable standards for active protection, and the authorities aims to maintain this guarantee. They are also desirable for avoiding – or at least restricting – damage in areas hitherto safeguarded from pollution. Furthermore, environmental standards are established on the basis of scientific data within the limits of current knowledge. Accordingly, on-going work to investigate the latest scientific discoveries must also go hand-in-hand with sound scientific judgment in order to integrate them.

#### 3.3.2.2 General objectives

The analytical and comparative study of the legal norms regarding the environment, safety and pollution in France, Brazil and Suriname aims initially to carry out an inventory of progress and setbacks in these countries in terms of protecting and preserving the natural environment in the Amazon by drawing up a map of protected zones. Knowledge about the legal norms of these cross-border zones, Saint Georges de l'Oyapock and Saint Laurent du Maroni, aims to show the importance of the actions taken by households, neighbourhoods, schools, churches and communities in helping to reduce the production of waste and pollutants. Furthermore, these actions may be identified as positivist, constructive and critical. In other words, we can say that positive action seeks to change the behaviour of individuals as part of an educational process; constructive action attends to the educational component throughout the learning process by factoring in the affect and body of individuals in an informative dimension; and critical action involves the participation of social groups. It prioritises emancipation and autonomy within a political perspective, without neglecting scientific, legal, economic and socio-cultural

information in the construction of new knowledge for the purpose of preserving and protecting the environment.

Our analytical and comparative study of the environment, safety and pollution may also lead to educational methods in the Guiana Shield that are contextualised to its reality and environment. It is important to be aware of the conceptions, representations, habits and customs of cross-border inhabitants as well as those of the social and economic actors responsible for environmental problems together with safety and pollution issues. Another objective of this study on legal norms is to analyse the social representations of the human-society-nature relationship in the legislation. It will be a question of identifying in the legal texts of the three countries the so-called "naturalist", "anthropocentric" and "systemic" visions (see table in Appendix 1).

In analysing and comparing legal standards in France, Brazil and Suriname, other information is expected to emerge from the study, such as:

From a legal perspective, what is the role of the cross-border society, Saint Georges de l'Oyapock and Saint Laurent du Maroni, in preserving the environment?

How can the relevant populations help to preserve the environment in the context of their daily lives?

What is the scope of recycling in the Franco – Brazilian and Franco – Surinamese cross-border zone?

If there is selective collection in the Guiana Shield, what materials can be recycled?

What is the role of industry in preserving the Amazonian environment?

Who are the social, economic, scientific and medical officials present in the cross-border zone under study?

**3.3.2.3 SUMMARY**

In order to limit and reduce the adverse environmental effects of regional land-development projects that could increase pollutant levels, environmental impact assessment studies are conducted in all French departments.

We will first investigate whether the equivalent of these environmental impact assessments exists in the Brazilian and Surinamese cross-border zones.

The study aims to conduct a review of environmental norms and standards in the Suriname / French Guiana and Brazil / French Guiana cross-border region. We will try to determine to what extent it is possible to map the items described below:

Type of practice according to community

Legislation depending on the region

Recycling reach

When verifying the legal framework, the anthropogenic pollution standards of each country will be provided by each of the partners in order to compare them with European Union standards (see Annex). A post-doctoral fellow will be recruited and will take part, within the Faculty of Literature and Social Sciences, in research on the environmental quality objectives in each country. He or she will build on the available standards and conduct research on the most widespread and toxic pollutants in each country. Statistical and modelling tools will also be used during the work. With the results of the inventory, the regional governments in Brazil, Suriname and French Guiana will be able to justify the need to strengthen environmental compliance in Brazil and Suriname with the implementation of cross-border environmental standards and norms.

The key results of this work will help policy makers issue recommendations regarding regional planning and public health.

**TIMETABLE OF ACTIVITIES**

The recruited post-doctoral researcher will be responsible for describing the historical development of laws, decrees and orders on pollution, the environment and safety. He or she will also be in charge of describing forms of pollution, forms of environmental conservation and safety in the cross-border zone.

During the three training missions (see Annex) in the Brazilian, Surinamese and French Chambers of Deputies, the study of the regulations will be carried out. At the end of this work, our research will initially be promoted at the Air Pollution Congress (see Appendix) in 2019. An article in a journal devoted to the humanities and social sciences is planned for the end of 2019.

## 3.3.3 Pollution study

### 3.3.3.1 Introduction

In addition to studying the legal framework, the proposed project is based, in the first instance, on setting up a system for the cross-border environmental monitoring of pollution (Suriname / French Guiana / Brazil) and devising e-learning material on monitoring the evolution of pollutants (anthropogenic or not) in the Amazonian environment by satellite and ground-based sensors.

This thematic application is backed on a local level by Atmo Guyane (French Guiana Air Quality Observatory), and must be contextualised within the objectives of the PCIA in order to meet the needs of regional stakeholders through genuine local benefits at the project's conclusion and in compliance with environmental standards by the population in these cross-border zones. As part of the partnership with Atmo Guyane, the latter will take part in communication operations with the general public and schools, helping to design booklets, posters and films on air quality and preventive material for the health of the population where there is heavy air pollution.

For each theme studied, it will be necessary to jointly define the potential adaptations of each partner's available data and evaluate their consistency in order to monitor the evolution of the pollutants common to the border areas during the project.

Santé Publique France (SPF) has undertaken a quantitative assessment of the health impact (EQIS) of air pollution in order to estimate how it affects health. The SPF study provides a new national estimate of the impact of PM2.5 particulate matter pollution in relation to human activity. There are a number of exposure routes to aerosols for humans. The first main route of entry is the respiratory tract. Then there is the digestive tract, for which the fallout of atmospheric pollutants is on the ground: contamination of water, soil, plants and the food chain (dioxins, pesticides, heavy metals, etc.). Particles larger than 10 µm

are stopped in the upper tracts. Particles under 10 µm penetrate the lower tracts, and particles less than 3.5 µm enter the lungs (diesel particles).

This new data serves to update the latest estimate published in 2000 by the European CAFE study that revealed that there are over 40,000 pollution-related deaths in France. The EU has estimated that there are 48,000 deaths a year, confirming the same order of magnitude as the European study.

Air pollution does not affect only large towns. Although the effects are indeed greater here, medium and small towns as well as rural areas are also impacted:

- In urban zones with over 100,000 inhabitants the results show, on average, a loss of 15 months of life expectancy at 30 years of age due to PM2.5;
- In zones of between 2,000 and 100,000 inhabitants, the drop in life expectancy is 10 months on average;
- In rural areas, an average of nine months of life expectancy is estimated to be lost.

Health gains are proven if air quality improves. SPF's work highlights the significant potential health benefits associated with improved air quality. The results show that the most ambitious scenarios for reduced pollution levels lead to substantial health benefits. For example, if all the municipalities succeeded in achieving the PM2.5 levels observed in the 5% of the least polluted municipalities in the same urban class, 34,000 deaths could be avoided every year (an average gain of 9 months of life expectancy).

In French Guiana, Atmo Guyane is responsible for monitoring air quality. It has already performed measurement campaigns in several municipalities in the country.

