# BILJOU

## PROJECT

*TOOL FOR CALCULATING AND INTERPRETING WATER FLOWS AND WATER BALANCE AT THE STAND LEVEL*

AFORCE

## PROJECT CONTEXT AND OBJECTIVES

Like all past severe or recurrent droughts, the exceptional drought of 2003 caused widespread tree dieback in the temperate regions of western and central Europe. Climatologists have attributed this extreme event to climate change. Climate change tends to lead to increases in inter-annual climate variability and the probability of extreme events occurring, in particular episodes of drought, heavy rainfall or temperature anomalies.

Many questions have arisen from foresters regarding this period of multi-species forest health crises. Among these, questions frequently arise regarding methods for quantifying the intensity of a drought in a forest environment, or concerning the role of soil properties and stand management on the intensity and frequency of this phenomenon.

These questions highlight the need to update our understanding of the various water flows and their balances. They also reveal the need for operational tools to assess the impact of climate, soil and stands (as well as their management) on the water cycle.

The aim of this project was to develop a website dedicated to forest water balance in order to provide answers to emerging questions regarding the water balance of stands.

## PROJECT CONTENTS

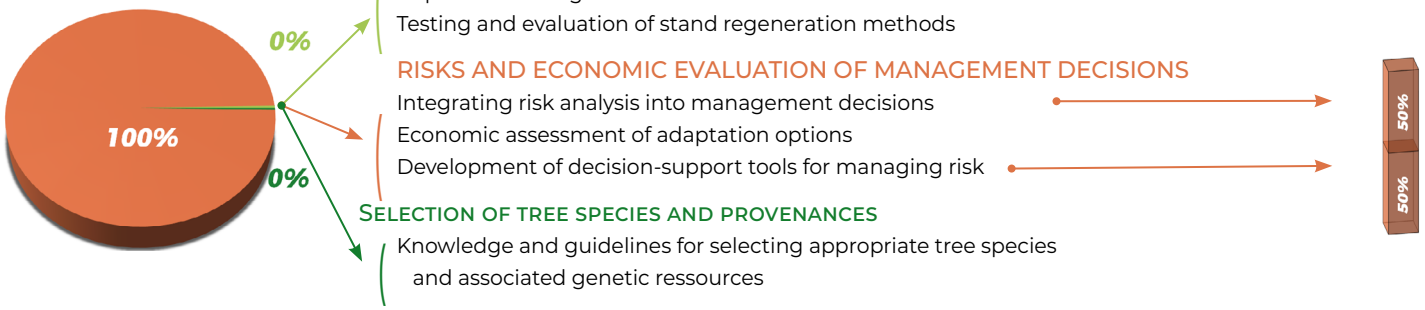
- ✓ TECHNICAL DOCUMENT
- ✓ SCIENTIFIC REPORT
- ✓ OPERATIONAL TOOL
- ✓ RESEARCH TOOL

**This website** (Fig. 1) **is divided into six sections:**

- ‘Home’ introduces the project, the owners and the funders;
- ‘Overview’ sets out the background to this work;
- ‘User Questions’ lists specific queries raised by foresters;
- ‘Forests and Water’ contains a series of technical fact sheets on the water balance and its variations;
- ‘Using the Tool’ enables users to carry out the calculation online, with a ‘User Guide’ page explaining how to use the tool and the format of the required files.
- ‘Contact’ allows users to send an email to the BILJOU© team.


**Figure 1:** Presentation of the BILJOU© website.

## THE PROJECT’S CONTRIBUTION TO AFORCE’S THEMES




## PROJECT PARTNERS

INRA SCIENCE & IMPACT — CNPF — Office National des Forêts — ECOFOR ECOSYSTEMES FORESTIERS

## THE ONLINE COURSE

**The online course (available for self-study) comprises ten learning modules** (Fig. 2).

These fact sheets provide information, first and foremost, on the definition, measurement, orders of magnitude and modelling of major water flows in forest stands.
They cover meteorological variables (precipitation and potential evapotranspiration) as well as parameters relating to two key interfaces: soil–root (root system, available water reserves) and canopy–atmosphere (phenology, leaf area index).
The concept of the water balance, its modelling process, and relevant indicators for characterising water deficits are explained.
Finally, a page is dedicated to the concepts of green and blue water, as drainage flows are also of interest to hydrologists and are relevant to research into forest ecosystem services.
For each fact sheet, users can consult a bibliography of reference scientific articles, in French or English, which can be downloaded, to facilitate self-study – a prerequisite for the informed use of the tool.


