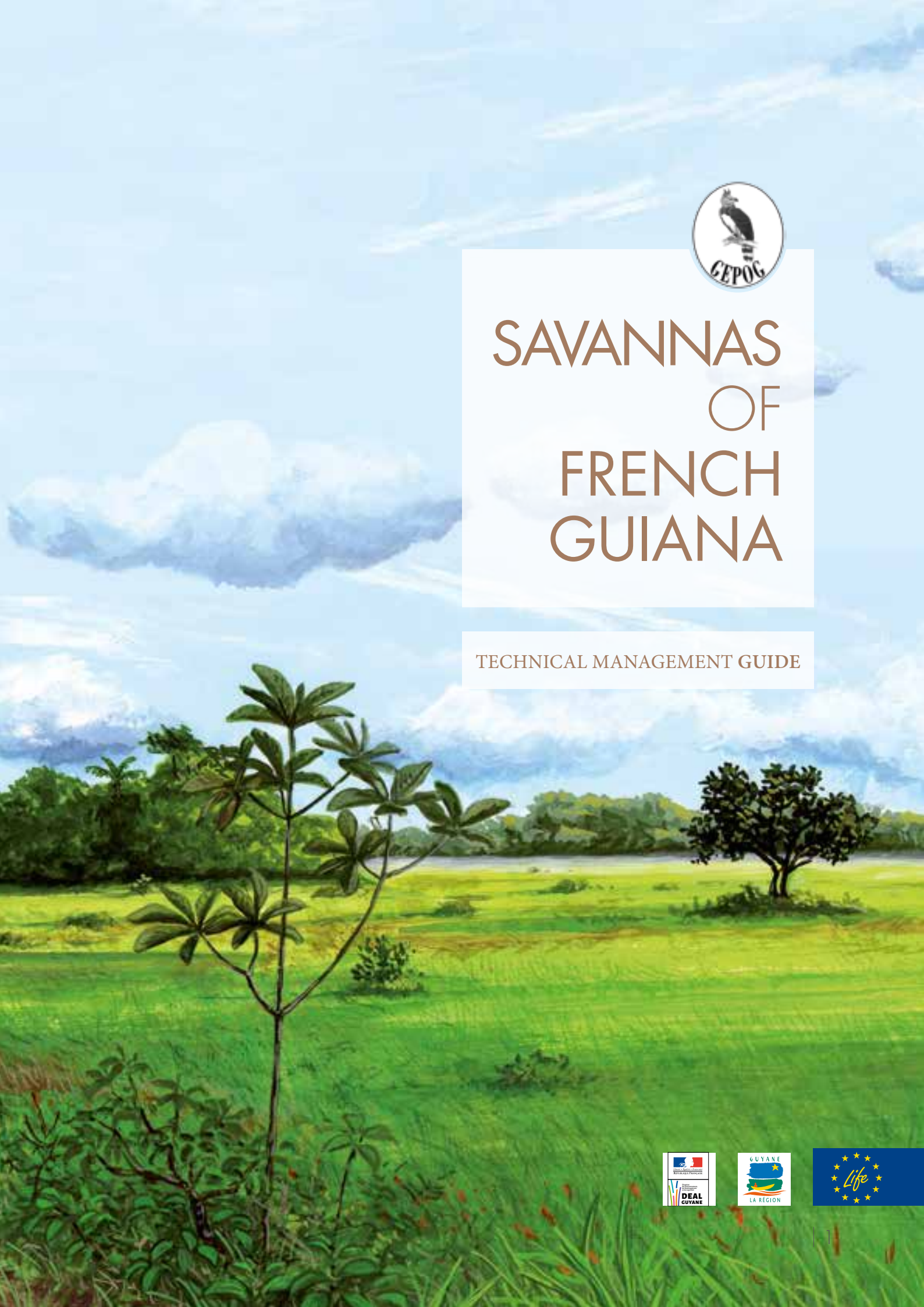


SAVANNAS OF FRENCH GUIANA

TECHNICAL MANAGEMENT **GUIDE**

Text
Anna Stier *Project Manager, GÉPOG (Group for the Study and Protection of Birds in French Guiana)* and Nyls de Pracontal *Director, GÉPOG (Group for the Study and Protection of Birds in French Guiana)*

Email for all correspondence
association@gepog.org

Geographic scope
This technical guide covers the savannas of French Guiana's central coast. Any extrapolation of the resultants to the savannas in the far West and East of the department, as well as to those of other countries in South America, would be difficult and is left to the reader's judgement. Nevertheless, the summary presented here represents the most developed basis for future action to date. The conservation and management strategies described can be generalized and will enable management authorities in neighboring countries to build their reflections and strategies on a solid foundation.

Recommended citation
Stier, A. and de Pracontal, N., 2015. Technical Guide to Managing the Savannas of French Guiana. Director of publication: Sylvain Uriot, Association GÉPOG, Cayenne, French Guiana.

This publication can be downloaded on the following websites
www.savanes.fr, www.lifecapdom.org and www.gepog.org

Graphic design
La Thénardière, le studio graphic', loosely based on the booklet "Savanes de Guyane, Livret de découverte", with the kind permission of ONF Guyane's Sylvétude department.

Printed in France by Imprimerie Lagarde 17600 Saujon, on Cyclus print paper, 100% recycled.

Illustrations
Carole Pourcher, except p.16: Sylvain Euriot, and p. 39 Vincent Zanuella, ONF Guyane.

Translation: from French to English: Catherine Guigui

For more information

Group for the Study and Protection of Birds in French Guiana: www.gepog.org or www.savanes.fr
15 Avenue Pasteur, 97300 Cayenne
Guyane/ France

Map of the savannas from the 2011 Coastal Expertise, created by the French National Forestry Office (ONF) using satellite images produced by the SEAS (Satellite Surveillance of the Amazon Environment) station and with the financial support of the Ministry of Agriculture, Agrifood and Forestry (MAAF).

Anna Stier and Nyls de Pracontal

SAVANNAS OF FRENCH GUIANA

TECHNICAL MANAGEMENT **GUIDE**

Methods and Tools Tested in the Savannas of French Guiana's Central Coast

ACKNOWLEDGEMENTS

We would like to thank all the members of the monitoring committee for their involvement in this project as well as the partners who kept it up and running over these years: the town of Sinnamary, the town of Iracoubo, the Department of the Environment, Spatial Planning and Housing (DEAL), the French Guiana Regional Council, the French Guiana Regional Nature Park, the Coastal Conservatory, the non-profit organization SÉPANGUY, the French National Forestry Agency (ONF), the University of French Guiana, the agricultural high school in Matiti, the agronomy campus in Kourou, the Association for the Discovery of Nature in French Guiana (ADNG), the World Wildlife Fund, the departmental fire and rescue service (SDIS), the Regional Air Observatory (ORA), the National Center for Space Studies (CNES), the non-profit organization Inonoli and the residents of the towns of Sinnamary and Iracoubo.

The actions of the program were made possible thanks to the support of many partner professionals and experts:Instituto Horus, ElaGuyane, Bitwip, AgenceRhiza, AgenceSonart, Copeaux& Co, Tauari, the non-profit organization SÉPANGUY, Sylvétude, Carole Pourcher, Jean-Pierre Penez, Guillaume Léotard and JérômeLefol, as well as all the landowners who allowed us to work on their property.

This project on the savannas was also a human adventure which brought together and grew out of the involvement of numerous people, more particularly:

Alain Alcide, Alexandre Renaudier (†), Alexandre Vinot, Aline Delafosse, Alizée Ricardou, Amandine Bordin, Annick Leveillé, Antoine Baglan, Arnaud Anselin, Audrey Guiraud, Aurore Poupron, Benoit Hurpeau, Bilitis le Guirriec, Bruno Gaucher, Camille Dezécache, Camille Guédon, Catherine Bergère, Catherine Corlet, Cécile Kouyouri, Cédric Husson, Chantal Berthelot, Charles Bergere, Charles Carbo, Christelle Sabayo-Hilaire, Christian Clifford, Claude Suzanon, Clément Cambrézy, Cynthia Jean-Charles, Damien Davy, Didier Elfort, Emmanuel Ruffinel, Eugène Coumba, Florent Taberlet, Floriette Méthon, Frédéric Blanchard, Geneviève Gazel, Germaine Coumba, Grand-Emile Ernest, Guillaume Fradet, Guillaume Léotard, Jean-Louis Antoinette, Jean-Luc Sibille, Jean-Marie Prevoteau, Jean-Paul Malaganne, Jean-Philippe Isel, Jean-Pierre Portut, Jennifer Deville-Chabrolle, Jérôme Le Fol, Jocelyn Cazal, Joseph Printemps, Julien Cambou, Karine Néron, Katarina Jean-Gilles, Kévin Pineau, Kulanon Appolinaire, Lambert Saibou, Laurent Garnier, Léodate Saibou, Léoncina Bureau, Leone Sophie, Lisette Fortin, Loïc Epelboin, Louise Bétremieux, Luc Ackermann, Luciano Kolino, Lucinda Gunther, Lydie Sénécaux, Manuel Delmas, Marianne Palisse, Marie Pinault, Mathieu Morel, Matthieu Delfault, Matthieu Villetard, Maurice Létard, Monia Zamor, Nathan Berthelemy, Olivier Chaline, Olivier Claessens, Olivier Tostain, Ombeline Vrignaud, Pascal Giffard, Philippe Jet, Philippe Portut, Philogène Sophie, Pierre Silland, Raphaël Létard, Régis Turpin, Rémi Girault, Roger Gambie, Sammy Baia-Ribeiro, Samuel Counil, Sandrine Richard, Sergine Nasja, Shirley Aurélien, Siaolane Beaufort, Simon Russeil, Sophie Lefèvre, Sophie Pradal, Stéfan Icho, Stéphane Traissac and the students of the agronomy campus in Kourou, Stéphanie Barthe, Sylvain Gutjahr, Sylvain Uriot, Sylvia Metella, Sylvio Sophie, Thomas Luglia, Valérie Pontana, Victoria Sophie, Vincent Reboul and Vincent Rufray.

PREFACE

The aim of the work carried out since 2009 by GÉPOG on the theme of savannas is to fill a gap in interest and knowledge at the scale of French Guiana but also, more broadly, of the Guiana Shield. The efforts developed with the help of numerous partners now make it possible to lay the foundation on which to build policies for the conservation, management and promotion of this highly singular natural and cultural heritage.

We hope that the momentum developed thanks to this participatory program will be strengthened and enriched by new partnerships and strategies so that together, we can succeed in taking full ownership of this cultural landscape, which is still beautiful and full of life.

Nyls de Pracontal
Director, GÉPOG

CONTENTS

Understanding and using this guide 8
Context and objectives 8
What is this guide ? 8
Limitations 9
What is a savanna ? 9

A THE ECOLOGY OF SAVANNAS 10
I. Baseline condition of dry coastal savannas and bioindicators 12
II. The impact of fires on the flora 24
III. Techniques to control *Acacia mangium* 38

B THE HUMAN COMPONENT 52
I. Current status of practices and usages: the anthropological study 54
II. The participatory approach: Constructing a development project 56
III. Close-up on: The Savanna Trail 62

Bibliography 64

© A. Stier

UNDERSTANDING AND USING THIS GUIDE

WHAT IS THIS GUIDE?

This technical guide is primarily intended for use by nature management professionals and local authorities.

In it they will find a collection of experiences acquired during the Life+ CAP DOM program between 2011 and 2015, the description of the protocols used, results, successes and failures, as well as avenues to explore for the management of natural savannas.

This guide also offers some very practical information for private landowners, in particular about ways to manage the invasive species *Acacia mangium*.

The technical details of the protocols, methods and analyses are not included in this guide. Complete descriptions can be found in the following reports and publications, available at www.savanes.fr:

- Girault R. & Silland P., 2015. Bilan de 3 ans de suivi d'une savane soumise au feu, sur le site des Pripris de Yiyi, SÉPANGUY – GÉPOG, Guyane, 358p.
- Palisse M., 2014. Savanes de Guyane française: la biodiversité bousculée par la diversité culturelle, ethnographiques.org, Numéro 27 - Biodiversité(S)

  [en ligne: http://www.ethnographiques.org/2013/ Palisse].
- Procópio, L., 2014. Analyse de données de savane de la Guyane dans le cadre du Projet LIFE+ CAP DOM – Rapport final, GÉPOG, 18p.
- Léotard G. & Stier A., 2013. Premiers éléments de typologie des habitats de savane du centre littoral Guyanais, GÉPOG, Guyane, 74p.
- Palisse M., 2013. Libres de savane – Pratiques et imaginaire autour des savanes de Guyane, UAG – GÉPOG, Guyane, 62p.
- Dezécache C., 2013. Étude et techniques d'épuisement de la banque de graines d'*Acacia mangium*, Mémoire de Master UAG-GÉPOG, Guyane, 48p.
- Léotard G., 2012. Projet LIFE+ Cap DOM: Étude botanique des savanes de Guyane – Rapport final, Guyane, 125p.
- Le Fol J., 2012. Étude pédologique des savanes de Guyane, Projet Life+ CAP DOM - Rapport final, Guyane, 94p.
- Stier, A., 2012. "Document de synthèse de l'action A4 "savanes" du programme LIFE+ Cap DOM ", GÉPOG, 40p.

CONTEXT AND OBJECTIVES

Covering only 0.3% of the territory (ONF, 2010), savannas are rare, very vulnerable and endangered, and are disappearing at a rate driven by the economic and demographic development of French Guiana's coastline (Delnatte, 2013; Delnatte & Meyer, 2012). Yet they are home to no less than 16% of the department's flora (Léotard, 2012), and are not well understood. In addition, they are linked to a specific cultural identity and history, which deserve to be more generally known, preserved and promoted.

Life + CAP DOM, based on collaboration between several French overseas departments (DOMs), is a program on knowledge, management and protection of endangered bird species and habitats in Réunion, French Guiana and Martinique. In French Guiana, a specific project on savannas was implemented by GÉPOG from 2011 to 2015.

The aim of this guide is to provide a summary of all the available elements in order to (1) improve management of savannas, (2) ensure that they are taken into consideration in spatial planning projects and (3) highlight priorities for research and monitoring.

LIMITATIONS

This document provides a summary of all the knowledge obtained from the bibliography and through studies carried out under the Life+ CAP DOM program in certain savannas on the central coast between 2011 and 2015. The results and recommendations are difficult to extrapolate to all French Guiana's savannas or to the savannas of South America, and may be modified as new knowledge becomes available. Applying them will require analysis and systematically adapting them to the scale of the site. Nevertheless, the summary presented here represents the most developed basis for future action available to date. The conservation and management strategies described can be generalized and will enable management authorities in neighboring countries to build their reflections and strategies on a solid foundation.

WHAT IS A SAVANNA?

The word savanna is used to designate grass-dominated plant formations in tropical and sub-tropical regions. In South America, savannas cover almost 20% of the continent, where they take different forms (savanes,cerrados or llanos) depending on the region. For example, vast cerrados cover almost a quarter of Brazil.

In French Guiana, the Creole term savanetraditionally refers to any open, non-forested area. Thus, the savanes de Kaw are a marshy area and savanes-rochesare inselbergs and rocky outcrops.

Scientists have a more restrictive definition: **savannas are grasslands that can occasionally include more or less isolated trees and shrubs.** It is not always easy to identify and define the boundaries of a savanna, since savannas can have variable compositions and structures, which are unstable over time and space (Marchant, 2010).

French Guiana's savannas occupy the coastal area covered by marine sandy clay loam sediments, forming a narrow strip between the coast and the interior. National Road 1 crosses through them and makes them easily visible: for most French Guianese, savannas can thus appear ordinary.

Yet they only cover 260 km^2 or 0.3% of the territory (ONF, 2010) and are some of the rarest environments in the department. In addition, almost 16% of the plants present in French Guiana can be found there (Léotard, 2012). Small in size and very rich, French Guiana's savannas are therefore an exceptional natural heritage.

A THE ECOLOGY OF SAVANNAS

The word " savanna " corresponds to what is known as a " biome ": a group of diverse ecosystems characteristic of a geographic area with a flora and fauna adapted to its ecological conditions. Thus, several ecosystems in Africa, Australia, India and South America correspond to this general definition of " savanna ". However, these ecosystems are different and it would be difficult to transpose the knowledge acquired on one continent to another.
In French Guiana, savannas develop on the sandy clay loam soils of the coastal plain, forming a narrow strip between the ocean and the forest. Compared to other ecosystems such as the tropical forest, they have not been studied much in the past and knowledge on their ecological functioning was almost inexistent at the beginning of the project.
They are present along the entire coast, but are far more numerous in the West than in the East of the department. The three municipalities of Kourou, Sinnamary and Iracoubo have the largest concentration of savannas: They cover 192 km^2 there, which represents three quarters of French Guiana's savannas.

It was therefore on this central coast that their ecology was studied and management techniques tested by:

1. establishing an initial ecological baseline,
2. testing the influence of fire on the flora and
3. determining methods to control the invasive tree species *Acacia mangium*.