The objective of our research will be to supplement the measurement campaigns carried out by Atmo Guyane in the cross-border zones. The aim will be to improve understanding of pollution rates and estimate the health risks in order to draw up a prediction scenario based on the urbanisation rate.

Remote sensing for aerosol detection will provide several levels of information based on SPOT satellite images, Landsat, MODIS AQUA and TERRA. We will have comprehensive information on the region on a wide scale, and on a regional level this information will be geared more towards rural areas and, on a smaller scale, we will be able to focus on one or more towns in particular. We will be able to add to the networks of pollutant sensors according to urbanisation, improve their location or put them in place if they do not already exist.

We will extract the aerosol component from the inversion of the satellite signal; we will determine the type of aerosol from the size, and will also determine the optical thickness, which will give us information about their profusion.

The combination of in-situ measurements derived from the project's measurement campaigns (see below) with the space-based observations (satellite signals) will provide a more accurate mapping of pollution rates over the project period. It will also confirm the importance of ensuring this type of study is sustainable as the number of inhabitants increases and the rate of urbanisation continues to grow.

Analyses of the chemical composition and structure of individual particles, in situ and remote sensing measurements of urban-industrial, desert and biomass particles (see paragraphs b and c below) will be taken from the surface in French Guiana and at different altitudes. A series of numerical simulations will be used to analyse the sensitivity of remote sensing observations for detecting the state of the aerosol mix.

Two master's interns (see attached form) will work on each border in order to collect, classify and analyse all the data harvested during the trial campaigns to draw up an inventory, establish a database of the types of pollutants and finally propose a suitable GIS tool.

It will be necessary to distinguish (via modelling and statistical tools) between anthropogenic pollution (PAH, NOx, CO2, volatile organic compounds, mercury, etc.) and natural pollution (desert aerosols, natural chlorine and others) in the cross-border regions between Brazil, French Guiana and Suriname in order to verify compliance with environmental standards based on detecting pollution limit thresholds. The verification of the legal framework of pollution standards presented at the beginning of the project will be used at this stage to validate convergences / divergences in the cross-border regions of French Guiana.

The key expected outcomes are the modelling (spatio-temporal evolution), statistical analysis and mapping of pollutants and predicting their evolution according to the regional planning envisaged by the political authorities.

#### 3.3.3.2 Trial campaigns and qualitative and quantitative pollutant study

- **a) Pollution resulting from population behaviour and displacement following the construction of the bridge and compliance with environmental standards**

This study will focus on issues arising from the other project sub-themes; it will:

i) Check the evolution of the urban and peri-urban landscape using satellite images and cadastral data in the cross-border zones in relation to the biomass study sub-theme

ii) Evaluate the population's compliance with environmental standards based on detecting pollution limit thresholds and the sub-theme focusing on the verification of the legal framework of pollution standards

- **b) Define the types and rates of pollutants in the air, soil and water (already existing or new)**

Regarding the impact and monitoring of anthropogenic and / or natural particulate matter pollution, a first measurement campaign is in the process of being implemented for the French Guiana / Suriname cross-border region with the French Guiana Air Quality Observatory (Atmo Guyane). The timetable for this campaign is as follows for the town of Saint Laurent:

November 2018 to January 2019: installation of the INDY mobile station for measuring PM10, nitrogen oxides and background ozone (the long-term goal is to set up a fixed station).

November 2018 to January 2019: installation of tubes (one site) for measuring benzene and its family (BTEX). Five 14-day campaigns are planned and tubes to be installed to map the town's NO2 (four 14-day campaigns on approximately 20 sites).

The next measurement campaigns in the French Guiana / Suriname cross-border region, which will take place in 2018 and 2019, will consist of:

Measuring polycyclic aromatic hydrocarbons (PAHs) (samples taken every six days throughout the year)

Measuring heavy metals (several samples taken every seven or 14 days spread over the year)

Other measurement campaigns will be planned in consultation with Atmo Guyane for Suriname and the French Guiana / Brazil cross-border region.

This study will be conducted jointly with Atmo Guyane, which is responsible for the project to install the measuring station and real-time pollutant sensors (Oyapock area early 2019).

Following this new campaign, we will seek to precisely map the changes in the urban and forest landscape using satellite imagery so we can predict the consequences of the rising pollution in the cross-border regions.

We will also characterise the increase in the anthropogenic and natural action of the pollution and evaluate the possible imbalances in the environment in the cross-border regions (French Guiana / Brazil and French Guiana / Suriname) via mathematical models.

It will be necessary to make the distinction (using modelling and statistical tools) between anthropogenic pollution (PAH, NOx, CO2, volatile organic compounds, mercury, etc.) and natural pollution (desert aerosols, natural chlorine and others) in the cross-border regions between Brazil and French Guiana and Suriname and Brazil to verify compliance with environmental standards based on detecting pollution limit thresholds.

#### 3.3.3.3 Interaction of the different stages of our project

The objectives specific to this thematic workstream are as follows:

- Building common objectives in terms of regional scientific cooperation
- Performing a comparative study of environmental pollution standards
- Pooling and promoting knowledge bases between the three regions
- Producing pollutant indicators between the three regions
- Monitoring in real and / or delayed time the evolution of pollutants (to define the mode of monitoring – hourly, daily, monthly – according to the borders, the types of pollutants and the seasons)

This workstream complements the workstream on the routine mode of environmental monitoring in the field. It follows that the complementary objectives are:

- Modelling and monitoring anthropogenic pollutants (mathematical models: dynamics, atmospheric dispersion of pollutants, air quality models will be used)
- Promoting the results for academic courses and training by preparing teaching modules to train students to monitor pollutants in the Amazon environment.

The implementation of each of the themes will include organising seminars on human behaviour and the evolution of cross-border and / or trans-national pollutants. This would, therefore, include incorporating the potential contributions into the expectations and needs of public actors. Educational workshops on content specification and distance learning will be offered.

**ACTIVITY TIMETABLE**

The post-doctoral researcher who is recruited will be responsible for inventorying and classifying the different types of pollutants in the cross-border regions, as well as modelling and mapping them, in close collaboration with the two master's 2 (M2) interns who will be working on the project. Both of the M2 interns will be called on to develop GIS tools at IRD to improve the spatial representation of the different pollutants (NOx, VOC, PAH, PM10, PM2.5, etc.) by promoting the various databases acquired during our measuring campaigns. We will invite a researcher with experience in pollutant modelling, Bruno Sportisse, and a university professor, Zenilda Cardeal, a specialist in PAH and VOC studies in the Amazonian environment (see Appendix).

During a training mission in Newcastle (see Annex), we will use a new pollutant modelling tool. At the end of this work, our results will be promoted first at the European Geophysical Union Congress (EGU; see Appendix) in 2019 and secondly at the Air Pollution Congress (see Appendix). A publication in a peer-reviewed environmental sciences journal is planned for the end of 2019.

### 3.3.4 Biomass study and change of land occupation and use

Tropical forests play a vital role in the functioning of the planet's natural systems. At the same time, these forests also play a key role in regulating local climate because of the way they interact with the water cycles.

