French Guiana and new technologies for ecology

The technological and methodological revolution in ecology has led to new and spectacular results. It should be recalled that this progressive transition from "opinel ecology, bits of string" to "technological ecology" was marked out by Legay and Barbault in 1995 [1]. Only a few recent advances since the publication of this book are mentioned here.

1. The Lidar

The Lidar technology [2], first used by space, has been adapted for aerial remote sensing to obtain "digital models" of the terrain. In tropical forests (dense and humid forests), it has made it possible to estimate the height of trees, map them at ground level and, on this occasion, detect archaeological artifacts, the discovery of which is revolutionizing our knowledge of the past of this immense territory that is the Amazon (see Figure 4 in Amazonia: a huge ecosystem in constant evolution) [3].

2. Canopy access and observation devices: from the ground to space

Figure 1. COPAS (Canopy Observatory Permanent Access System) device at the Nouragues station in French Guiana: each of the three pylons constituting the system is instrumented and has at its top a balcony allowing to observe the canopy (A), a pylon (B), and the nacelle during a test by a researcher (C). [Source: © CNRS & Alain Pavé]

In French Guiana, COPAS *(Canopy Observatory Permanent Access System)* [4] is an illustration of the systems used to study the canopy. This initiative was preceded by aerial tests, including the "canopy raft", and is now supplemented by the use of drones [6]. In addition, conventional, instrumented air assets are widely used (aircraft and helicopters), as are satellite assets.

This access to the canopy is necessary, for example to measure the gas exchange between the forest and the atmosphere, measures taken to assess the roles of these forests in climate dynamics [5]. However, the instrumentation of the COPAS system can only provide additional information to that provided by "flow towers" meeting international criteria of the Fluxnet network [7].

Figure 2. Flow tower to measure the gas exchange between the forest and the atmosphere (Paracou site in French Guiana). In the same area, ground-based sensors have been installed to assess GHG emissions, including NOx. [Source: © Alain Pavé]

Such a tower, part of the Amazonian subnetwork, has been installed in Paracou (Figure 2) [8].COPAS, on the other hand, allows access to the interior of the canopy and the observation and sampling of this particular ecosystem, in particular the living beings, animals, plants and microorganisms that inhabit it.

3. Metagenomics

High-throughput DNA sequencing, advances in bioinformatics and biometric methods open up great opportunities for biodiversity assessment at the local level and also for historical reconstruction (see DNA Barcode to characterize biodiversity).

It should be remembered that the metagenome is made up of pieces of DNA, fairly stable molecules, from various organisms and stored in the environment, particularly in the soil. Thus, analyses were carried out on soils from three origins, including a sample taken in Les Nouragues (Table) [9].

Sites	Nombre d'échantillons de sol	Plateforme de séquençage	Nombr séquences a
Zone boréale (Varanger, Norvège)	72	Roche 454 FLX	176 2
Zone tempérée (Alpes françaises, France)	200 (for 25 plots)	Illumina GA IIx	3 901
Zone tropicale (Station des Nouragues, Guyane)	49	Illumina GA IIx	1 636

Table. Assessment of metagenomic analyses carried out on several sites, including the Nouragues Station in French Guiana (see ref. [9]).

The use of sequencing methods makes it possible to establish a real collection of sequences allowing the identification of the species to which an organism taken from the environment belongs. There are plans to manufacture molecular identification kits.

4. Sensors

A major effort has been made on sensors for ecology [10]. Field stations are equipped with them, for example in Nouragues and Paracou in French Guiana: animal monitoring, continuous forest-atmosphere exchange measurements, automatic weather stations, satellite internet connection, etc. [11]. This equipment does not only concern field devices, but also air and space assets. Thus, the ESA BIOMASS mission was prepared in French Guiana as part of the TROPISAR project [12]. in particular to calibrate the radar that will be on board. Guyana was chosen because it has, thanks to the field stations managed by research organisations, a quality of scientific monitoring of forest areas that is unique in the world. The satellite carrying out this mission will be launched from Kourou in 2020 by the Vega launcher.

The header image of this focus is a view of the main site, known as the "inselberg site", of the Nouragues station in French Guiana (100 km south of Cayenne). The other site 5 km to the south, known as the "Arataye site", is equipped with, among other things, the COPAS system presented above. Both sites are equipped with sensors, in particular to measure atmospheric parameters (temperature, pressure, humidity, GHG composition) and satellite links. There are also cameras with automatic triggering for detecting animals and locally assessing numbers of individuals. As a result, the ONSFS [13] has reassessed the jaguar population upward.

Finally, research carried out in French Guiana and more generally in the Amazon region also concerns river and lake hydrosystems, as well as coasts. In the latter case, we can mention the work carried out on marine animals, particularly on Luth turtles, which are even used as carriers of sensors to measure marine parameters (temperature, salinity, direction and speed of the current) during their movements in the North Atlantic.

5. Chemistry of biologically active natural substances

The chemistry of biologically active natural substances is essential, not only for the research of these substances with recovery issues, but also their ecological role, for example as behavioural signals. This chemistry involves sophisticated techniques such as gas chromatography coupled with mass spectrometry (GC-MS) and nuclear magnetic resonance (NMR). This equipment has been installed in French Guiana and contributes to the identification of these substances. Cooperation exists with Brazilian laboratories.