" It is perhaps the complexity of the savanna ecosystem, or the spatially extensive nature of the biome, that has resulted in savannas being relatively neglected whilst other tropical forest ecosystems have attracted much scientific and public interest. Such neglect has to stop! "

Marchant, 2010

I. BASELINE CONDITION OF DRY COASTAL SAVANNAS AND BIOINDICATORS

Chaix et al., 2001; de Pracontal & Entraygues, 2009; Gond et al., 2011; ONF, 2010

Marchant, 2010; Werneck, 2011

Chaix et al., 2001; de Pracontal & Entraygues, 2009; Hoock 1971

ONF, 2010

In French Guiana, research efforts have often been concentrated on the forest environment, which predominates in the department. Savannas, which represent 0.3% of the territory | have not been a priority up until now. This reflects a global tendency of scientists and public interest to neglect open biomes compared to forests |. Before this study, a typology of savannas was inexistent in spite of initial attempts at classification in the 1970s | and by ONF in their adaptation of the CORINE code to the department in 2010 |. The general lack of knowledge about French Guiana's savannas, their small surface area combined with heavy anthropic pressure on the coast, constitute potentially serious threats for these environments, since the consequences of human impact cannot be quantified.

Objectives: Improve knowledge on the ecological functioning of savannas by:

- characterizing habitats;
- identifying possible indicator species for habitats and anthropic disturbance.

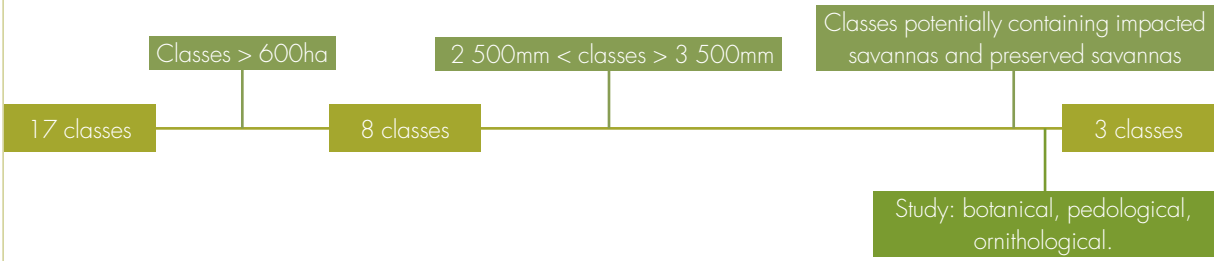
Sampling

Coastal savannas were divided into 17 classes according to rainfall (Météo France data) and type of soil (IRD data). Three main classes that receive between 2,500 and 3,500 mm of rainfall per year were retained:

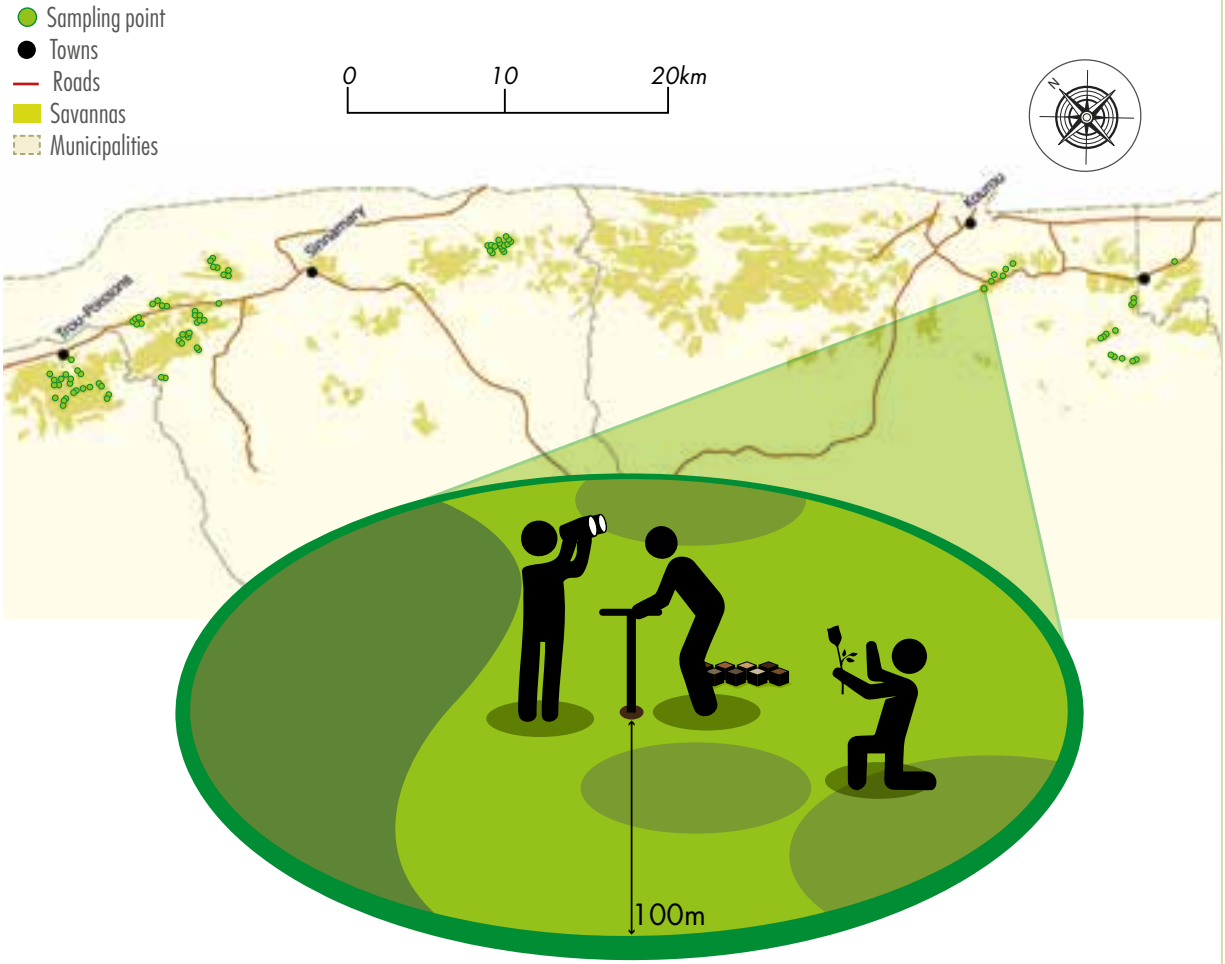
- "hydromorphic soils",
- "podzolized soils" and
- "ferralitic soils, highly desaturated in (B)"

These classes represent 50% of the surface area of French Guiana's savannas.

Sampling



Location of the 90 sampling points and close-up of the protocols used



30 sampling points were chosen per class of savanna on an imaginary grid made up of squares measuring 200 m by 200 m. At these points, the following was studied:

- botany, by means of an exhaustive inventory within a 100 m radius around each point,
- pedology, by means of a sample collected by auger boring, within the same 100 m radius, and
- ornithology, by means of three 20-minute replicates of visual and auditory detection within a 50m radius around the point.

Case containing soil samples

I.1. PEDOLOGY

Objectives: Verify IRD's soil typology, create, if necessary, a new typology based on soil composition.

Methods and protocols

A 1m20-deep soil core was collected at each sampling point. Samples were taken every 20 cm and at each new horizon detected. The composition of each sample was identified by a pedologist and analyzed statistically in order to create classes of soils.

Results

A typology of the soils was drawn up based on the composition of the samples:

Typology of the soils

	Definition
1	A Organomineral material with a clayey or silty texture, dark gray to black color, very high organic matter content. B Loose, homogenous and structured material, ochre color, sandy clay texture. C More or less hydromorphic material with presence of lithic structures in the light spots of the material, sandy clay loam texture.. Presence of coarse elements rich in sesquioxides and quartz.
2	A Sandy clay loam to sandy clay texture, varied, always dark color, high organic matter content. Sandy to coarse sand texture, heterogeneous color (dark spots linked to an accumulation of organic matter). B Loose, sandy-textured particulate matter, light ochre color, heterogeneous texture (fine to coarse sands) scant presence of clays and silts. Ochre-colored spots due to concentrations of iron oxides. C More or less hydromorphic material, sandy clay to sandy texture.
3	A Sandy to coarse sand texture, heterogeneous color (dark spots linked to an accumulation of organic matter). B Loose, sandy-textured particulate matter, gray color indicative of a penetration of organic matter to light ochre, heterogeneous texture (fine to coarse sands), scant presence of clays and silts.
4	B Loose, homogenous and structured material, sandy clay to sandy clay loam texture, dull brown to ochre color. C Hydromorphic material with presence of lithic structures in the material, sandy clay loam texture, presence of ochre and red spots.
5	A Sandy clay texture, varied brown to gray color, low to medium organic matter content. B Loose, homogenous and structured material, sandy to sandy clay texture, light ochre to dark ochre color. C More or less hydromorphic material, whitish or grayish background, red or ochre spots, clayey texture, massive structure.
6	A Clayey or silty texture, dark gray to black color, very high organic matter content. B Sandy clay loam to clayey texture, dull ochre-brown color. C More or less hydromorphic material with presence of lithic structures in the light spots of the material, sandy clay loam texture. Hydromorphic material, uniform, dull color, gray, bluish-gray or whitish shades, silty clay to clayey texture, massive, compact or plastic structure.
7	A Sandy clay texture, varied brown to gray color, low to medium organic matter content. B Sandy clay to sandy texture, color influenced by organic matter, light ochre to light gray or grayish mottling. Sandy clay loam, clayey or silty texture, dull ochre-brown color. C More or less hydromorphic material, whitish or grayish background, red or ochre spots, clayey texture. Hydromorphic material, presence of ochre or ochre red mottling. Millimetric concretions and ochre to purplish-red spots. Coarse elements rich in sesquioxides (nodules).

Auger boring

© O. Claessens / GEPOG

Collecting and storing a soil sample

Results show that:

- the soil classes chosen a priori for sampling at the outset, which werebased on IRD maps, do not correspond to reality in the field. On the strength of that observation, analyses to enable a typology of the savannas to be drawn up in the next chapter were carried out based on the 7 soil classes determined by the pedologist ;
- soil composition does not statistically explain the habitats described by the botanist in the next chapter. The only notable exception appears to be soil type 3, which in 11 out of 15 cases supports shortgrass savannas on white sands.

) Research and monitoring needs

In light of the results obtained, the need for continuity on the following aspects was identified as a priority:

- carry out soil surveys by habitat;
- determine seasonal variations in the water table in addition to soil composition in order to determine their potential influence on plant community composition ;
- include analysis of the topography.

) Conservation/management strategy and actions

- For each site, create a map of habitats with an associated soil analysis per habitat, in order to obtain a clear and detailed view of the baseline condition of the site before any management decision;
- different types of soil support savannas: It is important to determine those types and to take their characteristics into consideration before any management intervention (soils respond differently to trampling, drainage, fertilizing with organic material, etc.).

Savannas at Trou-Poissons

I.2. BOTANY

Objectives: Determine savanna habitats and any indicator species for those habitats and for anthropic disturbances.

Methods and protocols

Within a 100 m radius around the sampling point, the botanist:

- visually detects, crops and numbers habitats on printed orthophotographs ;
- carries out an exhaustive inventory of the presence/absence of species per habitat ;
- notes the number of bushes and groves of trees, the distance to the road and to the edge of the forest as well as the presence of pastureland, plowing, burning or a path(s), which are factors that indicate human-induced alteration or that could potentially influence bird populations.

Results

A few general results:

- 12,441 inventory data ;
- 762 taxons were counted, which shows that in spite of their small surface area, savannas are home to at least 16% of French Guiana's total flora. That flora is very specific, and numerous species cannot be found elsewhere in the department;
- The 10 most frequently-encountered species are: *Echinolaena inflexa* (present at 196 out of 318 sites surveyed), *Rhynchospora globosa* (171), *Tibouchina aspera* (170), *Curatella americana* (153), *Rhynchospora barbata* (150), *Hyptis atrorubens* (142), *Byrsonima crassifolia* (142), *Melochia spicata* (140), *Paspalum serpentinum* (139), *Spermacoce verticillata* (129);
- Only 116 species were present in more than 10% of the surveys ;

Examples of different savannas

Shortgrass savanna on white sand

High savanna on seasonally flooded soil

Bottomlands with earth mounds

- Close to 42 % of the flora is made up of rare species that were noted in less than 1% of the surveys;
- 174 species were encountered only once. For the most part, they were not savanna species ;
- The two most highly represented families were, logically, the two large grass families, the Poaceae and the Cyperaceae: Combined, they represent almost a third of all data. Far behind, from third to fifth place, are the Melastomataceae, the Fabaceae and the Rubiaceae.

A typology of 21 habitats

A classification of the 21 habitats is presented below. It should be noted that up to 6 habitats can be found within a 100m radius.

1. Pripris* and pools
   - 1.1 *Eleocharis interstincta* Pripris
   - 1.2 Savanna pools and ditches
2. Savanna bottomlands and edges of pripris
   - 2.1 Wide bottomlands with poorly-formed earth mounds
   - 2.2 Bottomlands with earth mounds
3. Savanes au sens strict
   - 3.1 On well-drained soil
     - 3.1.1 Dry Trachypogon savannas
     - 3.1.2 Dry *Scléria cyperina* and *Tibouchina aspera* savannas
     - 3.1.3 Small exposed mounds in seasonally-flooded savannas
     - 3.1.4 Savannas on coarse chenier sands
   - 3.2 Seasonally flooded
     - 3.2.1 On podzol / white sand
       - 3.2.1.1 Short grasses
       - 3.2.1.2 Medium high savannas
     - 3.2.2 On hydromorphic soil
       - 3.2.2.1 Short grasses
       - 3.2.2.2 Medium high savannas
   - 3.3 High shrub savanna
4. Small savanna groves (canopy < 15 m, no developed understory, surface area limited to small patches)
   - 4.1 On white sand
   - 4.2 On dry Astrocaryum vulgare savannas
   - 4.3 On swamp savannas
5. Large savanna groves (canopy > 15 m, presence of an understory
   - 5.1 Wooded patches on well-drained soil
   - 5.2 Wooded patches on seasonally flooded soil
   - 5.3 Morichal streams
6. Rock savannas, rock platforms and adjoining habitats
7. Human-altered, degraded or artificial habitats

** The Creole term for marsh*

Note: A detailed description of this typology can be found in a dedicated document: Léotard G. &Stier A., 2013. Premiers éléments de typologie des habitats de savane du centre littoral Guyanais (Initial Elements for a Typology of Savanna Habitats on French Guiana's Central Coast - available in French) GÉPOG, Guyane, 74p.

Example of habitat structuring in two 100-meter radiuses in Savane Garré

Different habitats within a 100-meter radius

Savannas are extremely rich in plant species, in particular due to this mosaic pattern which occurs at the scale of several hundred, or in certain cases, several dozen, meters.

A Correspondence Analysis (CA) was carried out on all the habitats, with the presence/absence of species. The parabolic shape of the scatter plot is a graphic manifestation known as the " Guttman Effect ", which is a common effect in phytosociology with a large number of data (Meddour, 2011). The dots located at the two vertices of the parabola correspond to the two endpoints of a gradient which, in the present case, can be interpreted as an ecological gradient (Plante et al., 1983).

This structure is defined by two main factors: the height of the vegetation (horizontal axis) and soil hydromorphism (vertical axis).

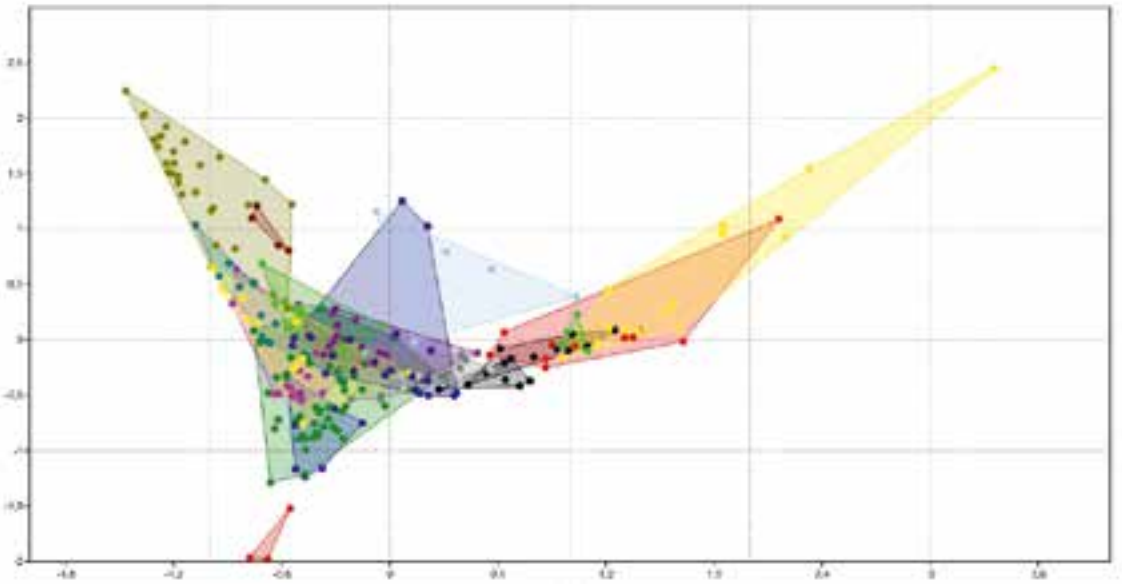
We therefore have:

- shortgrass savannas on the left, groves on the right ;
- pools at the bottom, drained habitats at the top ;
- surveys identified as ecotones (transition areas between two habitats), mid-way between the polygons of the habitats for which they are intermediaries.