The Amazon is home to 33% of the world's tropical forests. It is the largest and most diverse tropical forest on the planet. The deforestation and degradation of the Amazonian has been of global interest, mainly because of deforestation's contribution to increased global warming.

The causes of deforestation may be natural or anthropogenic. In the Amazon, deforestation is mainly caused by anthropogenic actions related to agrarian activities, population explosion, logging and underground mining (e.g. alluvial digging).

In the context of climate change, deforestation is a major source of carbon dioxide (CO2) emissions.

Forest ecosystems account for 80% of terrestrial carbon stored in vegetation, and 40% of that stored in soils (Seymour and Forwand 2010). According to Pan et al. (2011), tropical forests contain between 47.5 and 62.5% of this stock, and are the main victims of deforestation.

Deforestation causes climate change on a global scale as well as at regional and local levels: changes in the water cycle, soil erosion, a drop in the amount of rainfall, the increase in pollution (including vegetation that purifies the water and air), the loss of biomass in each forest type and loss of biodiversity.

For these reasons, it is necessary and imperative to ascertain the biomass of each type of forest in order to estimate the carbon stock. Biomass estimates are used to calculate the amount of carbon dioxide (CO2) released into the atmosphere during the combustion process, and the amount of methane (CH4) in the biomass decomposition process. CO2 and CH4 are two of the six greenhouse gases targeted by the Kyoto Protocol.

In parallel, we will monitor land use and occupation changes of anthropogenic origin in the cross-border zones (French Guiana / Brazil and French Guiana / Suriname). Changes in land use and occupation are one of the major anthropogenic reasons for increased greenhouse gas emissions.

The study of changes in land use and occupation and their interactions with human societies and land is a major challenge for the political and scientific community in a context of global, regional and local changes (climate, environmental, demographic, socio-economic and political).

The remote sensing data (medium and high spatial resolution satellite imagery) available to date will be used for the detailed spatio-temporal monitoring of regional land use and occupation in the cross-border zones.

The results of this analysis should make it possible to identify the anthropogenic factors related to changes in land occupation and thus verify the amount of carbon stored by type of land use at regional and cross-border level.

The time series data from NDVI and SAVI images and fraction images (shade, vegetation and soil) and field data (forest inventory) will be analysed to quantify the carbon (emitted and / or stored) of the forest biomass the in the cross-border zones.

This method has been used in the Central Amazon, where statistical analyses for the time series of managed forests clearly suggest that the NDVI, SAVI and fraction image values of the vegetation and shade change over time (Mabiane Franca thesis, 2009).

The two master's interns will work on the two borders to list and rank all available data. There will be a database by type of vegetation, biomass and carbon stock, with the aim being to improve regional management. The key expected outcome is the mapping of the type of vegetation and type of land occupation through the use of the images furnished by Workstream 1.

Defining the cross-border landscape

A preliminary study will focus on two issues:

I) Estimating the biomass in different vegetation types in the cross-border zone (French Guiana / Brazil and French Guiana / Suriname) based on field measurements obtained through forest inventories and available data to verify the carbon stock in each vegetation type.

II) Analysing the evolution, occupancy and use of anthropogenic soils around borders (peri-urban zones, bridges and rivers) using satellite images (Spot, Landsat, etc.).

**TIMETABLE OF ACTIVITIES**

The two master's 2 (M2) interns who will be working on the project will have to collect and analyse forest inventory data in cross-border zones and build a database by vegetation type, biomass and carbon stock. Both interns will go to one of the two borders accompanied by a researcher to collect and analyse the data (see Annex: field mission expenses).

We will also work on the Brazil region with Professor Eleineide DoffSota with the implementation of a forest inventory. At the conclusion of this work, the results will be promoted at the Landscape Ecology Congress in 2019. A publication in a peer-reviewed journal in environmental sciences is planned for the end of 2019.

## 3.3.5 Tasks

| Action | Title / Description | Period |
|---|---|---|
| Action 1 | Characterisation and evolution of the cross-border landscape through the acquisition, analysis and production of satellite images | Quarter 4 (2018) and Quarter 1 and 2 (2019) |
| Action 2 | Cross-border classification of the (forest) landscape using field measurements (forest inventory | Quarter 4 (2018) and Quarter 1 and 2 (2019) |

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| | and available data) | |
| Action 3 | Statistical study of anthropogenic pollution (PAH, NOx, CO2, volatile organic compounds, mercury, etc.) | Quarter 1, 2 and 3 (2019) |
| Action 4 | Modelling of anthropogenic pollution (PAH, NOx, CO2, volatile organic compounds, mercury, etc.) | Quarter 1, 2 and 3 (2019) |
| Action 5 | Statistical study of natural pollution (desert aerosols, natural chlorine and others) | Quarters 3 and 4 (2019) |
| Action 6 | Modelling of natural pollution (desert aerosols, natural chlorine and others) | Quarters 3 and 4 (2019) |
| Action 7 | Forecasting the evolution of pollutants in cross-border regions | Quarter 1, 2 and 3 (2020) |

### 3.3.6 Results and popularisation

| Results | Popularisation |
|---|---|
| Mapping environmental standards compliance in Brazil and Suriname | Information campaign on environmental standards on the border of French Guiana / Brazil and French Guiana / Suriname with Atmo Guyane |
| Production of pollutant indicators in the three regions | Public exhibition on the theme of environmental protection with Atmo Guyane |
| Mapping of pollution rates over the duration of the project based on combining in-situ measurements from the project's measurement | Popularisation of non-polluting personal behaviour among school children |

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| campaigns with space-based observations | |
| Biomass mapping in addition to pollution mapping | National and international conferences for presenting the results of this work |
| Proposal for a plan to protect our region from pollution for the decades ahead | |

### 3.3.7 Project members and partners

| Members in French Guiana | Members abroad |
|---|---|
| Kathy Panechou-Pulcherie: Atmo Guyane director | Eleneide DoffSotta: researcher in the Brazilian Agricultural Research Corporation |
| Abdennebi Omrane: university professor at the University of French Guiana | Paul Ouboter: lecturer at the Federal Anton de Kom University in Suriname |
| Marie-Line Gobinddass: lecturer and researcher at the University of French Guiana | Francisco Paulo Marques Lopes: university professor at the Federal University of Pará (UFPA), Faculty of Mathematics of Belem and Campus Universitario do Guama |
| Rosuel Lima-Pereira: associate professor at the University of French Guiana | Maria de Jesus Ferreira Caesar de Albuquerque: university professor at the Federal University of Amapá (UNIFAP), Faculty of Geography, Binacional Campus. Coordinator of the geography curriculum |
| Mabiane Franca: lecturer and researcher at the University of French Guiana | Cristina Lucia Dias Vaz: associate professor at the Federal University of Pará (UFPA), Faculty of Mathematics of Belem, Campus Universitario do Guama |

