ARCHI PROJECT

ARCHITECTURAL INDICATORS OF TREES RESPONSE TO CLIMATE CHANGE

AFORCE

PROJECT CONTEXT AND OBJECTIVES

There is uncertainties regarding the ability of trees to withstand abrupt climate change.
Developed in 2010, the Archi method derives its acronym from the word «architecture.»
The project aims to provide a visual field-assessment method for estimating tree resilience.
Notably, this method led to the creation of ARCHI identification keys.

PROJECT CONTENT

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

The tool consists of educational fact sheets featuring labeled diagram.
By comparing the tree they are observing with diagrams illustrating the sequence of development for that species, the user can determine the tree's stage of development.
The approach involves carrying out two sets of observations:

- Observing symptoms of crown deterioration
(sparse branching, loss of apical dominance, dieback, etc.);
- Observing crown recovery processes
(development of replacement shoots that can play a crucial, positive role following stress).

The ARCHI method is adapted for specific tree species or groups of species.
It is currently available for fourteen of them:
Broadleaved species: *Castanea sativa, Quercus robur Q petraea, Q. pubescens, Q. suber, Q. ilex, and Fagus sylvatica;*
Coniferous species: *Pseudotsuga menziessi, Picea abies, Pinus sylvestris, P. nigra. Corsicana and salzmanni, P.uncinata and Abies alba*.

PROJECT CONTRIBUTION TO AFORCE THEMES

PROJECT PARTNERS

CNPF INSTITUT POUR LE DÉVELOPPEMENT FORESTIER

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TREE ARCHITECTURE

The study of tree architecture is based on a morphological analysis of the above-ground parts. Each species has a number of categories of axes, each with specific functions, which constitute the Architectural Unit (AU) of that species (Fig. 1).
The crown of a young tree takes on a rounded shape, most often resulting from the duplication of the UA into main branches, which subsequently branch out into increasingly smaller branches according to a genetically programmed sequence.
The architectural sequence summarises the major events in the plant's life and the spatial organisation at each stage of development.

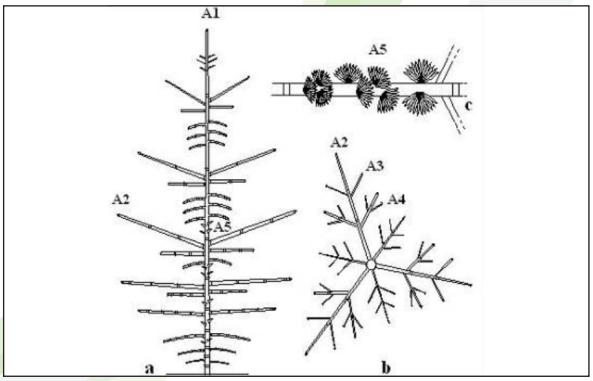

Figure 1: Architectural unit for Cedrus atlantica *(A1: Main stem, A2: Branches, A3: Twigs, A4: Fine twigs, A5: Annual shoots).*

Ontogenetic diagnosis

Identification of a tree's developmental stage

Juvenile stage (Fig. 2.1)**:** Consistent with the UA. The tree has a strongly hierarchical structure centred on a single trunk, and the branches bear twigs and slender branches. The crown has a pyramidal shape and the annual growth on the trunk is long.

Adult stage (Fig. 2.2 et 3)**:** Branching becomes more extensive through direct duplication of branches. Expression of sexual characteristics and the onset of crown formation. This stage is identifiable by the presence of main forks. The crown is regular and compact, rounding off at the apex.

Mature stage (Fig. 2.3)**:** Decline in branching capacity and strong expression of sexual reproduction. The crown consists of forks that are increasingly close together. The edges of the crown have very short shoots with little branching. Homogenisation of structures.

Senescent stage (Fig. 2.4 et 3)**:** Formation of minimal units; mortality of branches and delayed regrowth no longer compensating for this mortality. The crown breaks up and loses its compactness.

The resources consist of educational fact sheets with labelled diagrams of the four stages.