CA of all the surveys

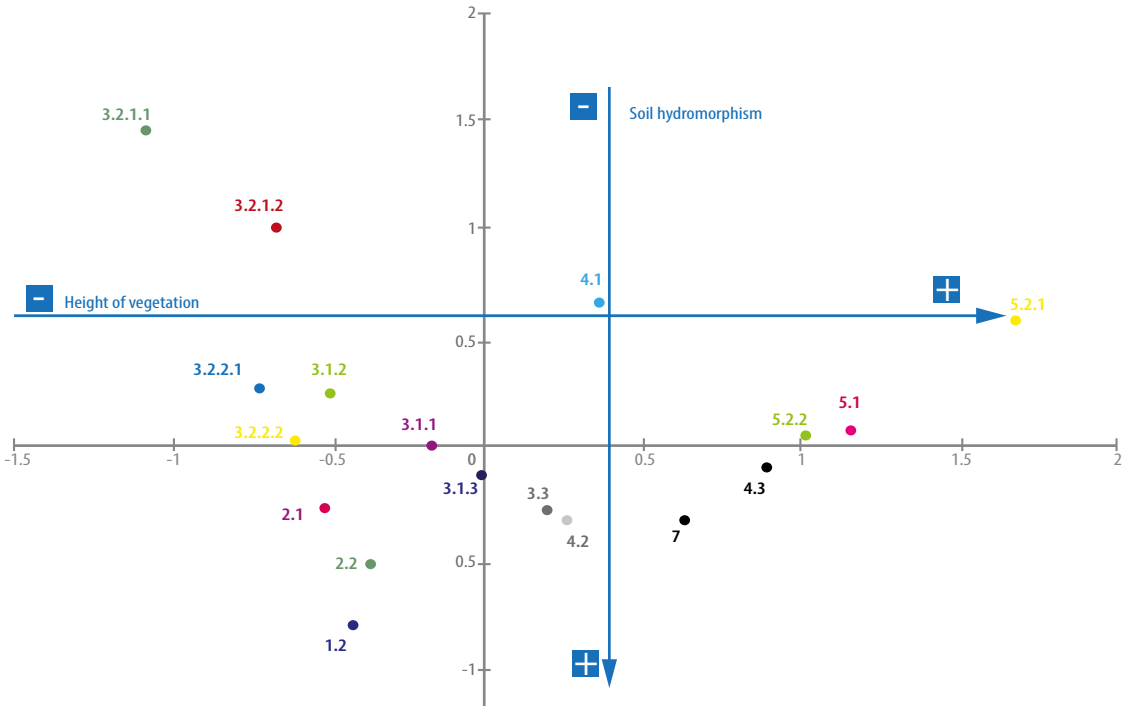
Each habitat is represented by a color. Hulls group together all the surveys for each habitat.

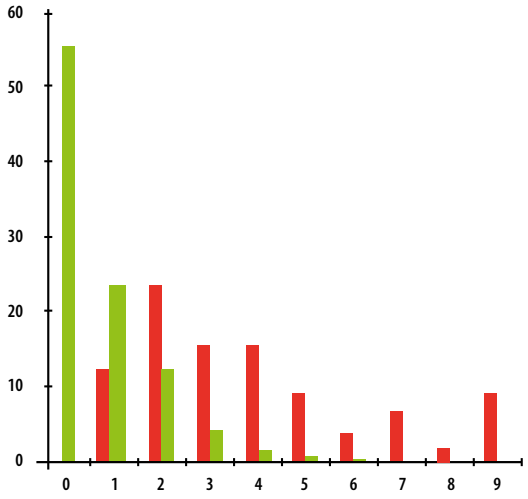
Absc.: Height of vegetation
Ord.: Soil hydromorphism

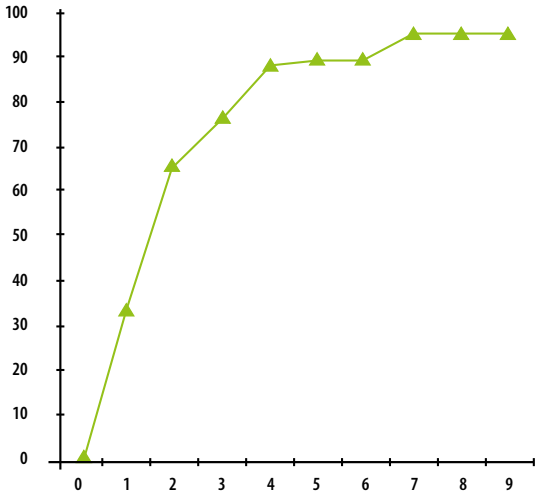


CA of the centroids of each habitat with the two influential axes

Note : The numbers above the dots refer to the habitat classification table on page 17







Change in the number of indicator species in human-altered and unaltered or slightly altered habitats

Left: Number of indicator species in human-altered habitats vs. unaltered or slightly altered habitats.

Absc.: Number of species
Ord.: Percentage of habitats
Human-altered habitats
Unaltered or slightly altered habitats

Right: Change in the probability of being in a human-altered habitat according to the number of indicator species present.
Absc.: Number of species
Ord.: Probability of being in a human-altered habitat

Indicator species

13 indicator species for human-induced change were identified: All the human-altered habitats had at least one of these species, whereas a large majority of unaltered or slightly altered habitats had none.

This tool can be used to infer the probability of being in a human-altered habitat according to the number of indicator species present:

- Above 6 indicator species: The probability of being in a human-altered habitat is 100%.
- For habitats comprising 1 to 6 indicator species: Uncertainty should be expressed as a probability. For example, if 4 out of the 13 species are detected, then " the probability that the inventoried habitat is human-altered is 91% " .

Flowering Amasoniacampestris

© A. Stier / GEPOG

Morichal stream

© F. Taberlet

Drosera

© A. Stier / GEPOG

Pripri in a savanna © A. Stier / GEPOG

List of 13 indicator species for human-induced change

Consequently, the list of 13 species chosen according to quantitative characters proved to be effective for determining the extent of human-induced change in a habitat and by extrapolation, its favorable conservation status.

Family	Botanical name	Frequency in human-altered habitats	Frequency in unaltered or slightly altered habitats	Ratio human altered/ unaltered or slightly altered
Asteraceae	*Rolandra fruticosa* (L.) Kuntze	0,29	0,09	3,23
Boraginaceae	*Varronia schomburgkii* (DC.) Borhidi	0,27	0,06	4,36
Cyperaceae	*Rhynchospora hirsuta* (Vahl) Vahl	0,27	0,07	3,70
Fabaceae	*Mimosa pudica* L. var. *tetrandra* (Humb. & Bonpl. ex Willd.) DC.	0,49	0,04	11,22
Linderniaceae	*Lindernia crustacea* (L.) F. Muell.	0,22	0,01	20,20
Melastomataceae	*Pterolepis glomerata* (Rottb.) Miq.	0,24	0,01	16,83
Onagraceae	*Ludwigia octovalvis* (Jacq.) P.H. Raven	0,32	0,08	3,80
Plantaginaceae	*Agalinis hispidula* (Mart.) D'Arcy	0,24	0,08	3,21
Plantaginaceae	*Bacopa sessiliflora* (Benth.) Edwall	0,29	0,06	4,75
Poaceae	*Brachiaria humidicola* (Rendle) Schweick.	0,34	0,03	11,78
Solanaceae	*Solanum stramoniifolium* Jacq.	0,29	0,04	8,08
Urticaceae	*Cecropia obtusa* Trécul	0,32	0,05	5,83
Xyridaceae	*Xyris jupicai* Rich.	0,41	0,13	3,18

Research and monitoring needs

In light of the results obtained and our field experience, the need for continuity on the following aspects was identified as a priority:

- Fine-tune the vegetation units already determined by presence-absence by working with species abundance, and draw up a final typology of savannas ;
- Fine-tune the list of indicator species for human-induced change by using abundances ;
- Produce a comprehensive habitat map for all of French Guiana's savannas using the final typology. This map would serve as a reference document to monitor changes in savannas over time.

Conservation/management strategy and actions

- Savannas are mosaics of habitats: Comprehensive inventories and a habitat map per site are essential requirements before any management decisions are made;
- The plant species richness of savannas concentrated on 0.3% of the territory is a strong argument in favor of their conservation ;
- All savannas are different: Management strategies must be adapted at the site scale.

Chestnut-bellied seed finch (Oryzoborus angolensis), called " Pikolèt " in Creole

I.3. ORNITHOLOGY

Objectives: Determine any indicator species for savanna habitats and for human-induced change.

Methods and protocols

The ornithological study was carried out by means of three visits between 6:30 and 9:30 am at the 90 counting points (30 per class of savanna).

The following information was noted at each visit:

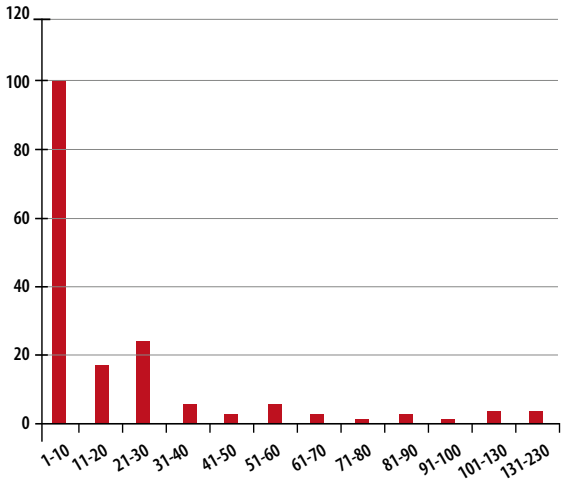
- date ;
- weather conditions ;
- name of the observer ;
- time at the start of the point ;
- presence/absence of species seen or heard;
- time at appearance of each species.

The " site occupancy " method used here requires three closely-spaced visits at the same point over a period considered to be homogenous, during which the bird population is supposedly stable (no arrivals or departures of species).

Results

Results show that:

- 55% of species (102 out of the 187 counted) were seen between 1 and 10 times over the total of 270 visits ;
- 13 species were identified as being savanna species, according to expert opinion (7% of the species counted) ;
- a large number of savanna bird species are difficult to detect (6 species out of 13), and three visits are therefore not enough to ascertain their absence at the site. Only two species were detected with certainty (*Elaenia flavogaster* and *Emberizoides herbicola*) ;
- of 13 savanna bird species, none proved to be an indicator for one of the identified habitats ;
- of 13 savanna bird species, none proved to be an indicator for human-induced change. Relationships between human activities, habitats and bird populations are relatively complex. Moreover, bird species' home ranges or detection ranges are not adapted to our habitat description scale. In the field, it is therefore impossible to use a bird species as an indicator of a given impact, knowing that the species will react differently depending on the habitat in question and will often show a certain tolerance for habitat disturbance (reacting with a certain delay or in a way not perceptible by this type of protocol) and knowing the diversity of overlapping habitats at the medium scale in savanna landscapes.



Breakdown of the number of observations of bird species

A large majority were seen less than 10 times.

Number of species
Absc.: Number of observations
Ord.: Number of species

© A. Stier / GEPOG

Ornithologist identifying a bird during a survey, using binoculars and a dictaphone

Research and monitoring needs

In light of the results obtained, the need for continuity on the following aspects was identified as a priority:

- Explore other taxonomic groups that are better adapted to determining indicator species (e.g. entomofauna, flora, etc.);
- Target specific study programs to priority savanna bird species (rare and endangered), to determine their ecological needs.

Conservation/management strategy and actions

- Develop conservation programs focused on species for endangered savanna birds ;
- Preserve sites that host rare species of savanna birds, even if those species are not indicators of well-preserved savannas in the sense defined in the present work ;
- Design conservation strategies at relatively large scales to guarantee the conservation of savannas with different typologies and which are highly complementary, to ensure that all the specificities sought by savanna birds are maintained.

II. THE IMPACT OF FIRES ON THE FLORA

Fires are a common phenomenon on French Guiana's coast during the dry season, with savannas being particularly affected. Since colonial times, they have been burned regularly, but neither the frequency nor the impact of this practice on the environment were known.

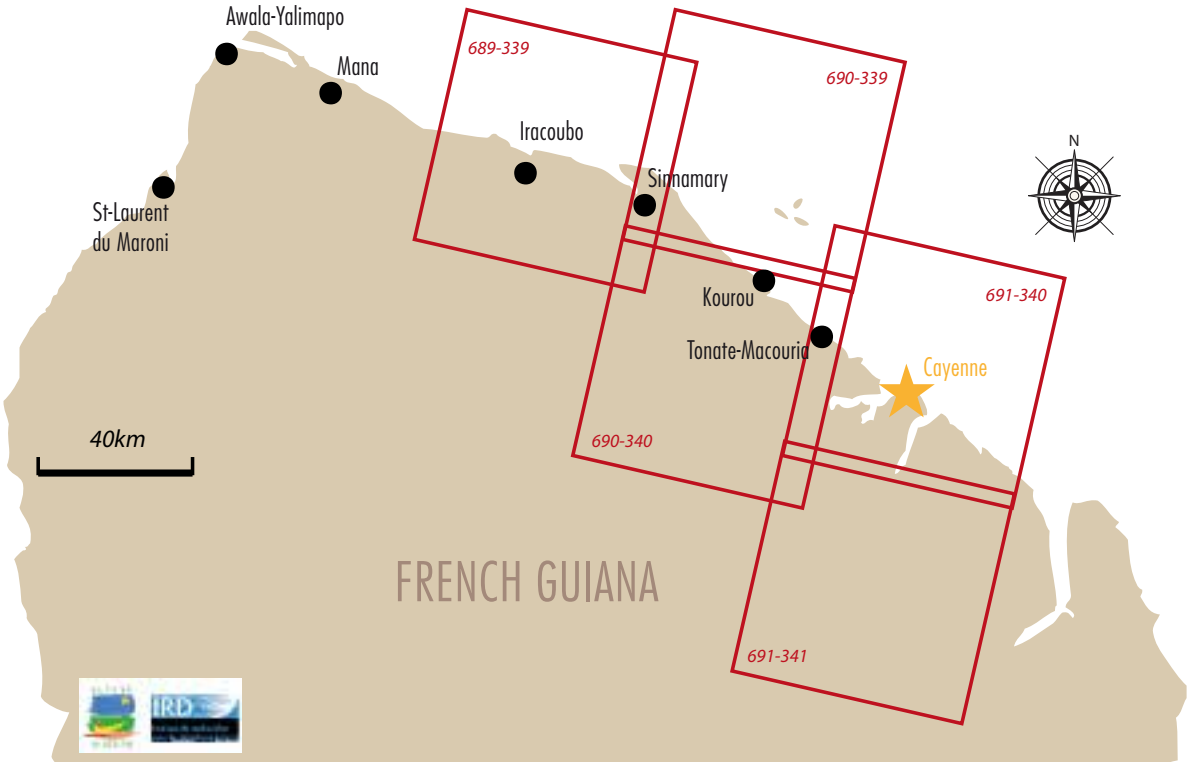
Objectives: Study the feasibility of detecting fires by satellite imagery and determine their impact on the flora of the savannas.

II.1. MAPPING THE EXTENT AND THE REGIME OF FIRES USING SEAS

Objectives: Study the input of SPOT images to map the regimeand extent of savanna fires for the period 2006-2012. This map could be used in the future as a baseline to quantify the impact of fires on biodiversity, but in addition to its ecological value, could also be used as an assessment and monitoring tool by management authorities in the territory (municipalities, fire and rescue centers, communities of municipalities, etc.)

Methods and protocols

SPOT satellites (2, 4 and 5) cover all of French Guiana. The department is divided into segments, and each segment is divided into sectors or KJs. In order to be able to monitor the fire regime on coastal savannas, SPOT images of KJs 689-339, 690-339, 690-340, 691-340 and 691-341 (covering the savannas between Iracoubo and east of Cayenne) were sorted between 2006 and 2012 , with only those taken during the dry season (between July and December) and containing less than 30% cloud cover being kept.



A total of 96 images were analyzed using ArcGIS 10 GIS software. Of these, 77, or 80%, were finally used. The 19 remaining images were considered to be unexploitable, because 1) they were overexposed, making it difficult to detect savannas and even more so savanna fires and/or 2) there were too many clouds located on the savannas.

All the areas considered as burned within the savannas (code 321 and 322 shapes of the 2005 and 2008 coastal expertise |) were digitalized. Once all the images had been processed, one shape per year for the burned savannas was generated. Combining these shapes made it possible to produce a map of the frequency of savanna fires on the coast.