## ANNEX 1

| Naturalistic vision |
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| This vision sees the environment as being synonymous with (untouchable) nature and harmony.<br>The environment concerns physical and biological aspects. It excludes human beings since they are only an external observer.<br>Discourse type:<br>Space: "place where living beings live";<br>Elements that surround this space: biotic factors (living beings) and abiotic factors (air, water and earth).<br>Teaching practices:<br>A traditional form of teaching;<br>Restricted to transmitting knowledge about nature (biotic and abiotic);<br>The human being is inserted into this space as a predator;<br>Importance of the methodology: observation of nature (nature that has been preserved or destroyed). |
| Anthropocentric vision |
| This vision considers that the usefulness of natural resources is required for the "survival of human beings" (utilitarian vision).<br>It recognises the interdependence of biotic and abiotic factors as well as the transformative action of human beings on nature, which shifts the "ecological balance".<br>Discourse type:<br>It is about everything that surrounds human beings: animals, plants, water and air. In short, "everything that enables humans to survive".<br>This is where humankind lives, taking advantage of all resources in order to survive.<br>Teaching practices:<br>A traditional form of teaching;<br>Its purpose is to make individuals more aware of the importance of preserving the resources they use and that are necessary for the survival of humanity;<br>When studying the environmental problem, this teaching gives priority to the political, social and |

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| economic aspects closely linked to human beings. |
| Systemic vision |
| This vision highlights the reciprocal relationship between nature and society. It is characterised to spotlight the complex interactions between social and natural aspects without forgetting the political, economic, philosophical, legal and cultural factors. In this vision, humankind is seen as a social being living in a community.<br>Discourse type:<br>"The environment is our home, our neighbourhood, our town, our country, our planet. It is the animals, plants, family, society and the relationship between all living beings and everything that surrounds humankind".<br>Teaching practice:<br>Plays an innovative role;<br>Transmits knowledge about the complexity of nature;<br>Sees humans as being as a constituent element of the environment as a social being that lives in communities;<br>Seeks to educate people about the need to preserve existing interactions sometimes in nature, sometimes in society but also between the two;<br>Includes other themes that are not part of day-to-day teaching or an official programme. The systemic vision seeks to develop other types of content and other areas of study such as pollution, safety, waste, recycling, health and poverty.<br>Adopts an interdisciplinary perspective. |

Source: O Rio da minha vida.

# ANNEX 2

**Standards**

**Limit values, target values and quality objectives**

| Pollutant | Limit values | Target values | Quality objectives |
|---|---|---|---|
| NO2 | Annual average for health protection:<br>40 µg / m3 | | 40 µg / m3 as an annual average |
| | Average hourly for health protection:<br>18 annual exceedances of 200 µg / m3 | | |
| NOX | 30 µg / m3 (NO2 equivalent) annual average for vegetation protection | | |
| PM10 | Annual average for health protection:<br>40 µg / m3 | | 30 µg / m3 annual average |
| | Daily average for health protection:<br>35 annual exceedances of 50 µg / m3 | | |
| Lead | 0.5 µg / m3 annual average | | 0.25 µg / m3 annual average |
| SO2 | 20 µg / m3 annual average for ecosystem protection | | 50 µg / m3 annual average |
| | 20 µg / m3 average over the period October 1 to March 31 for ecosystem protection<br>Daily average for health protection:<br>3 annual exceedances of 125 µg / m3 | | |
| | Hourly average for health protection:<br>24 annual exceedances of 350 µg / m3 | | |
| O3 | | 25 annual exceedances of 120 µg / m3 for the daily maximum of the 8-hour average for health protection | 120 µg / m3 for the daily maximum of the 8-hour average for health protection |

| | | | |
|---|---|---|---|
| | | 18000 µg / m3.h for AOT40 from May to July for vegetation protection | 6000 µg / m3.h for AOT40 from May to July for vegetation protection |
| CO | 10,000 µg / m3 for the daily maximum of the 8-hour average for health protection | | |
| Benzene | Annual average for health protection: 5 µg / m3 | | 2 µg / m3 annual average |
| Arsenic | | 6 ng / m3 annual average | |
| Cadmium | | 5 ng / m3 annual average | |
| Nickel | | 20 ng / m3 annual average | |
| B(a)P | | 1 ng / m3 annual average | |

Limit values, target values and quality objectives

Information and recommendation thresholds and alert thresholds

| Pollutant | Information and recommendation threshold | Alert thresholds |
|---|---|---|
| NO2 | 200 µg / m3 average hourly | 400 µg / m3 average hourly<br>200 µg / m3 hourly average if this value is exceeded the day before and there is a risk of exceeding the following day |
| SO2 | 300 µg / m3 average hourly | 500 µg / m3 hourly average if exceeded for three consecutive hours |
| O3 | 180 µg / m3 average hourly | threshold 1: 240 µg / m3 hourly average if exceeded for three consecutive hours<br>threshold 2: 300 µg / m3 hourly average if exceeded for three consecutive hours<br>threshold 3: 360 µg / m3 average hourly |
| PM10 | 50 µg / m3 averaged over 24 hours | 80 µg / m3 averaged over 24 hours |

Information and recommendation thresholds and alert thresholds

# 3.4 Satellite analysis of the dynamics of urbanised spaces in the Guianas (ADEUSA Guyanes)

## 3.4.1 General context and area of study

The population rose extremely quickly in the Amazon during the second half of the 20th century. The natural growth rate, which has only begun to stabilise in recent years, was much higher than the national averages. Furthermore, some of the national strategies for developing the regions were based on policies that involved large-scale projects (infrastructure, mining, agriculture, etc.): these attracted people in (or near to) the region's towns or remote rural areas, which they ended up leaving so that they could benefit from the services offered by urban life.


**Figure·1·:·Sous-région·des·Guyanes·considérée·par·ADEUSA·Guyanes**¶

*Sub-region of the Guianas studied by ADEUSA Guyanes*

The Guianas, a sub-region of the Amazon, form a geographic entity that is divided into five countries (Fig. 1). Despite the limited number of conglomerations, there is a rich diversity of urbanised landscapes, especially secondary towns. Although, in overall terms, this immense Amazonian space is not densely

occupied by humankind, there is still increasing urbanisation today, especially in the border towns and even more so in the capitals of the sub-region. Multifarious processes have fuelled the production of urbanised spaces to meet this situation, combining or succeeding each other to the point of shaping existing conglomerations: the development of new residential neighbourhoods or the creation of economic activity zones; the renovation or transformation of the historic architectural heritage; the planning and development of new towns or creation of workers' towns; the setting-up of metropolitan regions; land speculation in the most attractive conglomerations; the aggregation of and growth in precarious "spontaneous" settlements on undeveloped urban land or near new major highways or contiguous to business zones; the rehabilitation or reconstruction of unhealthy or precarious neighbourhoods; and real estate transactions involving verticalization.

Since the 1980s, and especially during the 1990s and 2000s, the very rapid expansion or densification of the urban fabric has left its mark on most major towns as well as smaller urban centres in the sub-region, such as mining, agricultural or border towns.