**Figure 2:** Extract from an educational web page on water balance.

## THE ONLINE WATER BALANCE CALCULATOR

This tool (Fig. 3) is derived from a more complex model used in research[1], which requires additional parameters and offers greater functionality.
It has been validated by comparison with direct measurements of soil water storage, for each individual flux (tree transpiration, soil and herbaceous layer evapotranspiration, and precipitation interception).

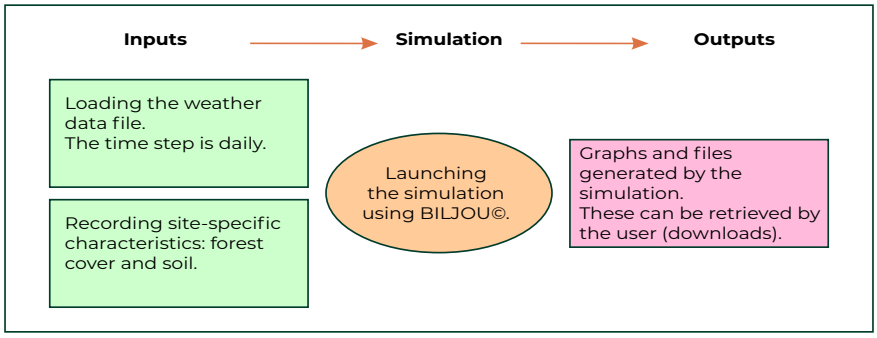



**Figure 3:** Flowchart of the simulation process.

To run an online simulation using BILJOU© (Fig. 4), the user must provide the following information by uploading temporary files (which are immediately deleted from the server upon log-off):

- A meteorological data file with a daily time step containing five parameters: rainfall, temperature, global radiation, wind speed and the air saturation deficit;

- A site characteristics data file containing parameters relating to the two interfaces: canopy cover (foliar index, date of budburst and leaf fall in the case of deciduous species) and soil (for each soil layer: available water reserve, proportion of fine roots, bulk density and wilting point moisture content).

***N.B: Weather data can be obtained via the RENECOFOR network or via Météo-France.***


**Figure 4:** Page for entering a simulation using the BILJOU© online calculation tool.

## Simulation results

**The simulation results are presented in two distinct formats.**

### Numerical results (Fig. 5)

Two files (in text format) are available for the user to download:

- The first provides an annual summary of the main water balance flows, along with a description of three indicators characterising water stress (its duration, intensity and early onset);

- A second set of daily time-series data enables us to track changes in the Penman FEC, the stand's ETR, tree transpiration, drainage and soil water storage (in absolute and relative terms).
It thus provides an accurate representation of ecophysiological processes.