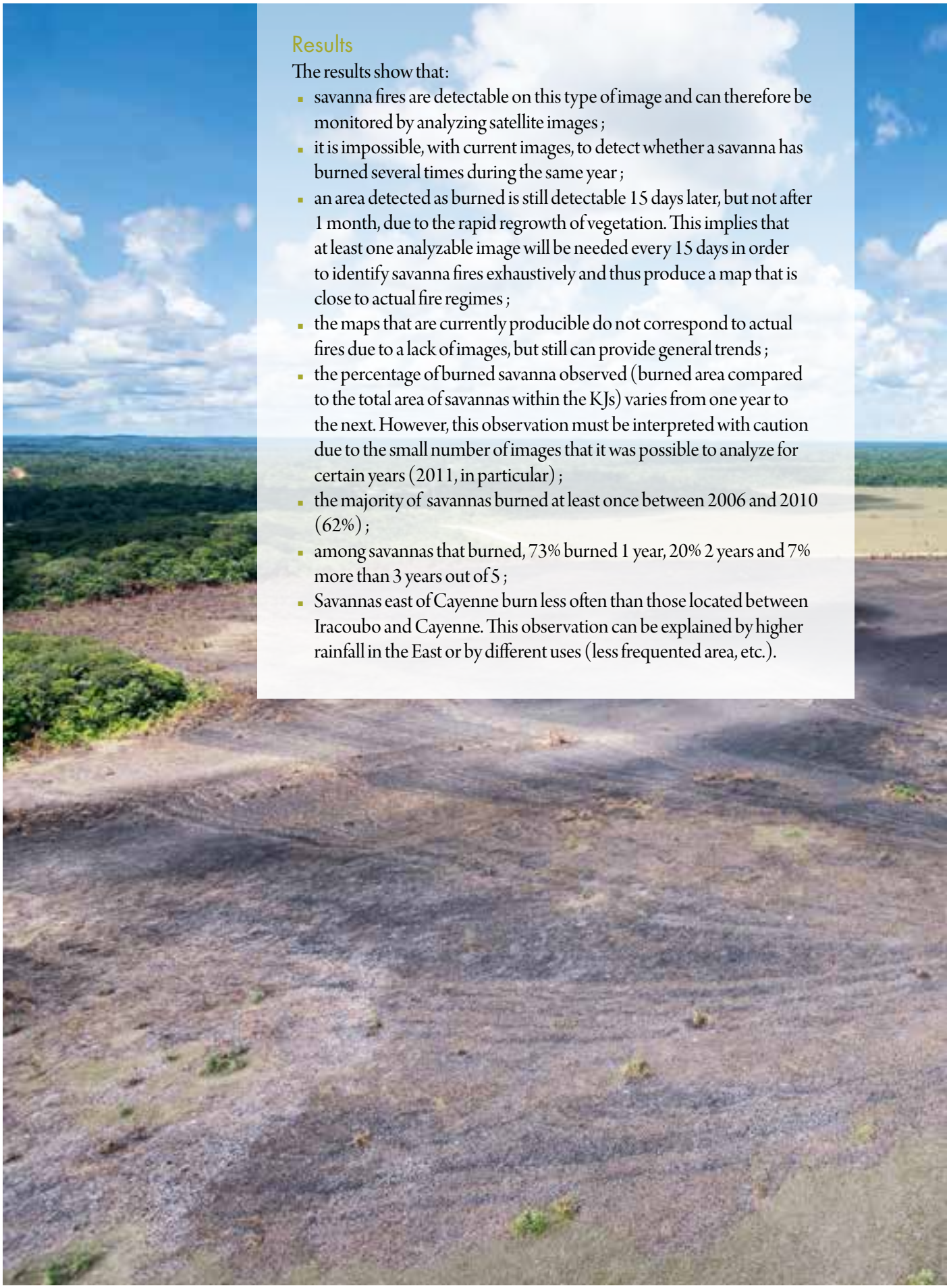
However:

- Due to the small number of images obtained in 2011 and 2012 in all the KJs, the final map was only produced for the period 2006-2010 ;
- Due to the small number of processible images obtained during a single year, it is impossible to detect whether a savanna has burned several times during a dry season. The map produced therefore attributes one fire per year by default to any burned sector ;
- For the 690-340 and 691-341 KJs, the final map will have to be interpreted with care: The small number of fires detected in this area does not mean that there were only a few fires.

Location of KJs used

- Towns/villages
- KJ

ONF, 2010

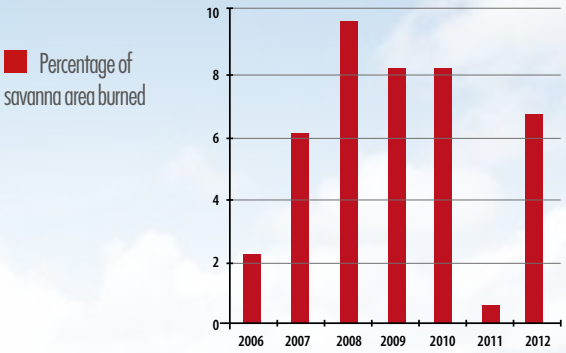


Results

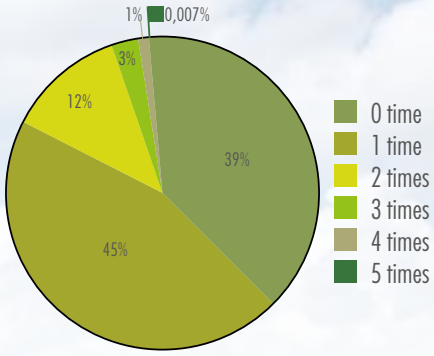
The results show that:

- savanna fires are detectable on this type of image and can therefore be monitored by analyzing satellite images ;
- it is impossible, with current images, to detect whether a savanna has burned several times during the same year ;
- an area detected as burned is still detectable 15 days later, but not after 1 month, due to the rapid regrowth of vegetation. This implies that at least one analyzable image will be needed every 15 days in order to identify savanna fires exhaustively and thus produce a map that is close to actual fire regimes ;
- the maps that are currently producible do not correspond to actual fires due to a lack of images, but still can provide general trends ;
- the percentage of burned savanna observed (burned area compared to the total area of savannas within the KJs) varies from one year to the next. However, this observation must be interpreted with caution due to the small number of images that it was possible to analyze for certain years (2011, in particular) ;
- the majority of savannas burned at least once between 2006 and 2010 (62%) ;
- among savannas that burned, 73% burned 1 year, 20% 2 years and 7% more than 3 years out of 5 ;
- Savannas east of Cayenne burn less often than those located between Iracoubo and Cayenne. This observation can be explained by higher rainfall in the East or by different uses (less frequented area, etc.).

Percentage of savanna area burned per year



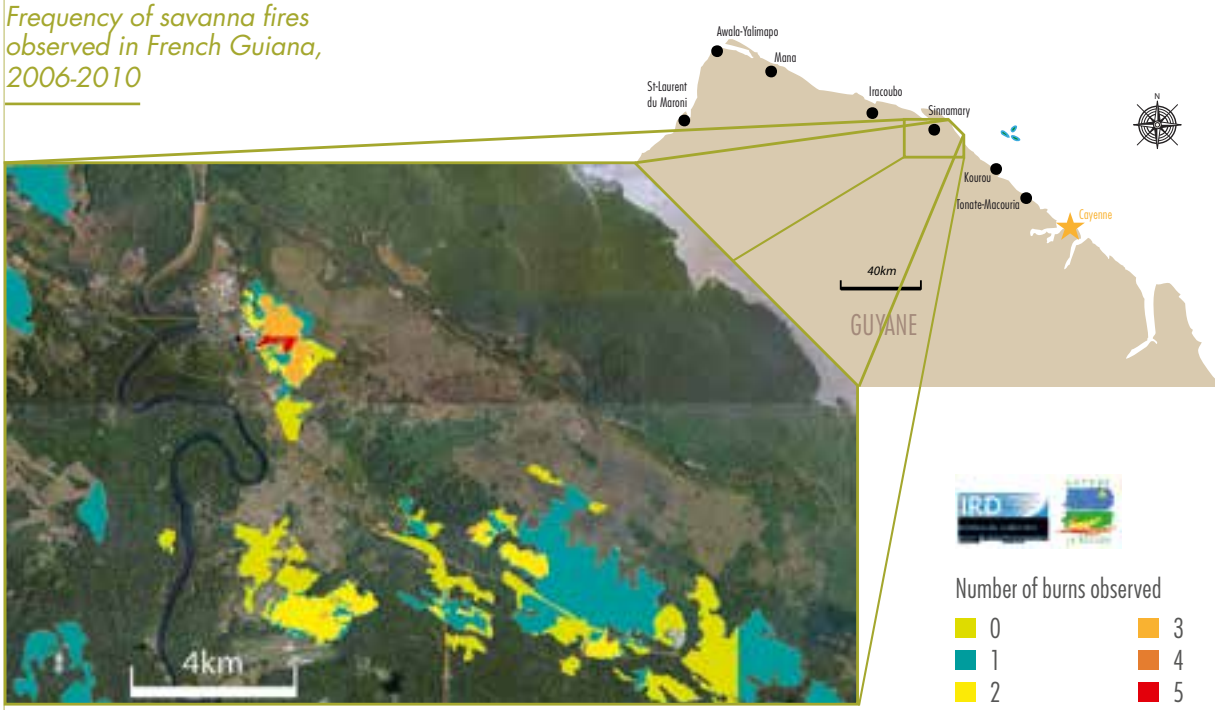
Percentage of savanna that burned 0, 1, 2, 3, 4 or 5 times between 2006 and 2010



Gallion savannas after a burn

© G. Feuillet / PAG

Frequency of savanna fires observed in French Guiana, 2006-2010



Detail from the map showing savanna fire frequency between 2006 and 2010.

Savanna after a burn

Research and monitoring needs

In light of the results obtained, the need for continuity on the following aspects was identified as a priority:

- Availability of one analyzable image per month, and if possible every 15 days, in order to fine-tune maps and closely approximate reality ;
- Identify a " fire " footprint so that analysis of satellite images by GIS every year could be automated;
- Study the vegetation in the field according to the frequency of savanna fires identified by satellite imagery ;
- Research the causes behind differences in fire frequencies (rainfall, proximity to homes or roads, traditional uses, protection of sites, etc.).

Conservation/management strategy and actions

- Create a savanna observatory in which the mapping tool could be integrated ;
- Integrate results with the actions and strategy of the French Guiana prefecture's " Fire Prevention " unit.

II. 2. ANALYSIS OF BOTANICAL DATA FROM FRENCH GUIANA'S SAVANNAS

Objectives: Establish a link between fire and plant community composition as well as the vegetation structure of savannas. Verify the hypothesis that isolated savannas not subjected to burning are floristically more similar to each other than they are to burned savannas. Savanna plant assemblages identified as less subjected to burning could then serve as a reference to evaluate human-induced change in other savannas.

Fruiting Amasonia campestris

Methods and protocols

Preparation of data took place in three phases:

1. Compilation and harmonization of botanical data bases derived from LIFE+ CAP DOM, ZNIEFFs (natural areas of particular interest in terms of ecology or wildlife) and the Trésor Regional Nature Reserve.
2. Classification of species according to their preferred habitat: savanna, forest, wetland or human-altered habitat.
3. Among the 30 sites identified, those presenting more than 40 taxons were selected, which reduced the data set to 20 sites.

The only possible analysis of this type of presence/absence data set is based on comparison of plant assemblages, in terms of species' preferred habitats and similarity in species composition. This comparison was carried out using three tools, 1) comparison of the proportions of species according to habitats, 2) correspondence analysis and 3) similarity index |.

Digby & Kempton, 1987; Everitt & Rabe-Hesketh, 1997; Tecnomo, 2014; Van Sickle, 1997

These analyses took into account the fire parameter. One of the following three codes was therefore assigned to each of the sites based on empirical knowledge:

- **Code 0**: isolated or/and difficult to accesssavanna (ex: Nancibo), or also protected savanna (Savane Trésor); therefore presumed not to have burned recently and to have undergone little human-induced change.
- **Code 1**: recently-burned savanna (direct observation of signs of fire; ex: Trou-Poissons).
- **Code 2**: non-isolated savanna, but without direct observation of signs of fire.

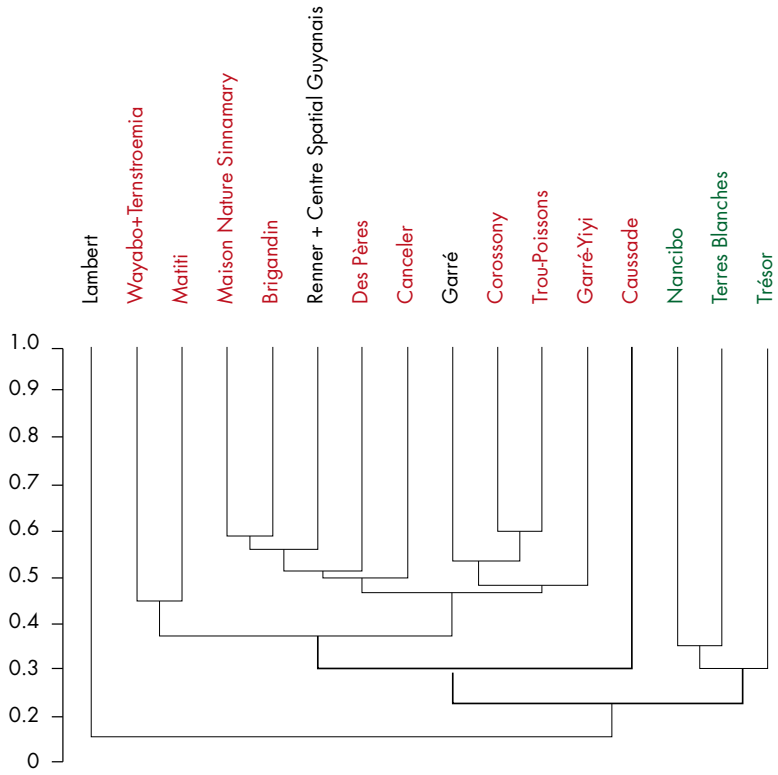
Results

Results show that:

- the most accessible sites, and in particular those that burned, presented plant community compositions that were similar and ordinary ;
- the unburned sites presented assemblages of savanna (in the strict sense of the term) species which were different from those of the burned sites, and in addition, which were always original (compositions were dissimilar both to those of the other sites in the same group as well as to those of the group of more human-altered sites) ;
- it is difficult to draw up a typical list of plants found in a well-conserved savanna, since the assemblages of the isolated sites were very different from each other.

Similarity of sites

Similarity (Jaccard index + UPGMA algorithm) of sites, based only on savanna (in the strict sense of the term) species (the sites presenting fewer than 40 savanna (in the strict sense of the term) species were excluded).
Green: Isolated or/and difficult to access;
Red: recently-burned savannas (direct observation of signs of fire);
Black: non-isolated savannas, but without direct observation of signs of fire.



List of savanna (in the strict sense of the term) species present only in habitats showing signs of fire

The table below presents the 12 savanna (in the strict sense of the term) species present at at least half the burned sites and absent from the others. It should be noted here that unfortunately, this list should be interpreted with caution, in light of the small data sets.

Taxons in human-altered habitat	Number of sites where the taxon was found
Miconia albicans	7
Paspalum melanospermum	7
Schizachyrium maclaudii	7
Rhynchospora velutina	6
Eriosema violaceum	5
Habenaria spathulifera	5
Aeschynomene histrix var. histrix	5
Andropogon selloanus	5
Byrsonima spicata	5
Isachne polygonoides	5
Paspalum pumilum	5
Vigna linearis	5

The table below presents the 18 savanna (in the strict sense of the term) species present only at the isolated (therefore presumed to be unburned) sites, although we had only 4 sites. The 18 taxons presented were found at at least 2 sites. It is nevertheless difficult to know whether these species are typical of a savanna not subjected to burning, or simply linked to a natural ecological distribution. This makes their indicator value relatively low.

List of savanna (in the strict sense of the term) species present only in habitats showing NO signs of fire

Taxons in human-altered habitat	Number of sites where the taxon was found
Becquerelia tuberculata	3
Calyptrocarya bicolor	2
Encyclia granitica	2
Adelobotrys scandens	2
Aganisia pulchella	2
Becquerelia cymosa subsp. cymosa	2
Clusia scrobiculata	2
Cochlidium linearifolium	2
Croton guianensis	2
Dictyostega orobanchoides subsp. parviflora	2
Lagenocarpus guianensis subsp. guianensis	2
Miconia tschudyoides	2
Notylia sagittifera	2
Octomeria exigua	2
Paepalanthus sp.	2
Pseudolycopodiella caroliniana var. meridionalis	2
Psychotria deflexa	2
Psychotria medusula	2

Research and monitoring needs

In light of the results obtained in this study, the following priorities for research were identified:

- Draw up protocols to better compare the richness of sites and species abundance in order to strengthen the value of indicators and better understand the action of fire ;
- Monitor burned and unburned sites, trying to eliminate other factors of anthropic disturbance (in particular pastureland) when designing the experiment;
- Take the 1,250 taxons analyzed one by one and evaluate their resistance to fire based on their known biological characteristics. This does not necessarily represent an excessive amount of work and will make it possible to fine-tune the list considerably.

Conservation/management strategy and actions

- Define the plant community composition for each site and whether or not it is regularly subjected to burning ;
- Adapt the management of the site by integrating the fire parameter: Depending on the floristic characteristics and management objectives, define a fire regime (which could range from banning burning to regular burning) ;
- For sites with an original and sensitive plant community composition, support the ban on burning, communicate about it and step up surveillance during the dry season.