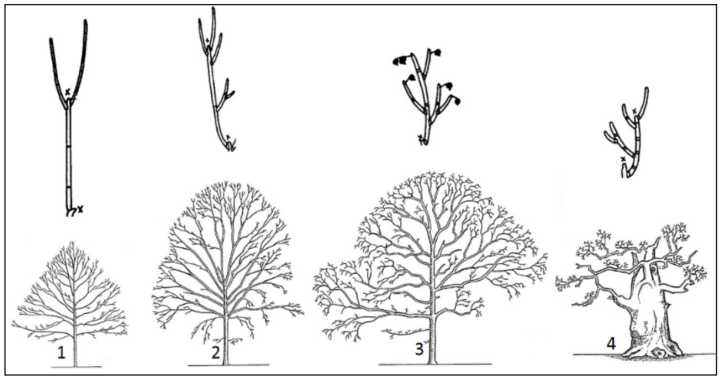

Figure 2: Example of a growth sequence (using the pedunculate oak as an example) with details of the apical axes.

Source: C. Drénou (IDF © CNPF)

Figure 3: An example of the structure of a mature pedunculate oak (left) and a senescent pedunculate oak (right).

Architectural markers

The criteria are assessed at various levels of the tree: the whole tree, the crown (excluding the topmost part), the treetop, the trunk, the lower branches, etc.
The tools consist of checklists (Fig. 4) of architectural markers to be ticked off by tree species.

Checklist of architectural markers for mature Abies alba in the crown, outside the competition zone

Crown shape: pyramidal, rounded or tabular
Inter-verticillate shoots on the trunk: yes / no
Abrupt clustering of branches along the trunk: yes / no
Recurring forks on the branches: yes / no
Vegetative zone between the crown bearing female cones and the male zone: yes / no
Epicormic shoots on branches: yes / no
Epicormic shoots on the trunk: yes / no
Branch straightening: yes / no
Temporary cessation of activity of the apical growth bud: yes / no
Lifespan of leaves on the trunk, branches and twigs
Mortality on the trunk, branches and/or twigs: yes / no

Figure 4: Example of a variety of architectural markers in the crown of Abies alba, excluding competition.

ARCHI METHOD

Substitutes = suckers, rejects, epicormic shoots

The method incorporates the dynamics of resilience by examining the substitutes.
It distinguishes between **branches** (the predictable growth of a tree) and **substitutes** (a reaction to disturbances) that serve to repair, compensate for or replace damaged structures.
A substitute can be recognised by the base it forms at its base (Fig. 5).

Three types of substitute cells, each with different morphologies and functions, can be identified (Fig. 6).

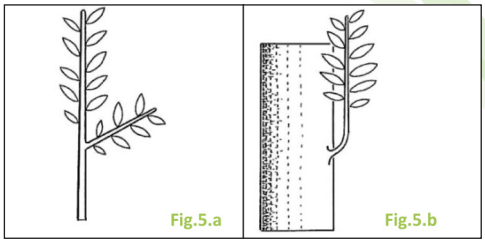

Figure 5: Difference between the main group (5.a) and the reserve group (5.b).

Type of substitute	Morphology	Function
Orthotropic (Fig. 6.a)	Vertical growth, radial symmetry, spiral leaf arrangement	Replicating the structure of young trees
Plagiotrope (Fig. 6.b)	Horizontal to oblique growth, bilateral symmetry, leaves arranged in a single row (distichous)	Reiterate the structure of the branches or twigs
Ageotropic (Fig. 6.c)	No preferred growth direction or symmetry; reduced growth; limited lifespan	Ensuring the survival of the main axis