simulation_journalier.txt-1 - Bloc-notes

Fichier Edition Format Affichage Aide

| ANNEE | JOUR | In | ETP | ETR | TR | Reserv | REW | Dr |
|---|---|---|---|---|---|---|---|---|
| 1993 | 1 | 3.1 | 2.6 | 3.5 | 0.4 | 1258.6 | 1.000 | 50.1 |
| 1993 | 2 | 2.9 | 2.4 | 3.3 | 0.4 | 1258.6 | 1.000 | 132.7 |
| 1993 | 3 | 4.3 | 3.6 | 4.3 | 0.0 | 1259.0 | 1.000 | 286.3 |
| 1993 | 4 | 6.0 | 5.8 | 7.2 | 1.2 | 1257.8 | 0.999 | 190.8 |
| 1993 | 5 | 0.6 | 0.5 | 0.6 | 0.0 | 1259.0 | 1.000 | 154.0 |
| 1993 | 6 | 1.5 | 1.3 | 1.5 | 0.0 | 1259.0 | 1.000 | 150.2 |
| 1993 | 7 | 3.1 | 2.6 | 3.1 | 0.0 | 1259.0 | 1.000 | 259.4 |
| 1993 | 8 | 6.0 | 41.5 | 35.9 | 29.9 | 1229.1 | 0.976 | 198.5 |
| 1993 | 9 | 6.0 | 23.8 | 22.6 | 16.6 | 1242.4 | 0.987 | 72.7 |
| 1993 | 10 | 6.0 | 23.5 | 22.3 | 16.3 | 1242.7 | 0.987 | 235.7 |
| 1993 | 11 | 1.8 | 1.5 | 1.8 | 0.0 | 1259.0 | 1.000 | 66.7 |
| 1993 | 12 | 6.0 | 35.8 | 31.7 | 25.7 | 1233.3 | 0.980 | 149.8 |
| 1993 | 13 | 6.0 | 13.6 | 13.4 | 7.4 | 1251.6 | 0.994 | 12.8 |
| 1993 | 14 | 6.0 | 9.8 | 10.2 | 4.2 | 1254.8 | 0.997 | 69.8 |
| 1993 | 15 | 6.0 | 14.4 | 14.0 | 8.0 | 1251.0 | 0.994 | 212.9 |
| 1993 | 16 | 2.5 | 2.1 | 2.8 | 0.3 | 1258.7 | 1.000 | 220.3 |
| 1993 | 17 | 6.0 | 29.5 | 27.0 | 21.0 | 1238.0 | 0.983 | 46.4 |
| 1993 | 18 | 6.0 | 45.3 | 38.8 | 32.8 | 1226.2 | 0.974 | 272.0 |
| 1993 | 19 | 6.0 | 52.6 | 44.2 | 38.2 | 1220.8 | 0.970 | 182.1 |
| 1993 | 20 | 6.0 | 47.6 | 40.5 | 34.5 | 1224.5 | 0.973 | 154.8 |
| 1993 | 21 | 6.0 | 13.0 | 12.9 | 6.9 | 1252.1 | 0.995 | 101.4 |
| 1993 | 22 | 3.7 | 43.8 | 35.8 | 32.1 | 1226.9 | 0.974 | 8.1 |
| 1993 | 23 | 3.8 | 3.2 | 3.8 | 0.0 | 1259.0 | 1.000 | 17.0 |
| 1993 | 24 | 6.0 | 29.7 | 27.1 | 21.1 | 1237.9 | 0.983 | 69.3 |
| 1993 | 25 | 6.0 | 6.1 | 7.5 | 1.5 | 1257.5 | 0.999 | 245.3 |
| 1993 | 26 | 6.0 | 26.1 | 24.4 | 18.4 | 1240.6 | 0.985 | 109.3 |
| 1993 | 27 | 6.0 | 21.5 | 20.4 | 14.4 | 1244.6 | 0.989 | 56.6 |
| 1993 | 28 | 6.0 | 13.3 | 13.1 | 7.1 | 1251.9 | 0.994 | 167.0 |
| 1993 | 29 | 3.2 | 2.7 | 3.6 | 0.4 | 1258.6 | 1.000 | 80.6 |
| 1993 | 30 | 6.0 | 16.8 | 16.2 | 10.2 | 1248.8 | 0.992 | 119.4 |
| 1993 | 31 | 6.0 | 52.4 | 44.1 | 38.1 | 1220.9 | 0.970 | 221.6 |
| 1993 | 32 | 6.0 | 8.0 | 8.8 | 2.8 | 1256.2 | 0.998 | 78.4 |
| 1993 | 33 | 2.0 | 20.8 | 17.2 | 15.2 | 1243.8 | 0.988 | 2.6 |

**Figure 5:** : Example of results in text files at daily time steps, generated by a simulation using the BILJOU© online calculation tool, which enables the modelled variables to be tracked.

### Graphical results (Fig. 6)

This tool displays the results of the calculation on screen using various graphs.
Bar charts can show the ranking of the years with the highest water deficits (Fig. 6.a) or graphs can illustrate changes in soil water reserves, ETR or precipitation interception over the course of the year (Fig. 6.b), for example.