Charred bark after a burn

II. 3. FLORISTIC MONITORING OF A SAVANNA SUBJECTED TO FIRE IN THE PRIPRIS DE YIYI

Objectives: Provide initial answers regarding the influence of fire regimes on the flora of savannas at the level of 1) plant community composition and 2) vegetation structure. In parallel, this study made it possible to:

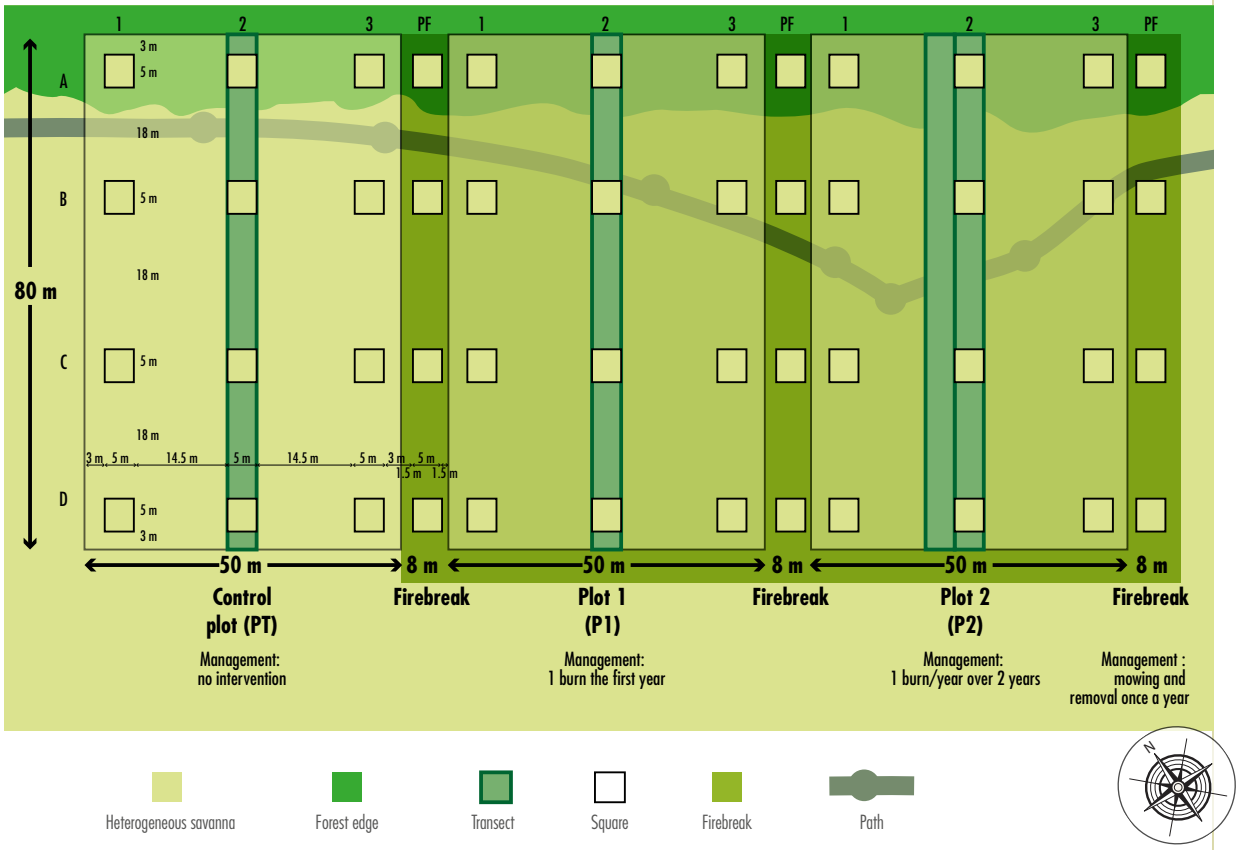
- experiment with a management tool for savannas ;
- obtain quantified data on setting up such a scheme, both from the point of view of its effectiveness (methodology, bioindicators) and of logistics (technical and human resources) ;
- obtain a baseline and data to support reflections on possible regulations for savannas ;
- recommend that the management plan for the Pripris de Yiyi be changed (if conclusions are pertinent).

Methods and protocols

Three adjacent 80 x 50 m test plots separated by 8 m-wide firebreaks were set up:

- PT: control plot: no burn.
- P1: managed plot (low fire pressure): 1 burn every 3 years.
- P2: managed plot (heavy fire pressure): 1 burn per year.

Location of three test plots



12 5 x 5m (25 m^2) squares were marked out in each of these three test plots. For each square, the following information was collected:

- the full list of species observed for each of the 5 strata: low herbaceous (0-20 cm), high herbaceous (20-120 cm), low shrub (120-300 cm), high shrub (300-500 cm) and wooded (>500cm) ;
- the abundance-dominance of all the species per stratum, established using Braun-Blanquet coefficients ;
- a rough map of shrubs, microtopography and termite mounds;
- a photo taken from the same spot at each visit ;
- a few notes and specific comments.

A 5 m x 80 m transect was set up in each of the 3 test plots, perpendicular to the edge. For each transect, the woody species over 2 m high were mapped. Since the first transect created in plot P2 contained far fewer trees and shrubs than plots PT and P1, it was completed by a second, similar transect alongside the first one. The following information was collected:

- identification and location of all shrubs > 2 m high ;
- vertical projection of the crown;
- height of all shrubs concerned ;
- location of path and termite mounds.

Results

Human investment required for the study (not including volunteers and partners)

		WORK EFFORT					
		2013		2014		2015	
		person-day	%	person-day	%	person-day	%
Installation of setup	overall setup	6	6,2	0	0	0	0
	squares*	6	6,2	0	0	0	0
	transects	0,5	0,5	0	0	0	0
	path	0,1	0,1	0	0	0	0
Inventories	squares*	23	23,8	14	26	12	49,6
	transects	7	7,2	2	3,7	1	4,1
	path	0,5	0,5	1	1,9	1	4,1
French Guiana Herbarium		30	31,1	26	48,3	10	41,3
Firebreak: mowing/removal		16	16,6	5	9,3	0	0
Rainfall/photo monitoring		0,5	0,5	0,8	1,5	0,2	0.8
Burns**		7	7,2	5	9,3	0	0
TOTAL (174,6 homme.jour)		96,6		53,7		24,2	
Cayenne-Yiyi trips(126 km)		19		7		3	

* setup installation and inventories include the squares located in the control, P1 and P2 test plots and the firebreaks

** the time required to perform burns does not include teams of firefighters, gendarmes, DEAL employees (roads department), coastal guards, ORA employees and volunteers

Results show:

1. **Two natural phenomena observed throughout the setup:**
   - significant renewal of species from one year to the next, even in the control plot: a "turnover" phenomenon probably linked to climate variations and to species phenology ;
   - a very wide range of changes among the 36 5 m x 5 m squares.

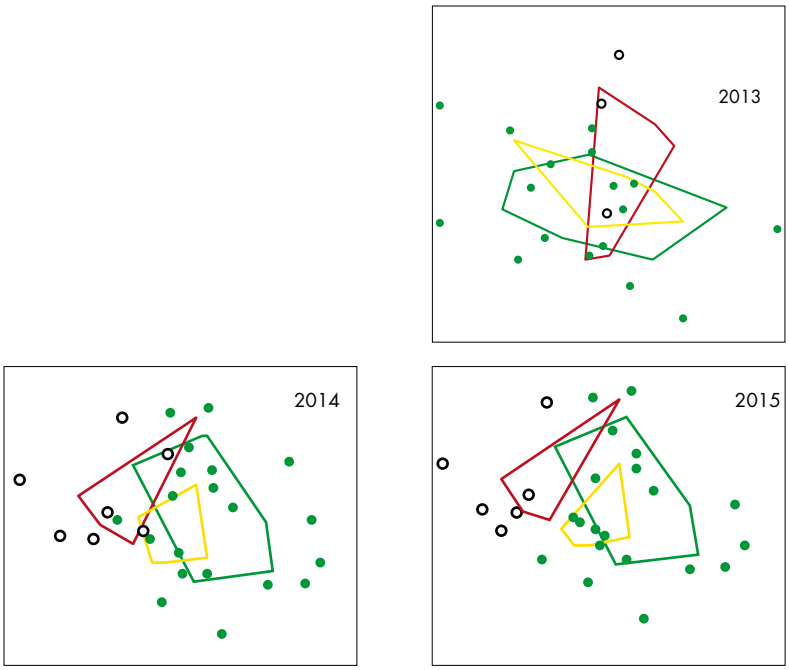
2. **Logistics lessons learned from setting up controlled burns:**
   - controlled savanna fires can be carried out in French Guiana under proper safety conditions, in collaboration with institutional partners ;
   - it proved to be impossible to burn the same area of savanna twice in the same dry season ;
   - it was impossible to burn the vegetation at forest edges (tree cover over 5 m in height) by broadcast burning under unfavorable dominant wind conditions. Closing of the vegetation may be irreversible once a certain stage has been reached, without a more severe disturbance than fire.

3. **Effects of fire on the structure of vegetation and plant community composition:**
   - setting fire to the savanna 2 years in a row apparently did not have a devastating effect on the flora: It is difficult to demonstrate statistically significant differences in vegetation between before and one year after a fire ;
   - a rapid reopening of the habitat through a decrease in the extent of shrub strata ;

- a significant decrease in certain shrub species that had closed the habitat (ex: *Clusia nemorosa*) ;
- increased cover of the herbaceous stratum and richness in herbaceous species ;
- the appearance of small, annual, herbaceous plants typical of shortgrass savannas, which in classic fashion " took advantage " of the opening of the habitat to colonize it ;
- NMDS analysis | excluding rare species showed that the three test plots initially had homogenous plant community compositions. Burning tends to differentiate these plant community compositions by promoting herbaceous savanna species to the detriment of woody species.

Anderson, 2001

Results of NMDS analysis for 2013, 2014 and 2015



2013: The plant community compositions of the three test plots are homogenous
2014 and 2015: Plant community compositions tend to differentiate, with small herbaceous savanna species and woody species promoted by fire and absence of fire, respectively

Firebreak P2

Firebreak P2

Firebreak P2

Firebreak

P2

Setting fire to plot P2

Research and monitoring needs

In light of the results of this study, the following research and monitoring priorities were identified:

- continue the current experiment: 2 years of monitoring are insufficient to draw solid and detailed conclusions on the effects of fire on the flora ;
- if a new experiment is carried out, adapt the sampling size and frequency of surveys ;
- collect information on biomass ;
- collect information on species ecology (phenology, adaptation to fire, metabolism, means of reproduction, etc.);
- extend monitoring to living groups likely to react to fire (ex:entomofauna, herpetofauna).

Conservation/management strategy and actions

- experimentation is necessary at each site before implementing generalized management by fire: The results of this study offer a starting point for further reflection ;
- brush fires are a regular and frequent phenomenon in French Guiana, but are prohibited by law. An organized system of controlled burns with the participation of competent and interested organizations (SDIS, ONF, ORA, etc.) at sites set aside for experimentation or maintenance by fire would be a win-win system to consider. This would constitute a continuity of the partnerships already created and would help achieve objectives faster.

III. TECHNIQUES TO CONTROL *ACACIA MANGIUM*

Today, exotic invasive species are recognized as being the third most serious threat to species survival according to IUCN, the second most serious for global biodiversity according to Millennium Ecosystem Assessment and lead to other serious economic, social and health consequences . A large number of international conventions and commitments as well as European provisions and national commitments deal with the subject of biological invasions . Acacias, and specifically Australian acacias, have been widely introduced outside their natural distribution area for hundreds of years and today dominate landscapes in numerous parts of the world . Their introduction is due to convergences in the fields of ecology, politics, ideology and means of subsistence at the regional scale .

Kirschner & Soubeyran, 2007; Soubeyran, 2008

Kirschner & Soubeyran, 2007

Soubeyran, 2008

Richardson et al., 2011

Carruthers et al., 2011; Kull & Rangan, 2008

Although French Guiana is not an island like the other French overseas entities, which are much more sensitive to invasions , it is one of the " major tropical wilderness areas " identified as key areas that are still largely intact at the scale of the planet and whose population density is low and it is part of a WWF/IUCN ecoregion .

Kirschner & Soubeyran, 2007; Soubeyran, 2008

Mittermeier et al., 1998

Delnatte & Meyer, 2012

The dry savannas are located on French Guiana's coast, in patches surrounded by urban areas, swamps or forest. Due to this particular distribution, they are comparable to " islands " of a particular biotope and are thus more sensitive to biological invasions . Moreover, the department's longest national road (RN1) runs through them, in the most highly-populated coastal area. They therefore contain the habitats that are the most vulnerable to the introduction of exotic species in French Guiana . In addition, more than 20% of protected species are found there on 0.3% of the territory, many of which do not benefit from any protective measures .

Soubeyran, 2008

Delnatte & Meyer, 2012; Dodet & Collet, 2012; Soubeyran, 2008; Ziller, 2012

Delnatte & Meyer, 2012

Due to its distribution and the dense populations that it forms, *Acacia mangium* has been identified as one of the two most problematic naturalized species in French Guiana, out of the 165 species identified (with *Melaleuca quinquenervia*) . Yet its situation is still controllable . While its regeneration remains limited under a closed canopy, its propagation in open savanna ecosystems is largely promoted by frequent fires . It appears likely that widespread use of the species by humans has contributed to the development of its invasive nature, as is the case for numerous species of Australian acacias . *Acacia mangium* was introduced into French Guiana in the 1980s to revegetate mining sites and is currently found mainly on the coast and at several sites located further into the interior of the department, spreading from plantations created in the 1990s, on gold mining sites, abandoned land, roadsides and agricultural areas, as well as in dry savannas .

Delnatte & Meyer, 2012; Soubeyran, 2008

Biotope, 2010; Biotope & CIRAD, 2010; Delnatte & Meyer, 2012

Griffin et al., 2011; Castro-Diez et al. , 2011; Biotope, 2010; Miller et al., 2011

Biotope, 2010; Biotope & CIRAD, 2010

Objectives: Develop an effective technique to control *Acacia mangium*, by:

- comparing techniques to eradicate adults,
- comparing techniques to deplete the seed bank and
- applying these results to test plots.

A cassava plant surrounded by Acacia mangium seedlings on a farm plot

Crown of an Acacia mangium

III.1. CONTROLLING ADULT TREES

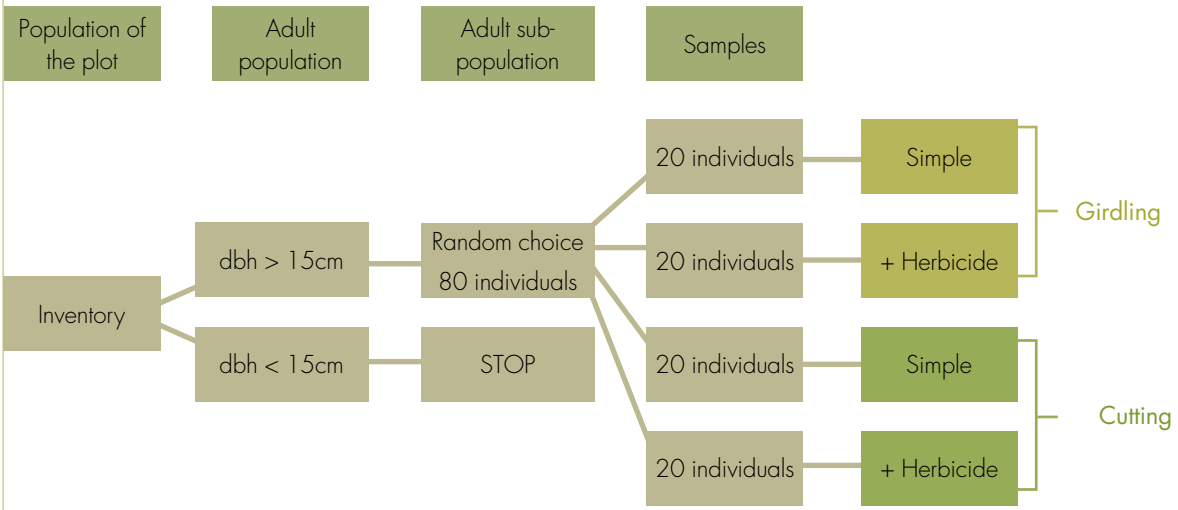
Objectives: Determine effective methods to control adult trees and assess their feasibility.

Methods and protocols

On a study plot located in Matiti (municipality of Macouria), 80 adult trees with DBH diameters over 15 cm (DBH = " Diameter at breast height ", a standard measurement in forestry, taken 1.3 m from the ground) were treated in the following manner in groups of 20 trees:

- Simple girdling: removal of a ring of bark from ground level up to a height of 40 cm, with elimination of the cambium.
- Girdling with application of an herbicide at the base of the ring: a 4% solution of Triclopyr.
- Cutting at ground level.
- Cutting at ground level with application of an herbicide on the cambium ring: a 4% solution of Triclopyr.