**French Guiana** had 252,338 inhabitants as of January 1, 2014 (INSEE), compared with 55,125 in 1974. Until the end of the 1980s, positive net migration accounted for around 50% of the region's population growth; subsequently, according to INSEE, it has largely been the consequence of the high birth rate. The population growth rate is currently 2.4% per year on average (between 2009 and 2014) with net migration close to zero as measured by INSEE (legal population). This growth is, however, dropping: it was 3.6% per year on average between 1999 and 2009. The fall in this average rate hides the fact that there are great disparities and induced phenomena. In the west, from Saint Laurent du Maroni (44,169 inhabitants in 2014) to Maripasoula (10,984 inhabitants in 2014), intense population growth has been recorded since the end of the 1990s. The population of Saint Laurent increased by 3.3% per year on average between 2009 and 2014 according to INSEE, and averaged 8.4% per year over the period 1978-2013 (GRET, 2013). In Papaïchton the number of inhabitants increased by 65% between 2009 and 2014. These demographic growth rates exceed the building capacities planned as part of urban policy. In Cayenne, the urban zone (demarcated in 2010) has over 120,000 inhabitants, or about half of the region's population; in 1967, the same area accounted for only 28,257 people. But the capital, despite its attractiveness (with its concentration of businesses, government offices and services) and a positive natural balance of 2.1% between 2009 and 2014, lost inhabitants in the same period (down 0.4% per year). Its small size does not allow for the construction of new housing and, therefore, for newcomers to settle there.

The limited capacity to host new inhabitants exerts strong pressure on public planning policies. In the Cayenne area, this pressure has repercussions on the adjoining municipalities, especially Macouria, Roura and Montsinéry-Tonnegrande but also on Matoury and Rémire-Montjoly. "Spontaneous" urbanisation phenomena are appearing in both Cayenne and western French Guiana. This is evident in the production and development of pockets of precarious, often unhealthy, habitats that are the subject of inventories and censuses are prior to resorption plans.

**In Brazil** population growth has caused an explosion of large towns. According to IBGE (Brazilian Institute of Statistics, 2012), the urban population of the Brazilian Amazon increased by 36.6% between 1980 and 1991, by 30.3% between 1991 and 2000 and by 18.8% between 2001 and 2010. The Amazon coastal area contains the metropolitan regions of Belém (Pará) and Macapá (Amapá), which in 2016 had a total of nearly 3 million inhabitants compared to just over 720,000 in 1970. The coastal area of Macapá alone saw a 55% increase in its population between 2006 and 2010 (UNIFAP, 2013). In the west, which was redrawn in the 1940s, the capital of Roraima, Boa Vista, had an estimated population of 326,419 inhabitants in 2016 compared to 36,464 in 1970. Manaus on the south-western edge of the zone (Fig. 01) had 2,568,817 inhabitants in 2016 compared to 311,622 in 1970. Since the 1980s, the Amazon has been recognised as an "urbanised forest" on a regional scale (Browder 1990, Becker 2005).

This massive population growth has generated a proliferation of unofficial and unhealthy neighbourhoods (*invasões*), heightened insecurity and property speculation, resulting in the socio-spatial segregation of the urbanised space. The planning policies that have been introduced are attempting to rehabilitate and develop certain neighbourhoods (including the Portuguese heritage of the historic centres) but the urban landscapes still bear witness to this poorly-controlled boom: *favelas* built on stilts in unhealthy (floodable) areas, vast working-class neighbourhoods in peri-central spaces and on the outskirts, verticalization and / or bunkerisation of central areas or peripheral housing blocks. Similarly, the basic public services provided to outlying neighbourhoods – such as public transport, education and health – are of poor quality and, in some cases, non-existent (Santos et al., 2016).

**In Suriname**, the Dutch core of the capital Paramaribo is classified (UNESCO) and lies at the centre of a vast and extensive urban zone. The town had 170,000 inhabitants in 1980 compared to more than 325,000 for the conglomeration in 2004 (Verrest, 2010) –equivalent to over half the country's population. Paramaribo's (horizontal) extension is schematically marked by two main types of neighbourhood: outlying habitats poorly arranged in "fishbone" patterns along the main roads, and residential neighbourhoods built in more favourable suburban environments (Weidum Celestine, 2014).

**In French Guiana**, Georgetown – the capital founded by the British – has a comparable location although it is only home to a third of the national population, and the country's rural population is significant (60% compared to 30% in Suriname).

### 3.4.2 Objectives and purposes

The objective of the ADEUSA workstream is to develop tools via satellite data processing for studying the dynamics of urbanised areas. Two levels of granularity in the theme are taken into account:

(i) to follow the evolution of the urban footprints of the different Guiana Shield capitals.

(ii) to map the main urban habitats (dense or discontinuous) with a focus on precarious habitats (this project is limited to Cayenne Island, Saint Georges de l'Oyapock, Oiapoque and Macapá).

Concretely, these activities will help develop, install and operate (retrospectively and in routine mode) – in connection with the actors in the area – a dedicated "urban" processing chain that will deliver comparable information for monitoring the urban footprint across the sub-region, and so that the nature and evolutions in precarious habitats are regularly documented.

The challenge is to produce new knowledge about the forms of historical and current evolution of the region's urban spaces:

- In order to equip SEAS Guyane with an application chain on the urban themes in order to increase the areas of expertise and skills of French Guiana based on the satellite platform, particularly in the context of regional cooperation between French Guiana and its immediate neighbours.
- To feed into discussions and analyses led by urban public policy managers in the towns (planning, development), especially those promoting the management of precarious urban habitats.

To achieve this objective, the proposing team will base their work on the latest developments in the field and on work previously carried out on the discrimination of urban landscapes by remote sensing. Among these works, we will cite those performed: (i) within the framework of the Copernicus LIMES project (http://www.copernicus.eu/projects/limes/); (ii) CARTAM-SAT (CARtographie Dynamique des Territoires AMazoniens: des Satellites aux AcTeurs); (iii) GUYAMAPA Observation Spatiale de l'Environnement transfrontalier Guyane-Brésil (2011-2015); (iv) COCLICO COllaboration, CLassification, Incrémentalité et Connaissance (2012-2016); and (v) APUREZA Analyse par télédétection des relations entre Paysages URbains dEngue et ZikA (2016-2020).

## 3.4.3 Methods and activities

The proposed methodologies focus on the choice of generic processing to be mobilised to guarantee the best possible reproducibility of the processing while preserving the quality of the extracted information. The methodologies concern the extraction of the urban footprint (historical data) and the urban habitats encountered in the conglomerations. Special attention will be given to defining a precise nomenclature for the urban spaces and landscapes to be mapped, which can be generalised to all towns in the sub-region. More specifically, the characteristics of precarious habitats will be studied (the size and spacing of buildings; the building density per unit area; the ratio of bare soil and vegetation; fractionation and radiometric indices; etc.) in order to introduce procedures for the automatic recognition of these areas based on the products of satellite imagery.

### 3.4.3.1 Mapping the urban footprint and monitoring the spatio-temporal dynamics of urbanised spaces in the sub-region

Mapping the urban footprint and monitoring the dynamics of urbanised spaces in time and in space will be carried out using Sentinel 2 high-resolution satellite imagery (optical, 10m resolution, temporal repeatability of 12 days) and Sentinel 1 (RADAR, 10m resolution, 12-day temporal repeatability). The combination of these two data sources in a tropical context with heavy cloud cover will help create temporal series of images from which will be extracted, via textural criteria, the contours of the urban footprint. It will also be used to detect changes in land occupation in an urban environment in the sub-region. This data is free and accessible to all users via the Sentinel products exploitation platform (PEPS) developed by CNES.

