Comparison among phenological monitoring methods on beech populations (*Fagus sylvatica* L.) of the Apennines

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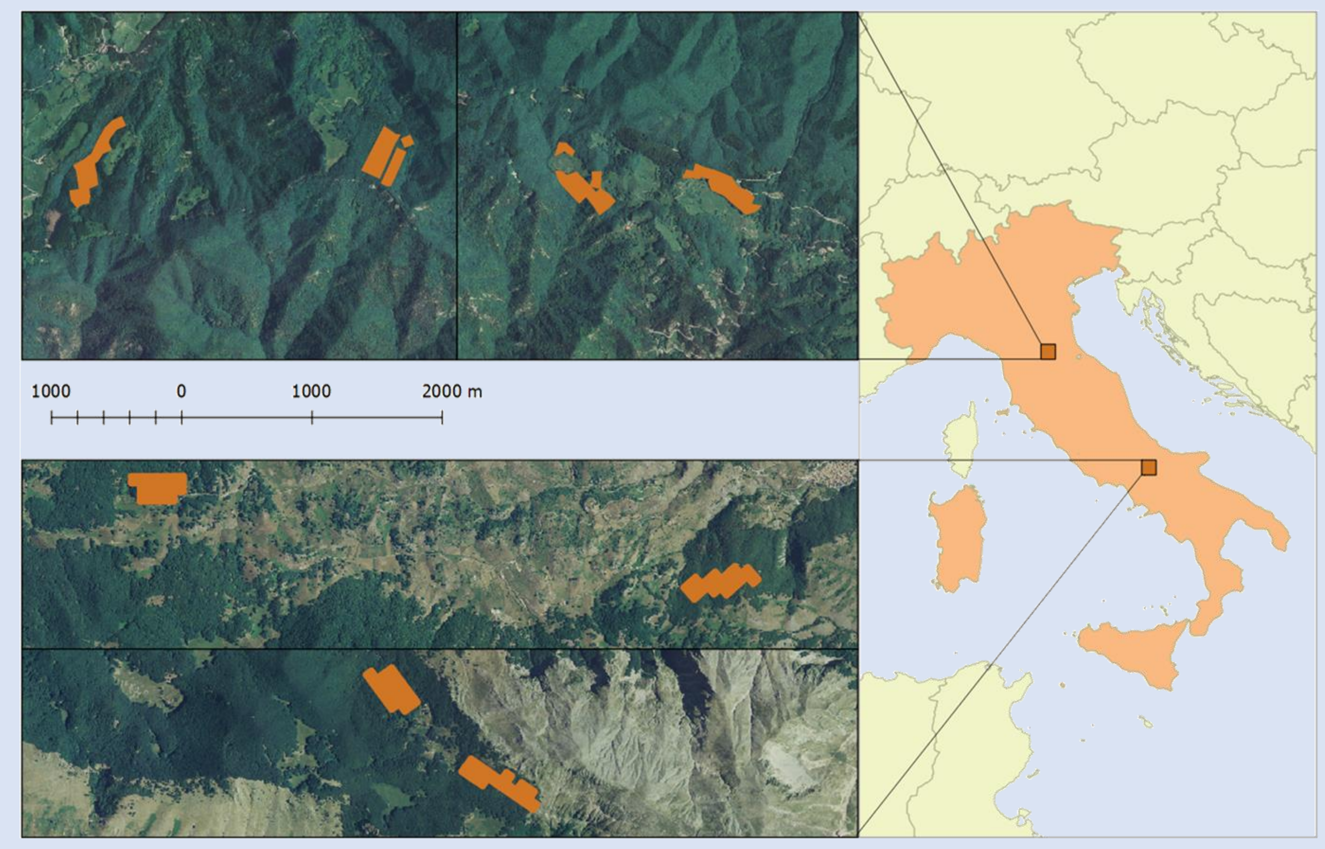
Introduction

Forest populations are generally characterized by good level of **phenotypic plasticity, an useful trait for survival, especially in relation to climate change**, which requires plastic responses in relatively short term. This feature is linked both to wide distribution range of forest species and to the length of their biological cycle, that expose trees to continuous fluctuations of pedo-climatic characteristics and biotic communities present within sites.

Phenological traits are adaptive, genetically controlled, but also influenced by environmental factors (air temperature, water availability and photoperiod). They can affect not only the duration of the growing season, but also the population fitness and the species distribution range. Phenological monitoring is therefore considered a valuable tool to study the effect of climate change on species and provenances, to define their resilience and to modelling their distribution range in the near future.