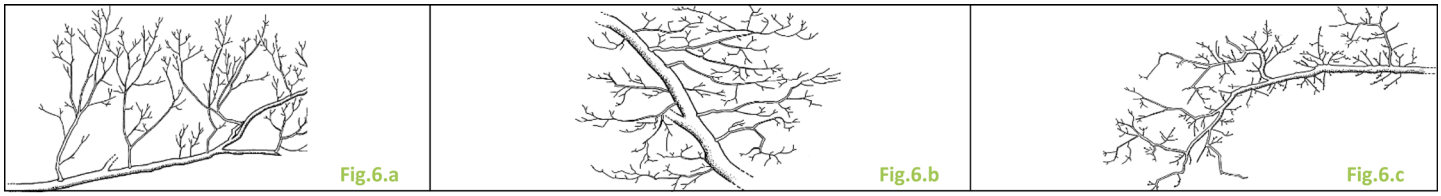

Figure 6: Graphical example of substitutes: orthotropic (Fig. 6.a), plagiotropic (Fig. 6.b) and ageotropic (Fig. 6.c).

ARCHI method and typology

Based on an observation of the symptoms, an ARCHI classification of the condition of the trees can be carried out (Fig. 7).

Typologie:

- **Healthy** (Type Sa)
- **Stressed** (Type S1, S2)
- **Resilient** (Types R1, R2)
- **Declining** (Type D)
- **Irreversibly dying** (Types I1, I2)
- **Dead** (Type M)

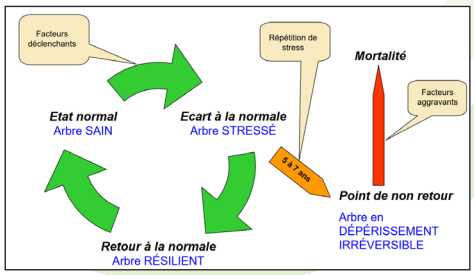

Figure 7: A schematic representation of the ARCHI method and associated typologies.

Example of a determination key

To facilitate field-based diagnostic procedures, identification guides for architectural types by tree species or group of species have been developed.
These tools cover all the necessary observations in the form of yes/no questions.
The ARCHI guides are available on the website of the National Centre for Forest Ownership.

THE KEY LESSONS

**The ARCHI method is based on observing tree architecture at different ontogenetic stages through symptoms of degradation (architectural markers) and dynamics of resilience (compensatory mechanisms) observed across the entire tree.
It reflects the non-linear nature of trees' response dynamics to stress.**

This method provides a short-term diagnosis of whether or not tree decline is reversible (the future of the trees). It prioritises the series of observations to be carried out using identification keys, taking into account the botanical characteristics of each tree species.

TARGET AUDIENCE AND AIM OF THE PROJECT

Difficulty in appropriation: LOW MEDIUM HIGH

This objective does not apply to this audience: ○

OBJECTIVE / TARGET AUDIENCE	**Management** Tools and recommendations	**Research and development** Tools and content creation	**Education** Knowledge acquisition
Forest owners	●	○	●
Technical forestry staff	●	○	●
Research and development practitioners	○	○	●
Higher education students	●	○	●
Technical education Students	●	○	●

This tool is **primarily intended for various technical practitioners** (managers, technicians, arborists, etc.) and also has **clear educational value for teachers.**

The ARCHI method can be applied in fields as varied as biology, forestry, autecology and genetics.

TEAM

The project coordinator is Ms Sylvie Annabelle Sabatier (CIRAD-AMAP).
This project was carried out with the participation of Mr Yves Caraglio (CIRAD-AMAP), Mr Christophe Drénou (CNPF-IDF), Mr Michael Guéroult and Mr François Pailler (INRA-AMAP), as well as Mr Nicolas Mariotte and Mr Hendrik Davi (INRA-URFM).

FOR MORE INFORMATION

Further information is available on the CNPF website, on the ARCHI project page and on the RMT AFORCE sylvoclimatic tools page.

To become proficient in the ARCHI method, approximately two days' field training is required for each tree species or group of closely related species: oaks, pines, etc.

Find out more about ARCHI training courses.

The keys have been translated into Spanish and are available as an app for Android phones and tablets (the release of the app is currently under consideration).

PROJECT FUNDERS

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MINISTÈRE DE L'AGRICULTURE DE L'AGRO-ALIMENTAIRE ET DE LA FORÊT

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