From a methodological perspective, this part of the study will be based on the method developed by Corbane et al. (2008) for mapping the urban footprint using a combination of RADAR and optical data (Fig. 2), which is a three-stage process: (1) urban texture analysis (Gaussian Markov Random Field (GMRF), Descombes et al., 1999); (2) unsupervised K-means type classification of the textural parameters derived from step (1); and (3) fusion of the information extracted for each type of sensor.

Our intention is to follow the same method to carry out a retrospective study of the evolution of the urban footprint based on the use of SPOT 4 and 5 data available through the SPOT World Heritage programme. The previous methodology was developed using this type of data and tested positively on the Cayenne site.

#### 3.4.3.2 Characterisation of the landscapes / typologies of the main urban habitats

This part of the project will take advantage of the use of very high optical resolution data (Pléiades, SPOT 6/7, resolution from 0.5 to 6m) and RADAR (TerraSAR-X, resolution of 3m) to perform classifications within previously-identified urban footprints. The habitat will be classified by typology at neighbourhood level using object-oriented methods on the optical data and via textual information extracted from RADAR, with a particular focus on the degree of precariousness of the habitat (Fig. 3). This will be quantified by spatial analyses carried out on the objects resulting from the classifications: the size of objects, their distribution, the building density per unit area, etc.

The typology of building extracted using satellite imagery will be validated on the ground in order to correlate the indirect observations with a precise characterisation of urban habitats in each town studied as part of the project.

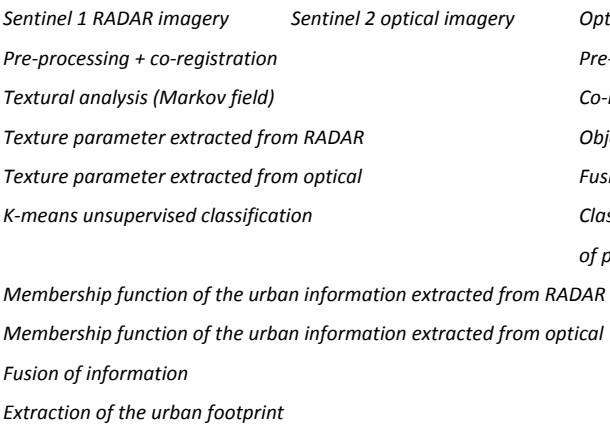


Fig. 2: Methodology in three steps of the mapping of the urban footprint combining optical data and RADAR (based on Corbane et al., 2008).

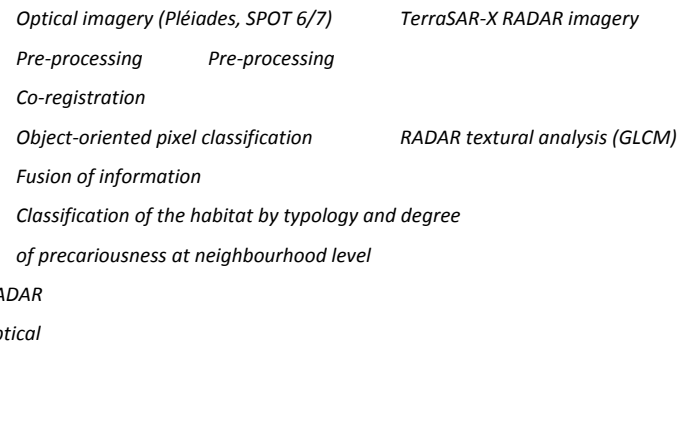


Fig. 3: Methodology for classification of habitat typology in urban zones by combining optical data and very high resolution RADAR.

### 3.4.4 Expected outcomes and promotion

- Production of an algorithm for downloading, pre-processing and processing S2 and RADAR S1 optical images as well as detecting the urban footprint. We suggest that this algorithm is implementable via open source platforms (python or R).

- Production of urban footprint maps for all the towns in the sub-region with annual updates in order to follow the evolution of urbanised areas. A retrospective approach will be carried out to characterise the evolution of the urban footprint based on historical data.

- Definition of a nomenclature of existing urbanised spaces within the urban footprint, standardised for all the towns in the sub-region, in order to provide homogeneous classifications at zone level.
- Characterisation of the typology of urbanised spaces within the urban footprint with a particular focus on precarious habitats (creation of a spatialised indicator on the degree of precariousness of the habitat).
- Analysis of the evolutions of the urban footprint in order to identify trends in terms of development and planning priorities for regional planning actors in the different study areas.
- Production of scientific articles with the results obtained and promoted by pooling and transferring these channels to other institutional actors in the southern hemisphere via the project tools, SEAS Guyane and the GEODEV network.

### 3.4.5 Link with the other workstreams in the PROGYSAT project

Pollution workstream: the characterisation of the urban habitat will enable the researchers in this workstream to compare the influence an urbanised site has on increased pollutant rates (PAH, Nox, PM10, PM2.5, etc.) compared to another, less urbanised site.

Vectrans workstreams: the characterisation of the urban habitat will enable researchers in this workstream to better assess the different levels of vulnerability of human populations in the framework of their study on vector-borne diseases (malaria, dengue).

### 3.4.6 Partnership

The work will be based on the interdisciplinary working group in this workstream in order to pool and produce harmonised data and indicators.

| Brazilian Partnership | French Partnership |
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| **Universidade Federal do Amapá (UNIFAP) / Department of International Relations**<br>Dr Gutemberg de Vilhena Silva (coordinator)<br><br>**Universidade de Brasilia / Departamento de Geografia – GEA**<br>Helen Gurgel coordinator of the Geography and Environment Laboratory<br>Yata Massulo (urban geography)<br><br>**FIOCRUZ**<br>Paulo Peiter urbanist, geographer specialising in cross-border issues (vulnerability of populations).<br>José Joaquim Carvajal Cortes, geographer and bio-statistician | **IRD / ESPACE-DEV / OSE and MICADO teams**<br>Nadine Dessay (coordinator)<br>Laurent Demagistri (texture remote sensing)<br>Morgan Mangeas (modeller, deep learning)<br>Jean-François Faure (urban geography, PROGYSAT co-leader )<br>Thibault Catry (remote sensing / Radar, MNT)<br>**Institutions to be approached for their expertise: DEAL de Guyane, regional government (SIG)** |

**Table 1: Partner organisations and participants in the ADEUSA workstream. (NB: Some individuals mentioned have not yet given their formal agreement to participate in the project)**

UMR Espace-Dev will mobilise researchers and engineers attached to the Space-Based Observation of the Environment (OSE) and MICADO (Modelling, Knowledge Engineering and Space Data Analysis) teams for remote sensing, spatial analysis, product standardisation and processing chain development aspects.

The unit in the Department of International Relations at the Federal University of Amapá (UNIFAP) will contribute to the regional political aspects and development of urban zones and promotion by communicating the outcomes within the graduate studies programme in border studies at UNIFAP.