The **Life15-CCA 000089 AForClimate** Project aims to **adapt the forest planning of beech forests** to climate variability, defining methods able to measuring the climatic factors that predispose and may predict specific behaviors related to phenology, growth and resilience. Indeed, forestry practices can influence the evolutionary processes and adaptation of forests, promoting growth, natural regeneration, genetic diversity and therefore the species resilience.

For these reasons during the project, starting from 2018, phenology is monitoring in two beech forests, the Giogo-Casaglia forest (Firenze, Toscana) and the Roccamandolfi forest (Isernia, Molise). Leaf and cambium phenology were monitoring comparing different methodologies, which consider different spatial and temporal scales, as scoring systems and remote sensing for leaf phenology, in order to define a method that improves the efficiency of monitoring in terms of quality of collected data, subjectivity of monitoring and economic sustainability. The following are the preliminary results related to the phenological monitoring carried out in spring 2018.



Methods and results

In each area the monitoring affected 4 site conditions, defined on the basis of exposure (northern and southern) and elevation range (high and low), and 20 test areas randomly distributed within these 4 sectors. In below tables both the different phenological methods used and the monitored material are reported

Monitoring of leaves unfolding by Sentinel 1
Monitoring method
Remote sensing of phenology on the 4 sectors. Backscatter (Gamma) in the C-Band of the microwave radar satellite sensor Sentinel 1. GRDH images products at 10 m of geometric resolution
Frequency of monitoring
12 days of complete swath revisiting periods at the available dates for each of the satellite (S1A and S1B). Combining the two satellites, and their partial revisiting period (6 days interval) the monitoring frequency can be increased from 6 to 3 days interval.

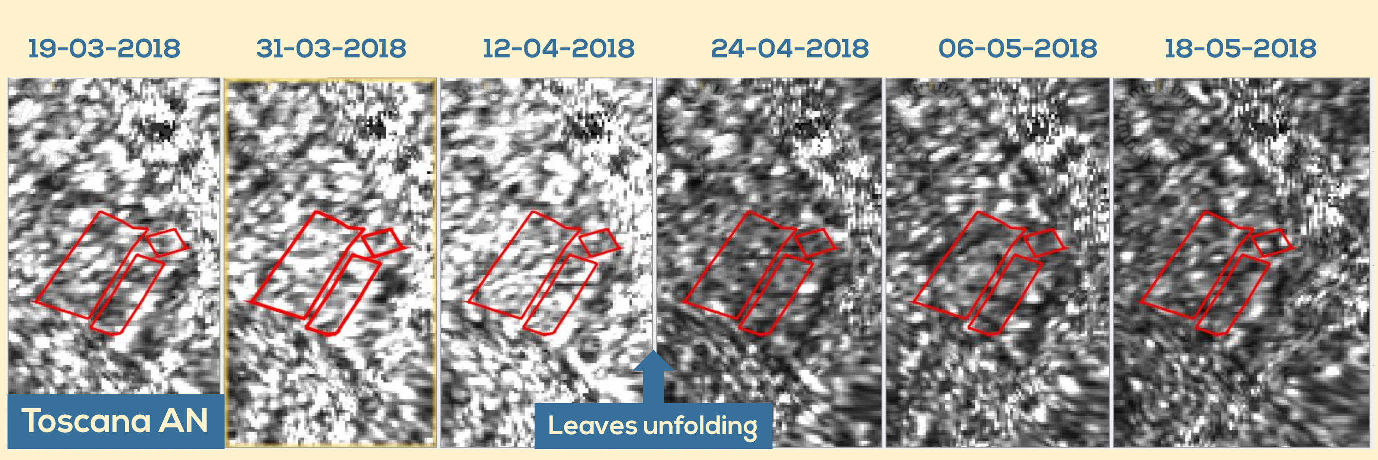
Monitoring of cambium phenology
Monitoring method
Collection of woody microcores at breast height with Trephor® and monitoring of intra-annual phases of xylem formation through microscope observation of thin slices under visible and polarized light at 20X - 40X magnifications.
Frequency of monitoring
Weekly intervals, starting from March 28, 2018
Number of monitored trees
6 dominant/co-dominant trees with minimum DBH of 25 cm for each of the 20 test areas. They are the same trees monitored for bud break