Sampling method

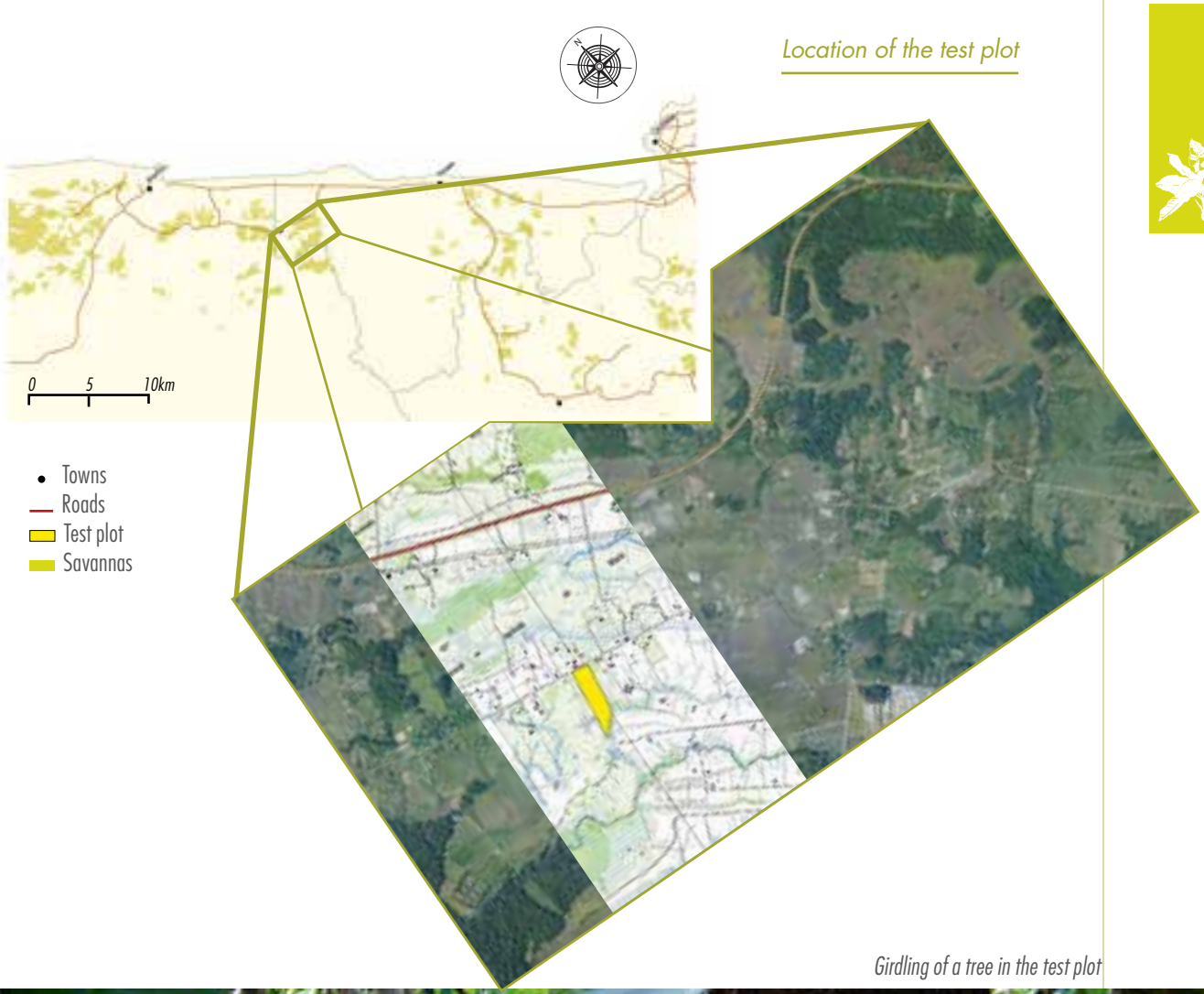


The trees were then monitored for a year as follows:

- Cut trees: the number and height of shoots from the stump.
- Girdled trees:
  1. color of the cambium by photographic monitoring, according to three color classes (white, beige and brown),
  2. crown density by photographic monitoring expressed as a percentage of the crown covered with foliage and
  3. presence of sap by means of machete cuts according to three classes (absence of sap, moist cambium and presence of sap).

Kruksal-Wallis tests were performed to test the correlation between the 3 monitored indicators.

Location of the test plot



Girdling of a tree in the test plot

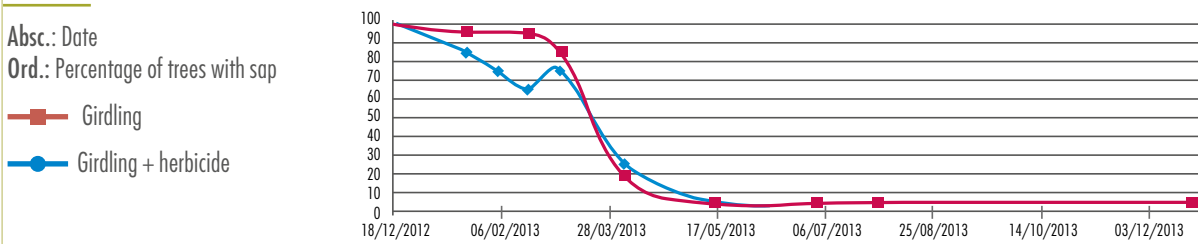
© A. Sitler / GÉPOG

Results

Results show that:

- no stump cut at ground level produced shoots, with or without herbicide ;
- all the girdled trees died after 5 months, with or without herbicide. Two trees that survived had been imperfectly girdled (there was some cambium left, which created a link between the roots and the crown) ;
- stumps that were not used for the study (trees cut for technical reasons at random heights) were regularly seen with shoots at the study site ;
- the presence of sap and the color of the cambium are correlated: These two indicators can be used indifferently to monitor tree status. Foliage density showed a progression that was significantly different from that of the first two indicators: The crown reacts more rapidly and more clearly to the progression of the tree's health status.

Change in the percentage of trees that still had sap after girdling



After girdling, a tree's cambium changes color

© A. Stier / GÉPOG

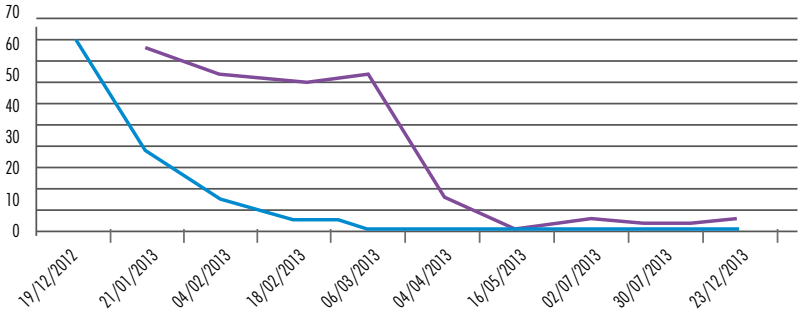
18.02.2013

© A. Stier / GÉPOG

06.03.2013

13.04.2013

Change in the percentage of trees that still had sap and in average foliage density after girdling



Absc.: Date
Ord.: Percentage of trees with sap – average percentage of the crown covered with foliage

sap
crown

Change in leaf density of a girdled tree

© A. Stier / GÉPOG

19.12.2012

21.01.2013

© A. Stier / GÉPOG

02.04.2013

Research and monitoring needs

In light of the results of this study, the following research and monitoring priorities were identified:

- Test the effects of cutting on trees with different diameters and heights ;
- Test the effects of cutting and girdling in all seasons (short rainy season, short dry season, long rainy season and dry season) ;
- Evaluate the human and budgetary investment required for a given number of trees ;
- Extend the study to other biogeographic regions in French Guiana.

Conservation/management strategy and actions

- The use of herbicides is not necessary ;
- Cutting is the quickest and cheapest method ;
- Trees that cannot be cut can be girdled to a height of 40 cm from the base of the tree. This technique requires that particular attention be paid to the layer of cambium, which needs to be completely removed in order for the girdling to be effective. Distinguishing the cambium from the rest of the sapwood is difficult, since both are an identical white color ;
- Post-treatment monitoring is required to check the effectiveness of the intervention and take further action if necessary. The recommended monitoring schedule is: t + 2 months, t+ 4 months, t + 6 months and t + 12 months.

Acacia mangium pods and seeds

III. 2. CONTROLLING THE SEED BANK

Objectives: Determine the species' seed dispersal methods and the methods to evaluate and deplete the seed bank.

Methods and protocols

Study of seed dispersal:

Four transects were created around mother trees: one on the study plot and three on the agronomy campus in Kourou.

Three variables were measured:

- distance of the specimen from the mother tree ;
- crown spread (measured from the base of the trunk using a 20 m tape measure) ;
- DBH (diameter at breast height) of the mother tree.

Ten specimens were collected up to a depth of 15 cm, using a hand auger with a gouge measuring 8 cm in diameter and 15 cm in length. A descriptive summary of each transect is presented below. Once the specimens were collected and air dried, they were passed through a 4 mm sieve (to eliminate coarse elements), then a 1.85 mm sieve (to collect the seeds).

Description of the four transects studied

Transect	Location	Crown spread (m)	DBH (cm)	*Sampling distances*
Parcelle1	Study plot, Matiti	4	18	1,5 – 3 – 6 m
FCamp1	Agronomy campus in Kourou	7	29	2 – 4,5 – 7 – 9,5 m
CIRAD1	Agronomy campus in Kourou	12	29	2 – 4,5 – 7 – 9,5 – 12 – 14,5 m
Maison Campus	Agronomy campus in Kourou	12	62	2 – 4,5 – 7 – 9,5 – 12 – 14,5 - 17 – 22 m

After sampling was performed on these transects, the density of seeds in the soil from the mother trees was modeled using R software.

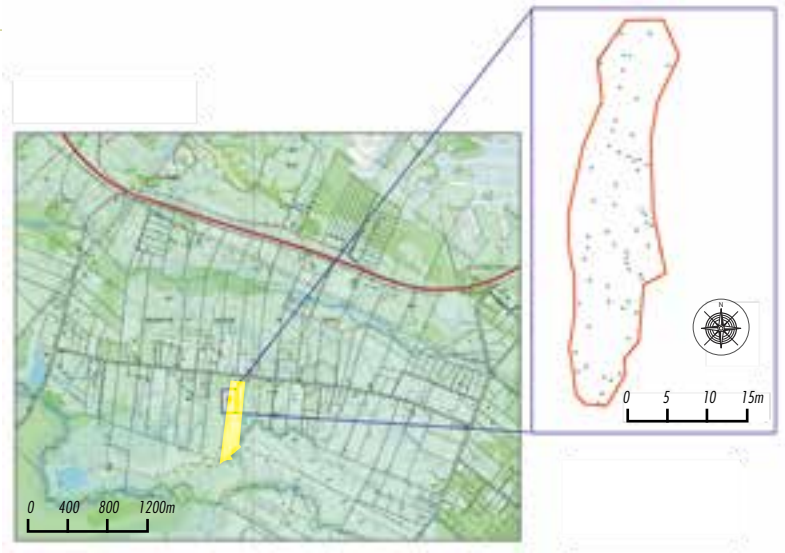
R Core Team, 2013

Seed bank depletion techniques:

Sixty geo-referenced specimens were collected using a hand auger (8 cm in diameter, 15 cm in length). Two sub-samples were distinguished according to their depth (0-10 cm and 10-15 cm). Specimens were collected randomly in the study area, following a pattern of points generated with the csr() function of the package . This sampling method seemed to be better adapted to situations where the seeds could form clumps (which is often the case) than a regular sampling grid.

R Core Team, 2013; Rowlingson & Diggle, 1993

Strydom et al., 2012



Map of the study plot

Map (base IGN 1/25000) of the study plot and close-up of the tree grove treated (the 60 sampling stations are indicated in gray)

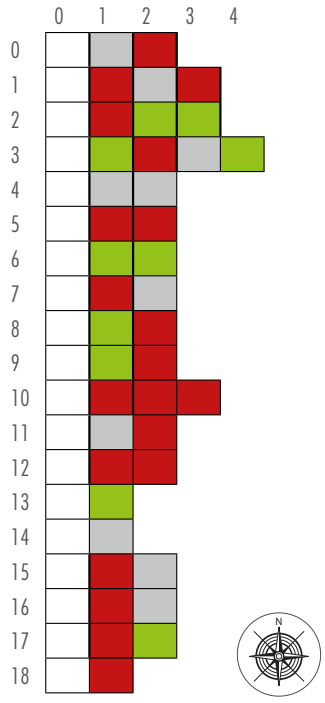
- Sampling points
- Grove

As was done in the first part of the study, once the specimens were collected, they were passed through a 4 mm sieve (to remove coarse elements) then through a 1.85 mm sieve (to collect the seeds).
Forty 2m x 2m test plots were distributed over the entire area and were randomly sorted into two groups of 10 plots and one group of 20 plots corresponding to different treatments:

- Control.
- Working the soil manually with a hoe to a depth of 15 cm (disturbance assimilated to what would occur if shrubs were pulled out).
- Burning using a standard 2 kg dose of hay per plot (500 g / m^2), which corresponds, according to Danthu et al. (2003), to an intense fire. This dose was adapted to field conditions and occasionally doubled (in case of damp soil).

Monitoring consisted in counting young seedlings roughly every three days. The young plants were pulled out at each visit to prevent errors in the counting of newly-emerged seedlings.
After monitoring of the burning phase was finished, 9 surveys were carried out on each plot to study the quantity of seeds remaining in the soil. Charred seeds were not counted, nor were those that had sprouted.

Distribution of square plots



Distribution of 2 m x 2m square plots.
Red: burning,
Green: hoeing,
Gray: control.
The hedge of adult acacias is located to the left (west) and is represented by empty boxes.

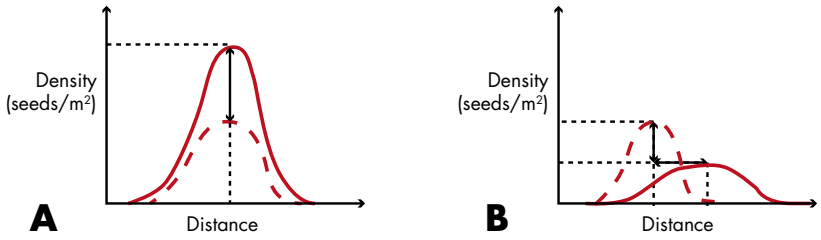
Results

Results show that:

- seed density per m^2 according to distance from the mother tree follows an upside-down, more or less flattened parabola, influenced by DBH and crown spread ;
- seed density per m^2 according to distance from the mother tree is modelable ;
- 100% of the seeds were observed in the 0-10 cm horizon. Therefore, no seeds seemed to be present below a depth of 10cm ;
- most of the seed bank was found under the crown, and the quantity of seeds shrank very rapidly several meters beyond the crown spread ;
- burning has a significant effect on the emergence of *A. mangium* seedlings. However, the number of sprouted seeds observed was very low compared to the average quantity of seeds calculated for the site, approximately 1.8% ;

- after 48 days of post-burn monitoring, no sprouting was observed on the " control " plots. During that same period, only one sprouted seed was observed on one of the ten " hoeing " plots ;
- Burning eliminated on average 43% of the seeds from the soil (this includes sprouted seeds + seeds destroyed by fire).

Diagrams representing the expected effect of an increase in DBH (A) or crown spread (B) on the pattern of seed dispersal along a transect



Burning two test plots

© A. Stier / GEPOG

Marking off the test plots using barricade tape

Research and monitoring needs

In light of the results of this study, the following research and monitoring priorities were identified:

- Test the impact of fire on the seed bank at several distinct sites to diversify the environmental conditions and verify its applicability ;
- Evaluate the human and financial investment required at the plot scale under varied conditions ;
- Study the potential effect of burning on the sprouting of other species (native and exotic) ;
- Test soil degradation in the first 10 centimeters ;
- Evaluate the role of animals in dispersal.

Conservation/management strategy and actions

- Visualize the area where seeds are present in the field: This corresponds to the understory itself and to the few meters of space surrounding it, where a large quantity of plant debris from neighboring acacias can be observed ;
- Burning can be used as a method to deplete the seed bank in the soil ;
- Cutting adult individuals as well as surrounding juveniles, if necessary, at ground level (this phase is also indispensible if the aim is to eradicate the species from a given area) could provide enough fuel to carry out a first burn in the dry season, by spreading the wood over the entire area ;
- After each burn, seedlings should be eliminated ;
- Although it is simple and inexpensive to set up, burning as a seed bank depletion technique is nevertheless burdensome to apply and would be highly impractical at a large scale ;
- The potential effect of burning on the sprouting of other species (native and exotic) must be taken into account ;
- It could be problematic to use burning in protected natural areas.

Eliminating and measuring the size of young trees on a test plot after treatment

III. 3. TESTS AT THE PLOT SCALE

Objectives: Test the results previously obtained on adult trees and the seed bank at the plot scale, under diversified environmental and field conditions.

Methods and protocols

Five plots spread out along the coast were used to test the results described in the two preceding chapters in the field.
For each of them, the following process was set up:

- Diagnose the plot: invasion status, surface area, access difficulties, etc.
- Carry out an initial inventory.
- Eliminate young trees by pulling them out.
- Eliminate adult trees by cutting them at ground level.
- Perform burns on two of the plots.
- Carry out post-treatment monitoring at intervals adapted to the speed of regrowth:
  - pull out young seedlings and trees
  - eliminate forgotten trees
  - measure stump heights
  - count and eliminate shoots, if necessary
  - note the survey habitat (savanna, abandoned land, forest, etc.)
  - for savannas: note the position of young trees (in/on the edge of a grove or in the grass)
  - note GPS position
- Analyze data.

Locations of test plots

The Saint-Laurent du Maroni plots include ADNG left, ADNG center and Kolino.
- Montsinéry: plot with savannas, forests and abandoned land.
- MNS: plot at the Sinnamary Nature Center with savannas, forests, abandoned land and marshes.
- Kolino: agricultural plot belonging to Mr. Luciano Kolino, initially a monospecific forest of *Acacia mangium*: The acacias were eliminated, then the plot was burned.
- ADNG left and ADNG center: a plot with a monospecific forest of *Acacia mangium* belonging to the Association for the Discovery of Nature in French Guiana (ADNG), divided into three equal plots. ADNG left: acacias eliminated, then burning, ADNG center: acacias eliminated, but no burning, ADNG right: plot that was not treated here, left as a control plot.