The geography laboratory at the University of Brasilia will collaborate on the vulnerability analysis of populations and public policies associated with urban landscapes.

The Oswaldo Cruz Foundation (FIOCRUZ) will contribute to the aspects on human geography and public health in cross-border regions.

Partnership actions to be carried out during the project: contact will be made with DEAL de Guyane and the regional government (SIG) to evaluate the outcomes and study the institutional uses of the processing chains and their possible appropriation; a relationship will also be established with the UFPa teams in Belém working on urban themes in order to open up additional collaborations.

# Knowledge and characterisation of forest regions

## 3.5 Characterisation of plant communities in the Amazonian regions using multi-spectral satellite imagery

### 3.5.1 Context

The characterisation and monitoring of the biodiversity and ecological status of natural environments is a major challenge for environmental protection in the Amazon basin and Guiana Shield for several reasons. First of all, the exceptional richness of the flora and fauna in these regions means that it is one of the key hot spots for terrestrial biodiversity (Myers et al., 2000). It is estimated that the Amazonian biome is home to 10 % of all the world's living species; it is also a major ecosystem for climate regulation and biogeochemical cycles, including water and carbon. In addition to this natural wealth, the Amazon has an important cultural dimension due to the numerous indigenous peoples that are directly dependent on its environmental state.

It follows that the conservation of the natural heritage in Central Amazonia is one of the priority objectives of the United Nations, with the creation of numerous national parks, such as the Amazonian Park in French Guiana and the Jaú National Park, a classified UNESCO World Heritage site, together with a wide range of programmes for setting up protected areas.

The resources of the Amazon Basin, including gold mining, are also essential for the economy of the Amazonian people and, more broadly, for the governments that are responsible for operating them. The harmonious cohabitation between environmental protection and economic development in these regions is, however, particularly delicate (Neves et al., 2016, Tsayem Demaze, 2008). The environmental disaster caused by the dike failure at the Samarco iron mine is a good illustration of this (Fernandes et al., 2016). Following this disaster, several recent studies have questioned the relevance of the Environmental Impact Assessments (EIAs) produced in the context of numerous industrial projects

that have been completed and are underway, whether for the construction of roads and hydroelectric dams or for ore mining (Dias et al., 2017; Ritter et al., 2017). The lack of scientific rigour in collecting and analysing data means that it is not a very suitable decision-making tool and may even be dangerous. Economic pressures add to the technical difficulties of monitoring the biodiversity and ecological status of natural environments effectively.

It is urgent, therefore, to develop effective, scientifically-rigorous programmes for monitoring biodiversity, supported by expertise and reliable sources of data. Among the tools identified to meet these objectives, satellite remote sensing appears to be a particularly apposite tool that can be used to collect information on biodiversity that, until now, had been highly incomplete and biased (Maldonado et al., 2015; Meyer et al., 2016).

### 3.5.2 Objectives

Within the framework of the project, the thematic application is designed to prepare for the implementation of an operational method for mapping different components of the floristic biodiversity of the Amazonian forests. This will use indicators derived from the processing of Sentinel 2 satellite data from the COPERNICUS Earth observation programme set up by the European Commission with the support of the European Space Agency. Biodiversity indicators include:

local biodiversity features (α diversity, identified indicator: Shannon index)

the spatial distribution of communities of species according to physical or environmental spatial gradients (β diversity, identified indicator: Bray-Curtis dissimilarity)

The methodological prototype will be based on implementing methods that have been recently developed and validated for exploiting hyperspectral imaging data (Féret and Asner, 2014a, 2014b) and specially adapted for use with data from Sentinel 2 satellites. Although their spectral richness is lower compared to hyperspectral imaging data, the Sentinel 2A and 2B satellites provide valuable information on the richness of optical features of vegetation (Ustin and Gamon, 2010), which can then be converted into a biodiversity indicator (Rocchini et al., 2016). This can provide valuable information to ecologists, in particular when supplemented by field expertise and observation databases on the ground. The frequency of acquiring the Sentinel 2 satellites (one image / 5 days) appears here to be perfectly suited to allow for regular acquisitions, even in a context of heavy cloud cover.

Implementing this type of monitoring tool to produce maps that power a knowledge base promoted by experts in ecology may make a significant contribution to improving the conservation of forests in the Amazon basin and Guiana Shield. It responds in particular to the high stakes associated with delivering an environmental impact study that truly reflects the influence of the numerous development and planning projects in the region on natural environments over time.

Figures 1 and 2 illustrate the spectral and space information acquired by Sentinel 2, as well as the preliminary results obtained by applying the method developed by Féret & Asner (2014a) to satellite data acquired on the CICRA trial site located in the Peruvian Amazon.

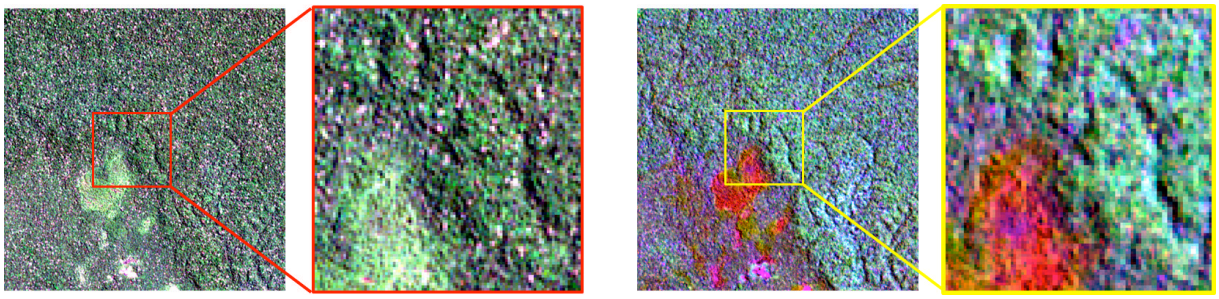

Figure 1. Area of 16 km2 extracted from a Sentinel 2 image acquired over the Amazon rainforest. The colour band is obtained from the red, green and blue (left) channels, and the green channels, near infrared 1 and shortwave infrared 2 (right) channels. The differences in colour illustrate the spectral contrast between individuals from different species.