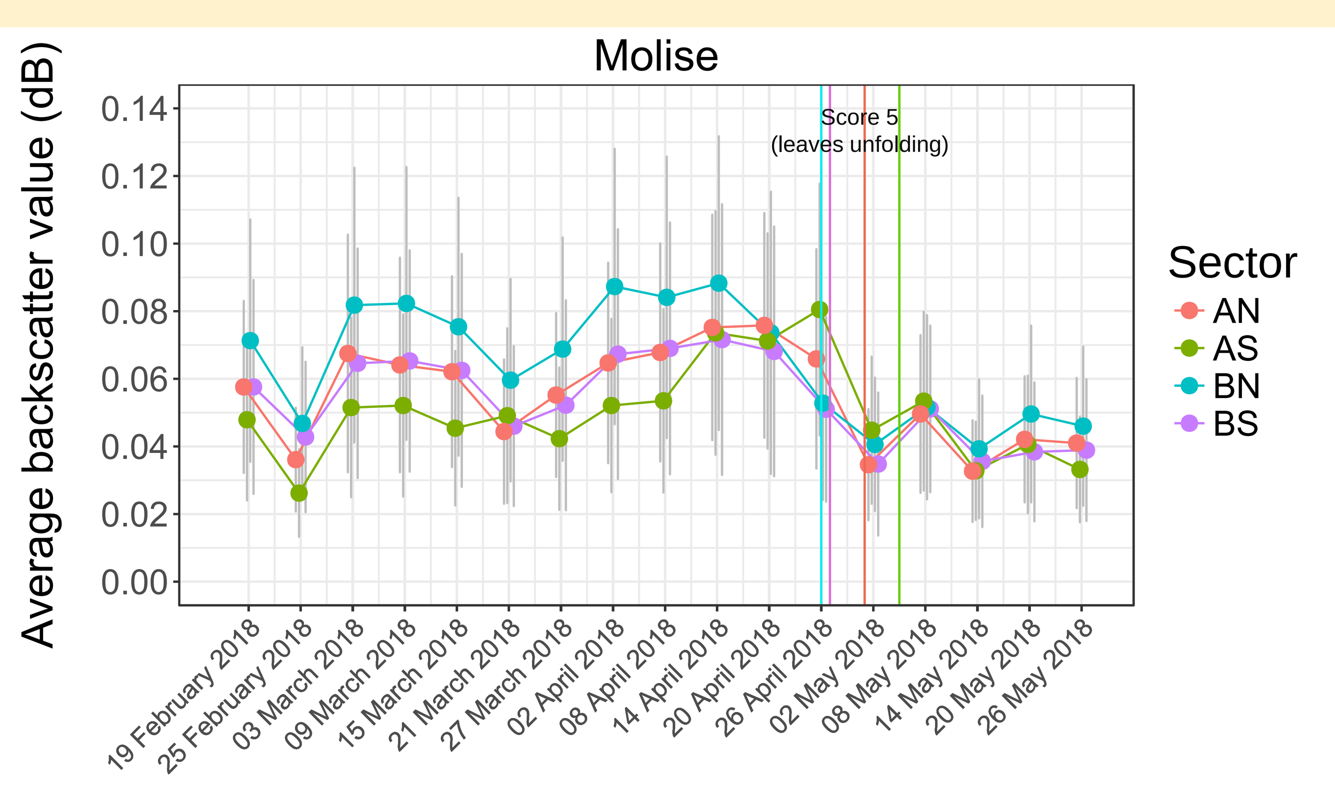
Monitoring of bud break phenology
Monitoring method
Direct visual observation in field of tree crown and assigning of a score to the phase reached by buds. Scoring system, with a 5 score scale
Frequency of monitoring
Weekly intervals Starting from March 28, 2018
Number of monitored trees
6 dominant/co-dominant trees with minimum DBH of 25 cm for each of the 20 test areas. Overall 120 trees were monitored

