



## Bridging Scales in Tropical Forest Monitoring with UAV Observatories Integrating Ecosystem Function, Biodiversity, and Satellite Data

**Nicolas Barbier**<sup>1</sup>, Pierre Ploton<sup>1,7</sup>, Patrick Heuret<sup>1,18</sup>, Julien Engel<sup>1,16</sup>, Benoît Burban<sup>2</sup>, James Ball<sup>3</sup>, Jean-François Bastin<sup>4</sup>, Bhely Angoboy Ilondea<sup>5</sup>, Germain Mbock<sup>6</sup>, Bonaventure Sonké<sup>7</sup>, Bertrand Endezoumou<sup>8</sup>, Baptiste Leborgne<sup>9</sup>, Elsa Ordway<sup>10</sup>, Jean-Christophe Lombardo<sup>11</sup>, Liezl Vermeulen<sup>12</sup>, Adeline Fayolle<sup>13,14</sup>, Donald Midoko Iponga<sup>14</sup>, Lucette Adet<sup>17</sup>, Geraldine Derroire<sup>15</sup>, Ninon Besson<sup>1</sup>, and the Canobs team\*

<sup>1</sup>UMR AMAP, Univ. Montpellier, IRD, CIRAD, CNRS, INRAE, Montpellier, France

<sup>2</sup>UMR ECOFOG, CIRAD, INRAE, AgroparisTech, CNRS, Uni. Guyane, Univ. Antilles, Kourou, France

<sup>3</sup>Dept of Plant Sciences, Cambridge University, Cambridge UK

<sup>4</sup>Gembloux Agro-Bio Tech, University of Liège

<sup>5</sup>INERA, RDC

<sup>6</sup>ENEF, Mbalmayo, Cameroon

<sup>7</sup>LaboSystE, ENS, UY1, Yaoundé, Cameroon

<sup>8</sup>Dja Reserve, MINFOF, Cameroon

<sup>9</sup>CIB OLAM, Republic of Congo

<sup>10</sup>CBI/UCLA, Yaoundé, Cameroon & Los Angeles, USA

<sup>11</sup>Inria, Montpellier, France

<sup>12</sup>MPI for Biogeochemistry, Jena

<sup>13</sup>UPR Forêts et Sociétés, CIRAD, Montpellier, France

<sup>14</sup>CENAREST, Libreville, Gabon

<sup>15</sup>University of Brasilia, Brazil

<sup>16</sup>UMR AMAP, IRD, Herbier de Guyane, Cayenne, French Guiana

<sup>17</sup>CREAF, UAB, Barcelona, Spain

<sup>18</sup>IRD, Noumea, New Caledonia

\*A full list of authors appears at the end of the abstract

Tropical forests play a critical role in the global carbon cycle, biodiversity conservation and climate regulation, yet their internal functioning, phenology and fine-scale dynamics remain poorly characterized. While satellite observations have revolutionized large-scale assessments of forest change, their interpretation is still limited by the scarcity of intermediate-scale observations bridging ground-based measurements and orbital sensors. This gap is particularly acute in dense African forests, where diffuse degradation, small canopy openings and climate-driven stress processes are difficult to detect and attribute, and the capacity of space-borne optical observation is limited by clouds and other atmospheric effects.

Here we present the potential of a network of UAV-based forest observatories (Canobs.net), deployed across tropical forest regions, in South America, Central Africa, South East Asia and Oceania. These observatories combine repeated drone acquisitions (RGB, multispectral photogrammetry and LiDAR), permanent forest inventories, targeted ecophysiological measurements and multi-sensor satellite time series. This integrated framework enables spatially continuous and temporally dense monitoring of canopy structure, forest functioning and biodiversity at resolutions inaccessible to satellites alone.

We show that such observatories are essential to: (i) resolve forest phenology and canopy functioning by linking UAV-based monitoring of canopy dynamics with photosynthetic capacity and satellite signals; (ii) quantify the dynamics and mortality of large trees, which dominate carbon stocks and fluxes; (iii) interpret, calibrate and validate satellite-derived biomass products, Essential Biodiversity Variables and functional forest maps. A major recent advance is the application of the PI@ntNet AI-based species identification app to UAV imagery, allowing identification and monitoring of canopy tree diversity.

The Canobs network forms a critical link between plant- and leaf-scale ecophysiology, field inventories and continental-scale satellite studies, providing a robust framework to better understand and monitor the shifting dynamics of tropical forests under climate and land-use change.

**Canobs team:** Nicolas Barbier<sup>1</sup>, Ninon Besson<sup>1</sup>, Patrick Heuret<sup>1,18</sup>, Maxime Réjou-Méchain<sup>1</sup>, Raphaël Pelissier<sup>1</sup>, Isabelle Maréchaux<sup>1</sup>, Kali Middleby<sup>1</sup>, Hadrien Tulet<sup>1</sup>, Grégoire Vincent<sup>1</sup>, Vanessa Hequet<sup>1</sup>, Thomas Ibanez<sup>1, 18</sup>, Ghislain Vieilledent<sup>1</sup>, Jérôme Munzinger<sup>1</sup>, Julien Engel<sup>1, 16</sup>, Jean-Louis Smock<sup>1,16</sup>, Claire Fortunel<sup>1</sup>, Stéphane Fourtier<sup>1</sup>, Benoît Burban<sup>2</sup>, Géraldine Derroire<sup>2,13,15</sup>, Clément Stahl<sup>2</sup>, Sabrina Costes<sup>2</sup>, Ariane Mirabel<sup>2</sup>, Jean-Yves Goret<sup>2</sup>, James Ball<sup>3</sup>, Jean-François Bastin<sup>4</sup>, Antoine Plumacker<sup>4</sup>, Bhely Angoboy Ilondea<sup>5</sup>, Germain Mbock<sup>6</sup>, Danièle Bikie Mindang<sup>6</sup>, Bonaventure Sonké<sup>7</sup>, Moses Libalah<sup>7</sup>, Bertrand Endezoumou<sup>8</sup>, Baptiste Leborgne<sup>9</sup>, Izaac Zombo<sup>9</sup>, Elsa Ordway<sup>10</sup>, Stéphane Momo Takoudjou<sup>10</sup>, Jean-Christophe Lombardo<sup>11</sup>, Liezl Vermeulen, Gregory Duveiller<sup>12</sup>, Adeline Fayolle<sup>13, 14</sup>, Donrald Midoko Iponga<sup>14</sup>, Lucette Adet<sup>15</sup>, Jordi Martinez Vilalta<sup>17</sup> Pierre Ploton<sup>1, 7</sup>