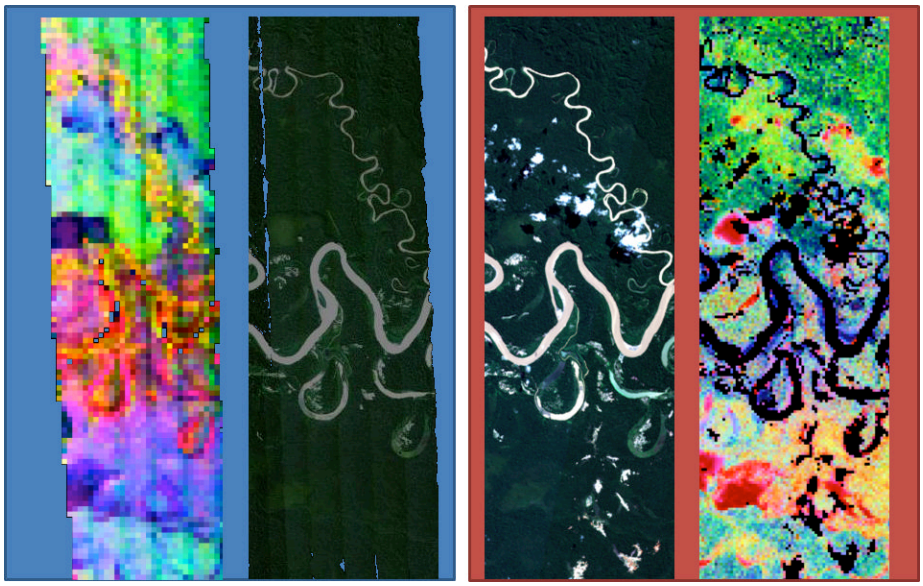

Figure 2 Comparison of results obtained after applying β diversity mapping method to hyperspectral imaging data (left) (Féret and Asner, 2014a) and Sentinel 2 data (right). The significant improvements applied to the method since its first release explain the higher level of detail that appears with the Sentinel 2 data, despite the lower spatial and spectral resolution.

The thematic application fits naturally into the priority workstream on protecting and promoting the exceptional biodiversity and natural and cultural heritage of the Interreg Amazon Cooperation Programme (PCIA). It relies in particular on the development of the SEAS Guyane satellite acquisition platform, with the implementation of satellite data processing and analysis tools derived from the EU's COPERNICUS programme, including data from Sentinel 2 multi-spectral satellites.

### 3.5.3 Implementation and cross-border collaboration

The infrastructure set up as part of the project will be included in Workstream 01 in the form of regional cooperation through access to Sentinel 1, Sentinel 2, Sentinel 3 and LandSat satellite data acquired over the relevant region, supplemented by a number of tools and methods.

In order to assist with the deployment and validation of the proposed methodologies, a prototype will be backed up by a collaboration between the French and Brazilian partners, particularly through the use of the existing knowledge base on the Brazilian region, including forest inventory data, knowledge about its ecological status, and the spatial distribution communities of species at local and regional levels.

**Partners: ONF Guyane, Forestry Commission of French Guiana. Collaboration expected with INPE (Brazil) and with an institution responsible for forest management in Suriname.**

### 3.5.4 Specific needs of the thematic application

Implementing the application will require the coordination of the technical progress of the work carried out within the framework of the BioCop project funded by the National Association for Research, and the cross-border collaboration with the partners, including Brazilian partners. This coordination will be undertaken by an experienced scientist as part of a one-year post-doctoral fellowship. The work will notably require the different partners to meet.

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# 3.6 Public policy and the impact on forest protection

## 3.6.1 Context

Global changes accentuate the challenges of sustainable regional development in fragile tropical environments, especially forest environments. Managers and politicians are sometimes called on to make urgent decisions in certain contexts (border situations, frequent extreme events, a rapidly advancing deforestation front or the construction of a dam-type infrastructure) and due to the absence of suitable methods for mobilising up-to-date expertise tailored to a particular region. They are also sometimes obliged to propose legal measures without being able to estimate the consequences of the actions undertaken; nor do they have the time in advance to discuss matters with the local populations living in or on the edges of the forests. Society today calls for – and sometimes demands – operational support for environmental management adapted to the diversity of management scales, from small plots to regional and state level.

How can we better understand and monitor in time and space the effects of anthropogenic actions on forest environments? How can we estimate the effect of the policies that have been introduced to protect the forest from these actions?

## 3.6.2 Objectives and purposes

### 3.6.2.1 General objective:

This application aims to produce space data (thematic maps) for qualifying and quantifying the different types of impact human actions have on forests, targeted according to a particular issue: the effectiveness of a protection policy; the introduction of subsidies and grants for families or "non-deforestation" incentives; forest exploitation; etc.

Starting from the implementation of *ad hoc* methods, a proposal will be made to define spatial indicators for estimating the impact in time and space of anthropogenic action on forests across the management regions (protected areas, municipalities, states, catchment areas, etc.).

#### 3.6.2.2 Specific objectives:

1) In partnership with regional management institutions in French Guiana and Brazil, monitoring indicators will be co-constructed to assess the magnitude and effects of these impacts not just in terms of the intensity of action on the forest (high / low) but also in terms of identifying the actions carried out (who does what / where / when?). Using regular measurements, these indicators will make it possible to monitor the dynamics of the transformation of environments in time and space from local level to forest-level.

2) It will also be necessary to determine the image processing chains needed for the semi-automated production of the thematic maps in order to access a rate for producing data based on the demands of managers (daily, monthly, annual, etc.).

### 3.6.3 Methods and activities

#### 3.6.3.1 For the general objective:

Methods for constructing indicators have already been identified as part of the earlier PO AMAZONIE OSEGUYAMAPA project, and tested during the SINBIOSE Guyamazon cooperation project. It will be a question here of adapting them according to the specific orientations that will be set during discussions with the region's managers in France and in Brazil.

#### 3.6.3.2 For the specific objectives:

1) The first phase will consist of identifying the areas to be evaluated by the indicators based on the initial consultations that took place with the development stakeholders in 2016, 2017 and 2018 in French Guiana and Brazil (see the SINBIOSE Guyamazon project). These discussions will serve as a starting point for defining the themes targeted by the indicators. Two examples of issues that will be targeted are: the intensity dynamic of forest fragmentation and evaluating the effectiveness of incentives for forest protection.

2) A major effort will be made to automate the image detection of forest transformation processes using landscape measures (fragmentation, shape, discontinuity, heterogeneity, etc.). The stages of the process will be as follows:

- image selection and classification (land occupation);

- identification of landscape metrics needed for constructing spatialised impact indicators;
- definition of algorithms for processing indicators;
- application of algorithms to classified images;
- production of thematic maps.

### 3.6.4 Expected outcomes

The results will be of two kinds:

1) Feedback in the form of methodological forms and work procedures necessary for carrying out the indicators and the automating image processing. These forms will focus on:

- the processing stages for carrying out the indicators (the choice of landscape metrics and algorithms for processing data);
- the image processing chains required for the semi-automatic production of impact indicators of human actions on the forest.

2) The production of spatialised environmental information characterising regional dynamics on study sites defined with managers.

Feedback in the form of maps on the impact of anthropogenic action on the forest, as measured by the indicators.

### 3.6.5 Identified or potential teams and partners

This list includes some of the partners already involved in the SINBIOSE Guyamapa project that is currently underway. It will be supplemented by individuals belonging to the regional management institutions in Brazil and French Guiana wishing to join forces with the project. The institutions already consulted are:

- For France: French Guiana Regional Nature Park, DEAL, French Guiana Energy Climate Association, Man / Environment Observatory
- For Brazil: RDS UATUMA, Amazonas State Conservation Unit Centre (CEUC), FAPEAM.

| **French partners** | |
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# P R O G Y S A T

## Regional Cooperation Project:

## Satellite Observation of the Guianas

**(Projet de Coopération Régionale d'Observation des GuYanes par SATellite)**

## *End of Document*

*Project Promotor:*

*IRD – Centre de Guyane*

*– October 2018 –*