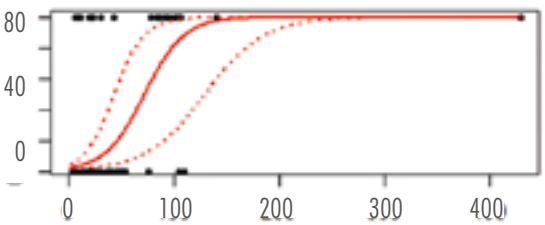
Results

Results show that:

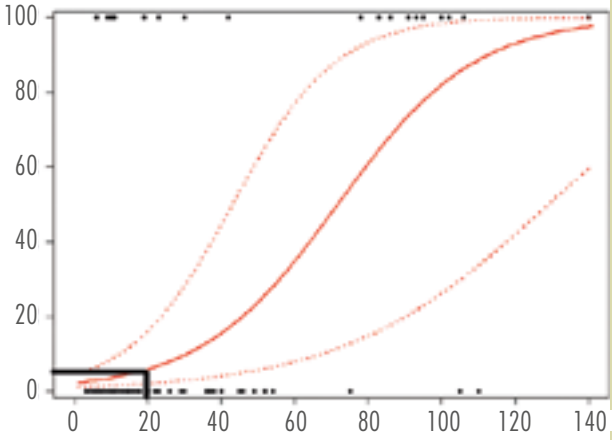
- cutting height has a significant effect on the probability of stumps sending up shoots: Below a cutting height of 20 cm, the probability of the stump sending up shoots is less than 0.5% ;
- 94% of young trees grow under mother trees and 6% beyond the reach of the crown of mother trees ;
- in savannas, 99% of young acacias grow on the edge of a grove, 0.7% within groves and 0.6% in the middle of expanses of herbaceous vegetation;
- eliminating adult trees leads to the growth of young trees, but their number decreases afterwards with the interventions carried out at the different monitoring visits ;
- if the surrounding vegetation is high, individuals that have reached a certain height may be missed and will only be noticed at the next visit: The sizes of the young trees pulled out are thus very variable between plots at a time t ;
- burning promotes sprouting ;
- acacias grow fast: In 200 days, most individuals reach a height of between 50 and 200 cm.

Results of GLM

Results of GLM (GLM = " generalized linear model "), with a significant (p-value = 2.43e-09) and positive effect of cutting height on the probability of the stump sending up shoots. Without the point at 430 cm, the results of the model do not change. A cutting height under 20 cm lowers the probability of a stump sending up shoots to below 5%.



Absc.: Cutting height (cm)
Ord.: Probability of stumps sending up shoots



Absc.: Cutting height (cm)
Ord.: Probability of stumps sending up shoots

Recording the GPS coordinates of a young acacia

Measuring the size of a young acacia

© A. Stier / GEPOG

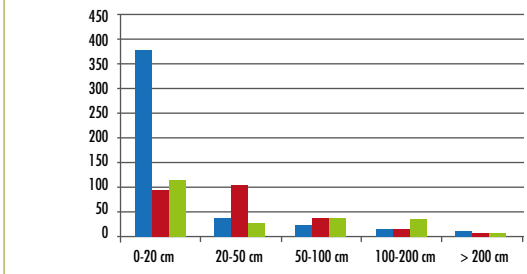
Change in the number of seedlings per plot at each visit

The left section of ADNG was burned after treatment; the central section was left as it was.

		Initial state	Visit 1. t + 80 - 255 days	Visit 2. t + 300 - 340 days	Visit 3. t + 510 days
NUMBER OF SEEDLINGS	MNS	96	476	265	230
	Montsinéry	132	3438	505	-
	ADNG left	-	114	43	-
	ADNG center	-	15	13	4

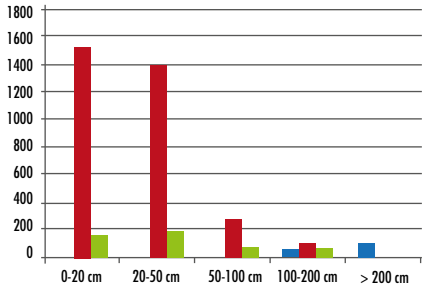
Change in the number of seedlings per plot and size class on each plot and at each visit

Absc.: Size of the young
Ord.: Number of individuals



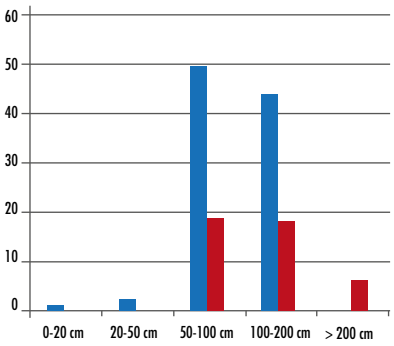
MNS

Visit1: t + 120days Visit 2: t + 300days Visit 3: t + 510days



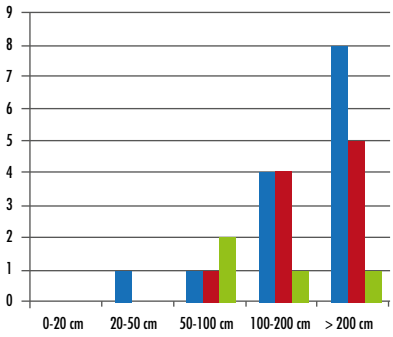
Montsinéry

Initial State Visit 1: t + 150days Visit 2: t + 340days



ADNG Left

Visit 1: t + 255days Visit 2: t + 335days

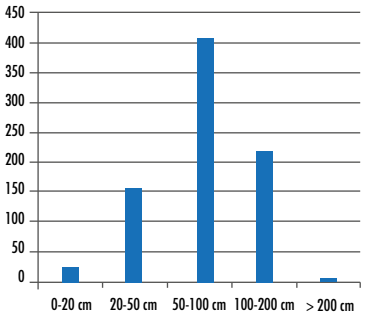


ADNG Center

Visit 1: t + 80days Visit 2: t + 330days Visit 3: t + 510days

Note: Kolino is a plot where a sample of 809 seedlings was measured; an exhaustive inventory was performed on the other plots.

- ADNG left and Kolino are burned plots: Monitoring times are " post-bare-ground " times and thus enabled the species' speed of regrowth to be evaluated.
- ADNG left and ADNG center are adjoining plots, where the only difference was burning: Burning promotes sprouting (8 times more seedlings on the left than in the center).
- MNS and Montsinéry are two plots in a natural environment (savannas, forests, abandoned land) that were partially invaded: The intervention promoted the sprouting of new seedlings, which were then depleted by the different monitoring visits.



Kolino

Visit1: t + 200days

Before

Cut

© A. Stier / GÉPOG

Burned / cut

After

© A. Stier / GÉPOG

Research and monitoring needs

In light of the results of this study, the following research and monitoring priorities were identified:

- evaluate the person/day cost according to the scenarios.

Conservation/management strategy and actions

- define a strategy to control the species at the scale of the department based on the map of its presence made by DEAL Guyane ;
- intervene in priority areas, adapting the techniques described above ;
- the preferred method should be cutting at ground level, with stumps no higher than 20 cm ;
- eliminate seedlings before any intervention on adult trees ;
- in areas presenting monospecific stands of adult trees, burning can be considered to deplete the seed bank, especially if the plot is likely to be reopened in the future ;
- carry out a first monitoring visit 150 days post-treatment to evaluate the speed of regrowth and adapt the intervals between the next visits.

B THE HUMAN COMPONENT

Savannas constitute a major element of French Guiana's coastal landscape. Located between the ocean and the highlands, they are the result of both natural processes and human activities (Chaix et al., 2001; de Pracontal & Entraygues, 2009; Marchant, 2010). French Guiana's coast has been inhabited for thousands of years, first by Amerindian populations, then by European colonists and Creoles, who over time were joined by different human groups that reflect French Guiana's contemporary multi-ethnic society (Haitians, Brazilians, etc.). This human presence has undoubtedly contributed to forming coastal savannas (Palisse, 2013, 2014).
It was possible to take this human influence into account by 1) carrying out an anthropological study and 2) setting up a participatory approach in one of the project's actions.

" An ecology without Man…
is true only for an environment without Man "

Sauer, 1958

I. CURRENT STATUS OF PRACTICES AND USAGES: THE ANTHROPOLOGICAL STUDY

" The issue of conserving the biodiversity of savannas cannot be resolved solely by prescriptions based on scientific studies. Once you acknowledge that the status of these habitats is the result of a balance with human usages – at least for coastal savannas – and that those usages are changing, then the question arises regarding where we want to go from there. »

Excerpt from Palisse M. (2014).

Objectives:

- Improve understanding of the way the different players regard savannas ;
- Identify and understand the activities that affect these habitats as well as the social and cultural context in which they take place, with a focus on the practice of burning and the spread of the invasive tree species *Acacia mangium*.

Methods and protocols

Field work was carried out in the region of Sinnamary and Iracoubo, among people who can be divided into four groups:

- environmentalists, responsible for studying, managing or protecting savannas ;
- professional farmers who use savannas, mainly to raise livestock ;
- senior citizens, who took part in and can bear witness to earlier uses of the savannas ;
- theKali'ña Amerindians of the village of Bellevue, located in the Yanou savanna, in the municipality of Iracoubo.

It should be noted that these categories are, of course, permeable.

Between May and September 2012, an anthropologist from the University of the French West Indies and French Guiana met with 22 people, whom she questioned using semi-directive interviews and who were contacted thanks to the "snowball" method, meaning that the people who were interviewed were asked to provide the names of other people whom it would be interesting to meet.

These interviews were supplemented by visits to farms and excursions to the savannas with certain players, as well as by exchanges of documents. Bibliographic research was also carried out in order to obtain precise historical information on the region.

© N. de Pracontal / GEPOG

Results

Savannas:

- have an image of empty and hostile spaces ;
- are associated with numerous age-old practices: Amerindian raised fields, small-scale food crop farming, raising livestock, opportunistic hunting and fishing, gathering, burning ;
- were an integral part of the complex of activities carried out on small Creole family farms until the 1970s ;
- underwent significant transformation with the arrival of the Plan Vert (Green Plan) agricultural development scheme, privatization of land and the creation of pastures ;
- are linked to the local imagination and a disappearing way of life, which lend them heritage value ;
- are open spaces that convey the notion of freedom and unrestricted movement;
- are only suited to extensive practices that should be adapted to each site by means of a series of field tests,
- are considered as being threatened by *Acacia mangium*.

Research needs

In light of the results of the anthropological study, the following research priorities were identified:

- extend the geographic area covered by research;
- extend research to other human groups that have contact with savannas (Brazilians, Haitians, Hmongs, etc.);
- further cross-check the information obtained from the interviews with other sources, in particular archives;
- improve understanding of how the concept of invasive species is perceived;
- evaluate the feasibility of shared and participatory management of savannas that would combine complementary approaches.

Conservation/management strategy and actions

- anthropology makes it possible to obtain the current status of local practices and knowledge so as to better take them into account ;
- redefine the concept of savanna " conservation " on a case-by-case basis. There is no general strategy that can be considered for all of French Guiana's savannas, but rather a range of solutions adapted to each site ;
- depending on the site, conservation could involve 1) prohibiting any human activity or, on the contrary 2) maintenance similar to former Creole and Amerindian activities or 3) a deliberate choice to transform the habitat ;
- the heritage value of savannas is a definite asset for the planning of conservation actions ;
- savannas are ecological mosaics. Management actions need to be adapted to the site and tested on a small scale ;
- it is important to take local populations' former and current practices into account and to allow them to participate in decision making ;
- current savanna landscapes are partially the result of practices that specialists are not perfectly familiar with: A transmission of know-how between the populations that implemented them and experts would be beneficial for informed management measures (burning, livestock grazing, etc.) ;
- anthropologists can play an important role as transmitters of positions and visions, legitimize certain points of view and thus promote the joint construction of objectives to achieve for a site through its management.

II. THE PARTICIPATORY APPROACH: CONSTRUCTING A PROMOTIONAL PROJECT

The participatory approach, which enables "a person to take part in a collective action", is increasingly used to set up projects, in particular in the environmental and sustainable development fields. This can be explained by the very essence of two major concepts:

- **Ecology**, which studies "living beings in their environment and interactions between them as well as the consequences of those interactions." To that end, it necessarily combines different scientific fields (life sciences, chemistry, physics, mathematics). Ecology is therefore interdisciplinary by definition ; and
- **Environment**, which is defined as "the sum total of natural (physical, chemical, biological) and cultural (sociological) conditions that act on living organisms and human activities." The environment is therefore not only natural but cultural as well, and concerns the notion of living conditions. The aim of **environmental education** is to "help individuals and authorities grasp the complexity of both the natural and the human-made environment, which is due to the interactivity of its biological, physical, social, economic and cultural aspects."

Indeed, actions relating to the environment must necessarily become collective actions whose success is linked to mastering the notions of ecology, urban planning, social and cultural dynamics, history and the living conditions of a territory... The participatory approach therefore offers the best means of carrying out those actions successfully, as it allows experts, professional players and inhabitants to share their expertise on these subjects and take part in decisions.

French Guiana's savannas are rare, endangered, but unique from an environmental, historical and cultural point of view. Long considered as empty, hostile spaces, the activities used topromote them must be original and adapted to the local context. For these reasons, the monitoring committee of the LIFE+ CAP DOM Savannas Project decided to establish a working group on the subject.

Objectives:

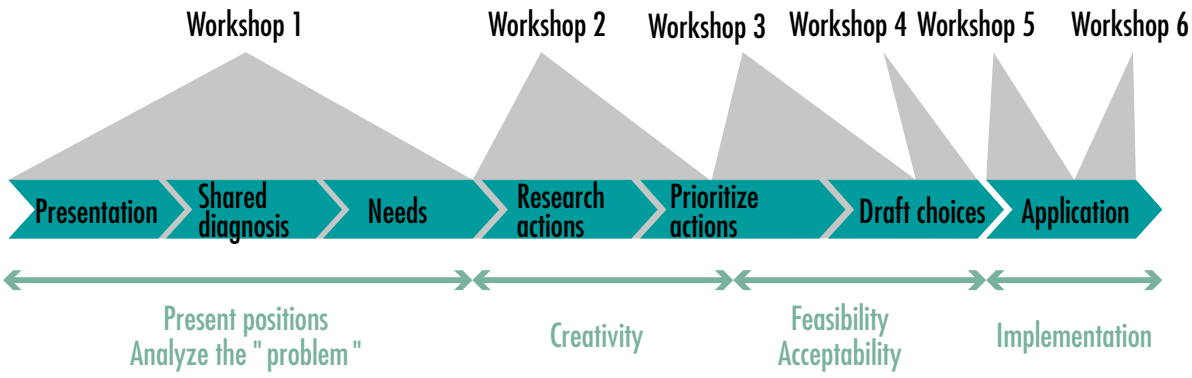
- Take into account recommendations to integrate the human component into any project on the savannas ;
- Give the working group free rein to " invent " a promotional project " tailored " to the savannas of Sinnamary and Iracoubo ;
- Integrate the new ecological and anthropological knowledge produced by the program ;
- Give local populations the possibility to take part in discussions and decisions.

Methods

GÉPOG ran the working group made up of members of the monitoring committee, which was open to the residents of Sinnamary and Iracoubo for one half-day every two months from March to September 2014, according to the basic principles of mediation and participatory meeting tools |.
Several key stages led the group to propose an original and ambitious project, supported by all. This same group was involved in the implementation of that proposal the following year, participating in new meetings with professionals and carrying out certain aspects of the project.
GÉPOG had to adopt an approach and a stance derived from the principles of territorial dialogue in parallel to the numerous facilitation tools used in order to successfully complete the project.

Barret & Guilheneuf, 2011; Communagir, 2015; Réseau École et nature (France) & Réserves naturelles de France, 2013

Steps of the project and their distribution in the workshops over time



Workshops

The workshops took place as follows:

Workshop 1: The goal was to define the elements to promote as well as the objectives to achieve through the project.

The group therefore defined:

1. **3 heritage assets linked to savannas:**
   - Changing usages and ways of life ;
   - representations, an intangible heritage (the notion of freedom, of harshness, of open landscapes, etc.);
   - exceptional, rare, specific and threatened nature.

2. **5 objectives for the project:**
   - Improve knowledge ;
   - participate in the preservation of sites ;
   - promote transmission of knowledge and know-how ;
   - promote the spirit of freedom linked to savannas ;
   - contribute to the spatial planning and development of the territory.

Workshop 2: The goal was to discuss the criteria used to judge successful promotional projects for natural areas and to propose a preliminary list of actions.

The group therefore:

- drew up a list of success criteria ;
- drew up a " rough " list of actions ;
- compared this list to the heritage assets and objectives of the previous workshop.

Workshop 3: The goal was to integrate actions into the reality of the territory.

The group therefore:

- created a map showing the location of natural and landscape heritage assets, a map of historical and cultural heritage assets and a map of sites that could be developed within the savannas, with a systematic description of points of interest ;
- combined these three maps into one ;
- divided the territory into thematic areas ;
- started drafting action sheets for each area based on the results of the two previous workshops.