6. Modeling and theorization

Of course, ecological models and theories are not specific to tropical forest ecology, but the objects of study exhibit amplified and specific properties compared to their temperate counterparts. The first is due to their low anthropization, ecological processes are expressed spontaneously. For example, the resilience of these forests is mainly the result of their largely random local spatial structures: the stand is very mixed, very diversified, so that a local disturbance does not obliterate forest regeneration with equivalent diversity.

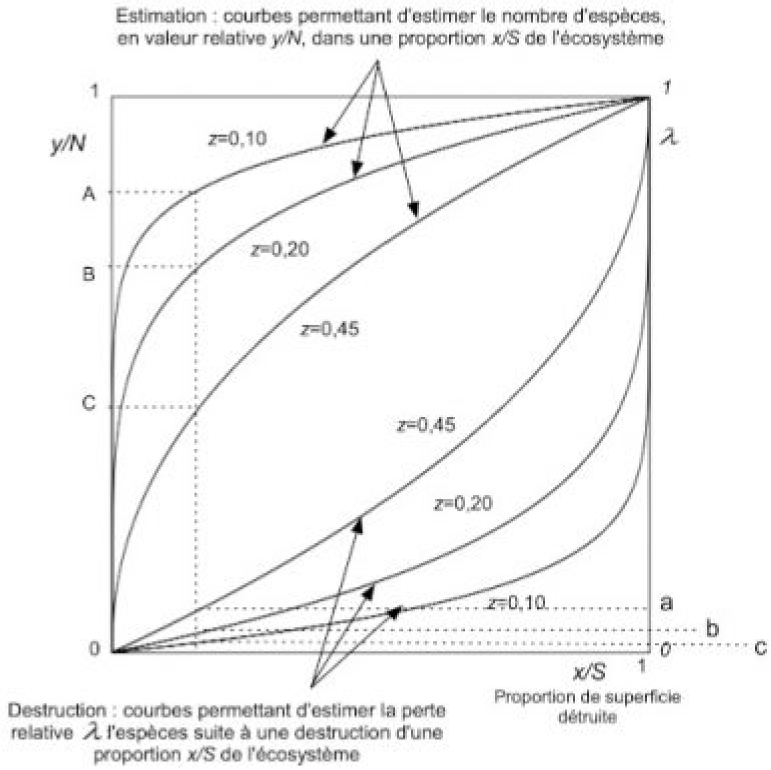

Figure 3. Area-species relationship: use for estimating the relative number of species from a sample area x or for estimating the loss of species following the destruction of the equivalent area. The concavity parameter z must be evaluated from experimental data. For example, curves were plotted for several values of z. x/S represents the relative area involved for an ecosystem with an area S containing N species. For the estimation of the relative number y/N of species present, depending on the value of z, we obtain A or B or C. For the estimation of the relative number of extirpated species, depending on the value of z, we obtain a or b or c. The classical error is to confuse A and a (or B and b, or C and c), resulting in a significant overestimation of disappearances. [Source: Alain Pavé & Gaëlle Fornet, 2010]

Recent theoretical advances include the work of Stephen Hubbell and his team on the "neutralist theory of biodiversity" [14]. His work has had important consequences, including the radical questioning of the "species area law" for the direct estimation of species extinction in an ecosystem [15]. This law, first discovered empirically at the beginning of the 20th century, can also be formally established. Stephen Hubbell demonstrated that the formulas for estimating the number of species and assessing extinction are different. They are nevertheless matched, including an identical z parameter for the same ecosystem. Figure 3 provides examples and shows how misuse leads to an overestimation of extinctions. A simplified presentation can be found in the book [16]. This type of theoretical approach has important and immediate practical consequences, including the need to reduce extinction rates. Hubbell tested his model on intertropical forest ecosystems. In addition, Xubin Pan presents a geometric study of these curves [17], highlighting the symmetries with respect to the center to that of the unit square. In particular, we can deduce the "lower" curves, characterizing the number of extinctions, from the easier to establish upper curves. It is not clear that the message has reached the scientific community. This example illustrates the value of theoretical thinking in developing useful and relevant applications.

Many other examples could be cited: ecology has resolutely taken the technological, methodological and theoretical shift. Nevertheless, there is still a long way to go if we resume the comparison, nevertheless daring, with astronomy. The latter has the advantage of having solid theoretical and mathematically formalized references, ecology is still far from that. Nevertheless, we can be surprised by the progress made before the war, particularly in France, highlighted by Scudo and Ziegler [18]. Second, it seems that the use of theoretical reflection was slowed down until the 1980s, for reasons that are not well known.

Notes and references

Cover image. [Source: © Alain Pavé]

[1] Legay J.M. & Barbault R. (Dir.) (1995) La révolution technologique en écologie. Masson, Paris. (in French)

[2] Laser remote sensing or lidar, an acronym for the English term "laser detection and ranging", is a remote measurement technique based on the analysis of the properties of a beam of light reflected back to its transmitter. Unlike radar, which uses radio waves, or sonar, which uses acoustic waves, lidar uses light (visible spectrum, infrared or ultraviolet). It is almost always produced by a laser.

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[4] Project carried out in collaboration between the University of Ulm, the Körber Foundation, the EU and the CNRS; see http://www.guyane.cnrs.fr/IMG/pdf/FICHE_COPAS_JUILLET2014.pdf

[5] The CNRS has made a significant contribution to the development of certain instruments.

[6] Measuring the forest: http://www.guyane.cnrs.fr/IMG/pdf/Poster_AnAEE_EC_2016.pdf

[7] https://fluxnet.fluxdata.org/

[8] http://sites.fluxdata.org/GF-Guy/

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