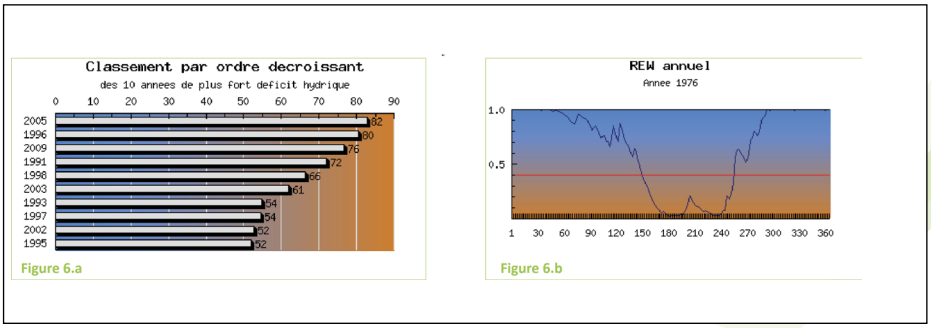



**Figure 6:** Examples of graphical representations of the results from the BILJOU© online calculation tool
**Fig. 6.a:** Example of a ranking of the 10 years with the highest water deficit over a 25-year period
**Fig. 6.b:** Example of the intra-annual variation in soil water reserves for a single year.

### Examples of simulations already carried out

Some examples of applications already carried out are listed below:

- An assessment of the impact, in terms of frequency and intensity, of the risk of drought under contrasting climate scenarios up to the year 2100 (example from the ANR CLIMATOR programme);

- A study of the geographical variability in the local intensity of water deficits in lowland beech forests at the western limit of their range (example from the ANR DRYADE programme);

- A study of water consumption in Douglas fir stands managed using different contrasting silvicultural practices in the context of stand decline (example from the ANR DRYADE programme).

## THE KEY LESSONS

First and foremost, BILJOU© enables the gradual integration of water dynamics into silvicultural decision-making. The tool provides realistic simulations of silvicultural and/or climatic scenarios, as well as quantifications of stand water consumption and drought events. The tool also quantifies the impact of stand type, its phenology (in the case of deciduous stands) and its development on the stand's water consumption. It replicates the dynamics of water uptake by roots according to their distribution and the water status of the various soil layers. It differs from other models with longer time steps, which do not accurately represent ecophysiological processes such as stomatal regulation and precipitation interception. Finally, compared with other ecophysiological models, it requires only a limited number of parameters to be input by the user.

# TARGET AUDIENCE AND AIM OF THE PROJECT

Difficulty in appropriation: LOW | MEDIUM | HIGH

This objective does not apply to this audience: ○

| TARGET AUDIENCE \ OBJECTIVE | **Management**<br>Tools and recommendations | **Research and development**<br>Tools and content creation | **Education**<br>Knowledge acquisition |
|---|---|---|---|
| **Forest owners** | ● | ○ | ● |
| **Technical forestry staff** | ● | ○ | ● |
| **Research and development practitioners** | ● | ● | ● |
| **Higher education students** | ○ | ● | ● |
| **Technical education Students** | ○ | ○ | ● |

The target audience for this tool comprises forest managers and experts, as well as those responsible for development or training in bioclimatology, silviculture, ecophysiology and forest health monitoring. The tool is also intended for teachers, researchers and students. Two training courses, held at INRA Champenoux, have trained the first cohorts of users. Some training institutions (forestry BTS programmes) regularly use the online tool for their teaching and projects.

# TEAM

The website and the BILJOU© tool were developed by the UMR EEF and INRA.
The project coordinator was Mr André Granier (Integrated Tree and Ecosystem Functioning Team).
This project was carried out with the participation of Ms Nathalie Bréda (Forest Phytoecology Team).
Mr Damien Maurice and Mr Guillaume Ehinger (Geographic Information Systems & Databases Technical Unit).

# FOR MORE INFORMATION

Further information is available on the RMT AFORCE's BILJOU© project page and on the RMT AFORCE's sylvoclimatic tools page.

This tool can be accessed at the following address (https://appgeodb.nancy.inrae.fr/biljou/fr/).

A service providing access to drought maps covering past, present and future climates is currently being developed (funded by MP ACCAF, MAAF – Forest Health Department, and MAAF FORET-21).

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[1] Granier, A., Bréda, N., Biron, P., & Villette, S. (1999). A lumped water balance model to evaluate duration and intensity of drought constraints in forest stands. Ecological Modelling, 116(2-3), 269-283.


# PROJECT FUNDERS

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
MINISTÈRE DE L'AGRICULTURE ET DE L'ALIMENTATION

ECOFOR
ECOSYSTEMES FORESTIERS

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