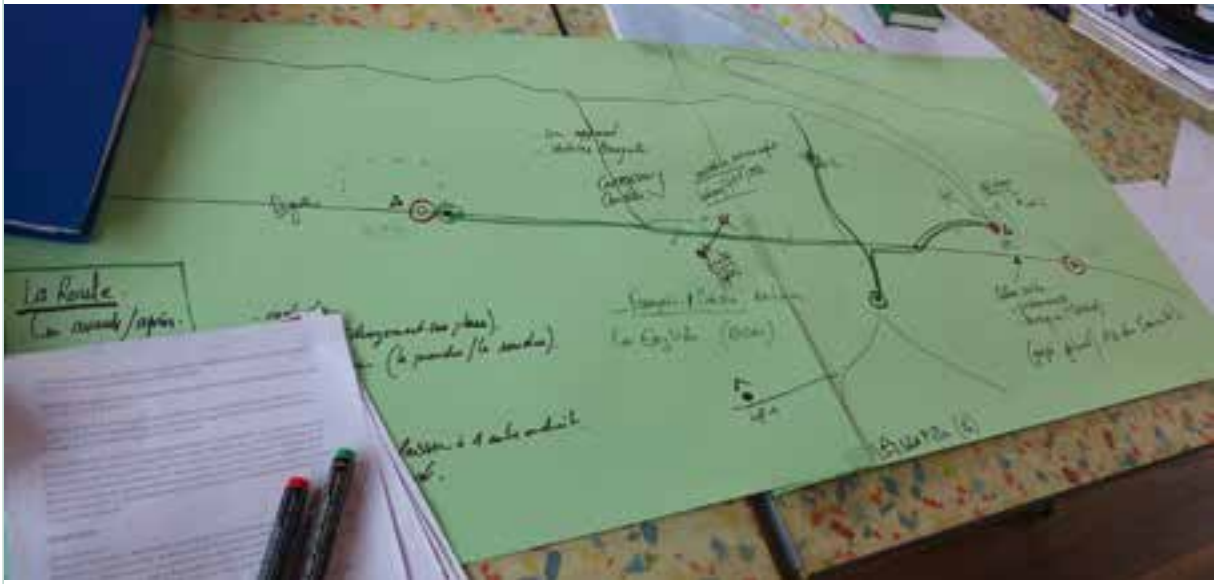
Workshop 4: The goal was tocompare the conclusions of the first three workshops and a list of concrete proposals presented to the group by GÉPOG and to validate a preliminary project to submit to municipal authorities and to implement.

The group therefore:

- reviewed all of GÉPOG's proposals ;
- eliminated and added actions ;
- validated a map of thematic points.

© A. Ricardou / A. Stier / GEPOG

Workshop 5



© A. Ricardou / A. Stier / GEPOG

Setting up the Savanna Trail

Workshop 5: The goal was to have the group work with a scenographer on the implementation of a promotional concept based on the results of the workshops, within an allocated budget.

The group therefore:
- moved thematic points ;
- specified themes ;
- proposed scenic design ideas ;
- discussed and validated the technical aspects of a tour route (direction of the route, stops, use of new technologies, etc.) ;
- validated a list of people to interview for a soundtrack.

Workshop 6: The aim was to validate the scenographer's proposal and to provide guidelines to the sound director.

The group therefore:
- analyzed and modified the scenography proposal ;
- drew up a list of unmissable sounds to record and include in the soundtrack ;
- modified and validated the questionnaires for residents and professionals with the themes to cover ;
- validated a title for the tour: " The Savanna Trail ";
- drew up a list of proposals for logos.

Results

- a project that grew in scope: a budget that doubled, 27 participants including 10 organizations involved in 6 workshops, 2 years of work and 5 external service providers ;
- participants got involved outside of the working groups (personal work and productions between workshops, support for the concrete implementation of the project, etc.);
- an original and well-adapted promotional action.

Conservation/management strategy and actions

- the participatory approach can provide the impetus for conservation or management actions that are adapted to the local context and supported by all ;
- joint construction of actions cannot be rushed and can take a long time (two years for this project) ;
- for participants to feel the urge to make a commitment, the following are required: 1) real issues (represented by the participants), 2) real powers, 3) a feeling of usefulness, 4) a workload that can be handled by all, 5) create group dynamics and 6) overcome the fear of getting involved ;
- the tools and methods as well as the role of leader/facilitator require training or support ;
- the participatory approach is a way to experiment with new forms of governance for natural sites.

III. CLOSE-UP ON: THE SAVANNA TRAIL

Inauguration of the Savanna Trail, September 2015

The Savanna Trail is a 7-stop tour to do by car and on foot, located in the municipality of Sinnamary. It includes a free mobile application, public amenities and a soundtrack combining surrounding sounds, music and about twenty statements by residents and experts.
Visitors are guided by the mobile application along the entire route: When a stop comes up, the application detects its geographic position and displays content using geolocation. The application can be accessed off-line: Once it has been downloaded, the guided tour is available without an Internet connection, including the map.
At four thematic stops along the route, visitors have access to public amenities in the form of wooden structures that guide the visitor's attention towards a part of the landscape linked to the theme being covered. One of the wooden beams of each structure includes a riddle for children to solve and texts related to the theme.

Between the four stops, soundtracks are automatically triggered when the tour is done by car, depending on the location of the vehicle.

Inauguration of the Savanna Trail

© O. Claessens / GÉPOG

Fully installed landscape frame

© A. Stier / GÉPOG

Scan this QR code to connect to the savanes.fr website
Download a QR code scanner application.

LE CHEMIN DES SAVANES

© J. Devillechabrolle / GEPOG

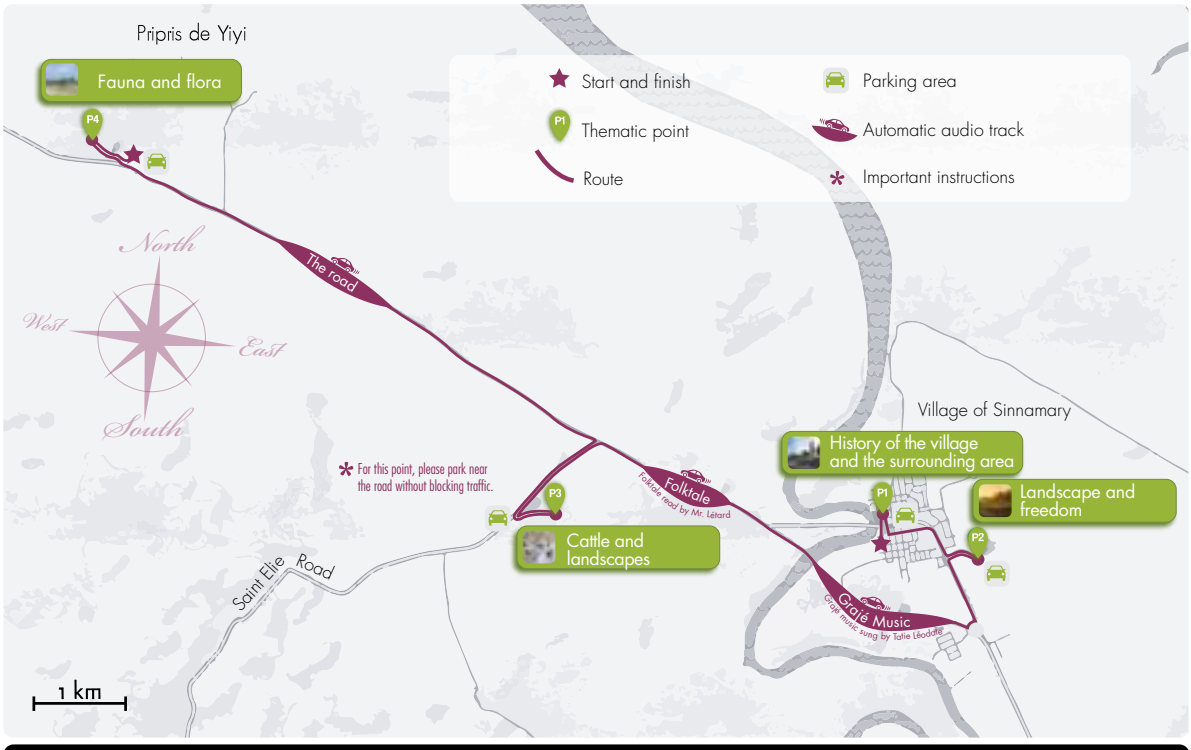
© O. Claessens / GEPOG

© O. Claessens / GEPOG

© O. Claessens / GEPOG

Download the Savanna Trail application

Map of the route of the Savanna Trail



Drive CAREFULLY. Obey traffic safety laws, which prohibit the use of any mobile equipment while driving. As you follow the trail, audio tracks will turn on automatically, which is normal. This application has been designed so that you do not have to handle your equipment while driving, so keep your hands on the steering wheel and be careful.

BIBLIOGRAPHY

- Anderson, M. J. (2001). A new method for non-parametric multivariate analysis of variance. Austral Ecology, 26, 32-46.
- Barret, P., & Guilheneuf, P.-Y. (2011). Guide pratique du dialogue territorial. Editions de l'Aube (seconde édition).
- Biotope. (2010). Les invasions biologiques en Guyane - Note de synthèse concernant le caractère envahissant d'*Acacia mangium* (Note de synthèse No. 2009378). Direction Régionale de l'Environnement - Guyane.
- Biotope, & CIRAD. (2010). Les invasions biologiques en Guyane 1e phase : Diagnostic (No. 2009378) (p. 170). Direction Régionale de l'Environnement - Guyane.
- Carruthers, J., Robin, L., Hattingh, J. P., Kull, C. A., Rangan, H., & Van Wilgen, B. W. (2011). A native at home and abroad : the history, politics, ethics and aesthetics of acacias. Diversity and Distributions, 17(5), 810-821. http ://doi.org/10.1111/j.1472-4642.2011.00779.x
- Castro-Diez, P., Godoy, O., Saldana, A., & Richardson, D. M. (2011). Predicting invasiveness of Australian acacias on the basis of their native climatic affinities, life history traits and human use. Diversity and Distributions, 17, 934-945. http ://doi.org/10.1111/j.1472-4642.2011.00778.x
- Chaix, M., Hequet, V., Blanc, M., Tostain, O., Deville, T., & Gombauld, P. (2001). Connaissance et conservation des savanes de Guyane (p. 108 + Annexes). IFRD - WWF Guyane.
- Communagir. (2015). Des activités d'animation mobilisantes et participatives. Consulté à l'adresse : http ://pouremporter.communagir.org/
- Danthu, P., Ndongo, M., Diaou, M., Thiam, O., Sarr, A., Dedhiou, B., & Ould Mohamed Vall, A. (2003). Impact of bush fire on germination of some West African acacias. Forest Ecology and Management, 173, 1-10.
- Delnatte, C. (2013). The Guiana Shield and French Guiana and Their Savannas. In Savannas : Climate, Biodiversity and Ecological Significance (Nova Science Publishers, Inc., p. 141-145). Céleste Perrault & Leone Bellamy.
- Delnatte, C., & Meyer, J.-Y. (2012). Plant introduction, naturalization, and invasion in French Guiana (South America). Biological Invasions, 14(5), 915-927. http ://doi.org/10.1007/s10530-011-0129-1
- De Pracontal, N., & Entraygues, M. (2009). Savanes de Guyane - Connaissances et Enjeux de Conservation (p. 30). Groupe d'Étude et de Protection des Oiseaux en Guyane (GÉPOG).
- Digby, P. G. N., & Kempton, R. A. (1987). Multivariate analysis of ecological communities (Chapman and Hall). London.
- Dodet, M., & Collet, C. (2012). When should exotic forest plantation tree species be considered as an invasive threat and how should we treat them? Biological Invasions, 14(9), 1765-1778. http ://doi.org/10.1007/s10530-012-0202-4
- Everitt, B., & Rabe-Hesketh, S. (1997). The analysis of proximity data. Statistics in Medicine, 18(4), 491-492. http ://doi.org/10.1002/(SICI)1097-0258(19990228)18 :4<491 : :AID-SIM57>3.0.CO;2-T
- Gond, V., Freycon, V., Molino, J.-F., Brunaux, O., Ingrassia, F., Joubert, P., … Sabatier, D. (2011). Broad-scale spatial pattern of forest landscape types in the Guiana Shield. International Journal of Applied Earth Observation and Geoinformation, (13), 357-367.
- Griffin, A. R., Midgley, S. J., Bush, D., Cunningham, P. J., & Rinaudo, A. T. (2011). Global uses of Australian acacias - recent trends and future prospects. Diversity and Distributions, 17(5), 837-847. http ://doi.org/10.1111/j.1472-4642.2011.00814.x
- Hoock, J. (1971). Les savanes guyanaises - Kourou - essai de phytoécologie numérique (Thèse de 3e cycle Montpellier 1968 - Mémoires ORSTOM 44).
- Kirschner, F., & Soubeyran, Y. (2007). Espèces exotiques envahissantes : vers un état des lieux global et un réseau d'action coordonné à l'échelle de tout l'outre-mer. Présenté à 13ème Forum des Gestionnaires - Espèces Exotiques Envahissantes : Une Menace Majeure Pour La Biodiversité, MNHN-Paris.
- Kull, C. A., & Rangan, H. (2008). Acacia exchanges : Wattles, thorn trees, and the study of plant movements. Geoforum, 39(3), 1258-1272. http ://doi.org/10.1016/j.geoforum.2007.09.009
- Léotard, G. (2012). Projet LIFE+ Cap DOM : Étude botanique des savanes de Guyane – Rapport final (p. 125). Groupe d'Étude et de Protection des Oiseaux en Guyane (GÉPOG).

- Marchant, R. (2010). Understanding complexity in savannnas : climate, biodiversity and people. Current Opinion in Environmental Sustainability, 2, 101-108. http ://doi.org/10.1016/j.cosust.2010.03.001
- Meddour, R. (2011). La méthode phytosociologique stigmatiste ou Braun-blanqueto-tüxenienne. Université Mouloud Mammeri de Tizi Ouzou, Algérie.
- Miller, J. T., Murphy, D. D., Brown, G. K., Richardson, D. M., & Gonzalez-Orozco, C. E. (2011). The evolution and phylogenetic placement of invasive Australian Acacia species. Diversity and Distributions, 17(5), 848-860. http ://doi.org/10.1111/j.1472-4642.2011.00780.x
- Mittermeier, R. A., Myers, N., Thomsen, J. B., da Fonseca, G. A. B., & Olivieri, S. (1998). Biodiversity Hotspots and Major Tropical Wilderness Areas : Approaches to Setting Conservation Priorities. Conservation Biology, 12(3), 516-520.
- ONF. (2010). Occupation du sol et dynamique foncière - Bande côtière de la Guyane Française 2001-2008 (p. 30). ONF. Consulté à l'adresse GD 20100125.
- Palisse, M. (2013). Libres de savane – Pratiques et imaginaire autour des savanes de Guyane (p. 62). Université des Antilles et de la Guyane (UAG) - Groupe d'Étude et de Protection des oiseaux en Guyane (GÉPOG).
- Palisse, M. (2014). Savanes de Guyane française : la biodiversité bousculée par la diversité culturelle. ethnographiques.org, (27 Biodiversité(S)). Consulté à l'adresse http ://www.ethnographiques.org/2013/ Palisse
- Plante, R., Frontier, S., Le Boeuff, P., & Reys, J.-P. (1983). Stratégies d'échantillonnages et fluctuations naturelles dans des écosystèmes benthiques. Deux exemples en milieu tropical. Oceanologica Acta, (N° SP), 153-157.
- R Core Team. (2013). R : A language and environment for statistical computing. Vienna.
- Réseau École et nature (France), & Réserves naturelles de France. (2013). Nature Biodiversité, tous concernés ! Impliquer les citoyens dans la préservation de la biodiversité. Editions Réseau Ecole et Nature.
- Richardson, D. M., Carruthers, J., Hui, C., Impson, F. A. C., Miller, J. T., Robertson, M. P., … Wilson, J. R. (2011). Human-mediated introductions of Australian acacias - a global experiment in biogeography. Diversity and Distributions, 17, 771-787. http ://doi.org/10.1111/j.1472-4642.2011.00824.x
- Rowlingson, B., & Diggle, P. (1993). Splancs : spatial point pattern analysis code in S-Plus. Computers and Geosciences, 19, 627–655.
- Soubeyran, Y. (2008). Espèces exotiques envahissantes dans les collectivités françaises d'outre-mer. Etat des lieux et recommandations. (Imprimerie Caractère - 2, rue Monge - 15000 Aurillac).
- Strydom, M., Esler, K. J., & Wood, A. R. (2012). Acacia saligna seed banks : Sampling methods and dynamics , Western Cape , South Africa. South African Journal of Botany, 79, 140–147.
- Tecnomo, K. (2014). Jaccard's coefficient. Consulté à l'adresse : http ://people.revoledu.com/kardi/tutorial/Similarity/Jaccard.html
- Van Sickle, J. (1997). Using mean similarity dendrograms to evaluate classifications. Journal of Agricultural, Biological and Environmental Statistics, 2(4), 370-388.
- Werneck, F. P. (2011). The diversification of eastern South American open vegetation biomes : Historical biogeography and perspectives. Quaterny Science Reviews, 1-19.
- Ziller, S. R. (2012). Recommendations for *Acacia mangium* control in French Guiana. Instituto Horus de Desenvolvimento e Conservaçao Ambiental.

© N. de Pracontal / GEPOG

© A. Stier / GEPOG

© A. Stier / GEPOG

© A. Stier / GEPOG

© F. Tabarlet

www.savanes.fr

9 782955 551301

ISBN 978-2-9555513-0-1