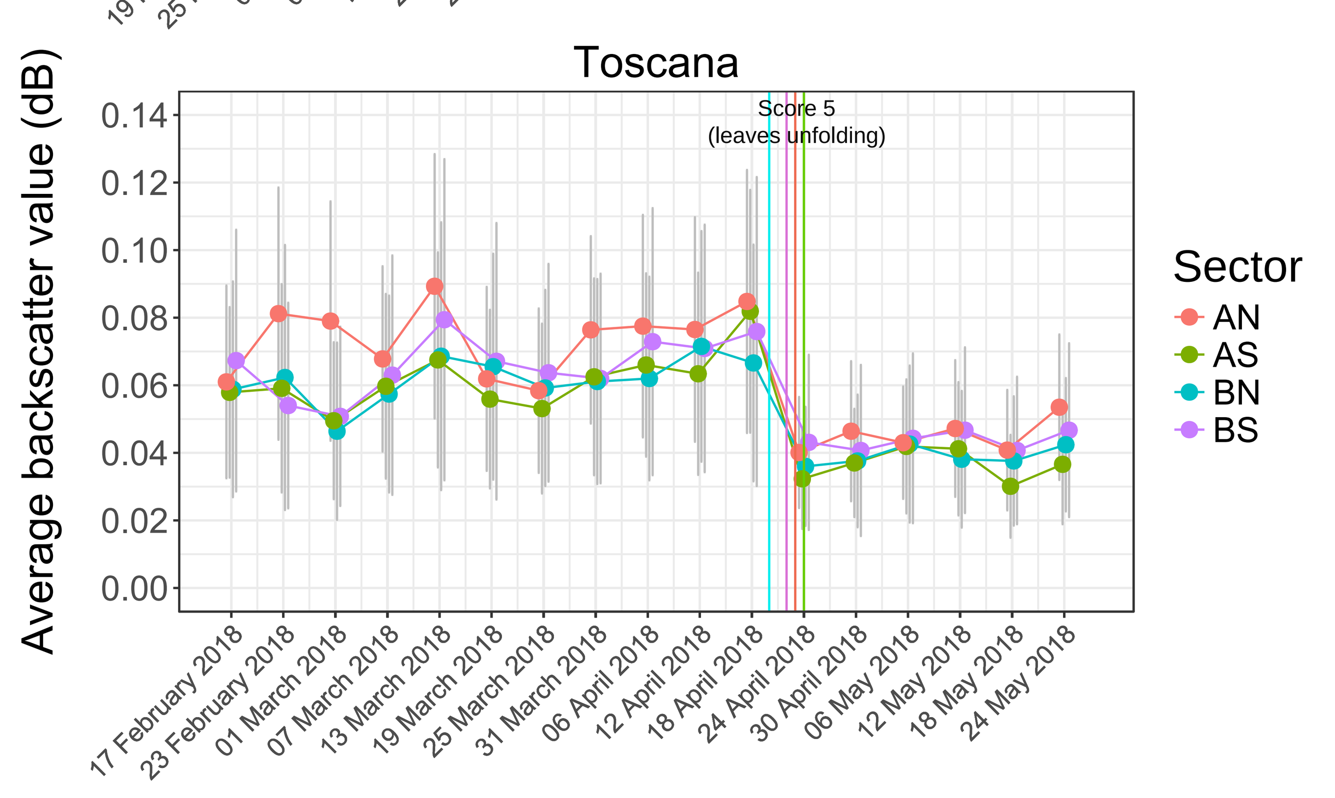
Scoring system adopted for bud break monitoring on *Fagus sylvatica*

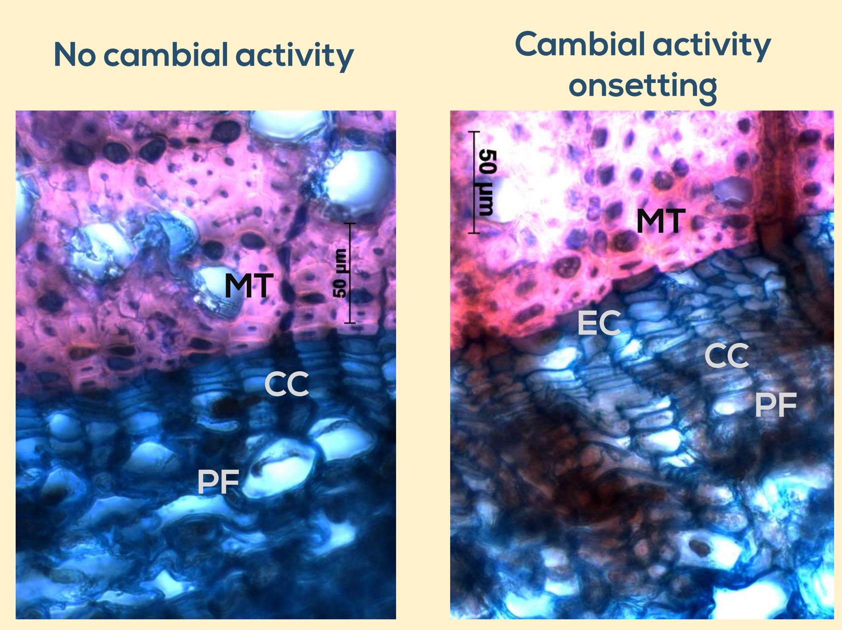
Score 1	Score 2	Score 3	Score 4	Score 5
Dormant bud completely enveloped by the scales (perulae)	Bud swelling with scales slightly diverging showing a narrow yellow/green margin	Bud breakdown, scales still present, young leaves emerging from the upper part of the bud, but still joined	Leaf opening stage, first young leaves are visible	Leaves completely unfolded on at least 50% of the crown

According to BBCH international system the score is considered reached when at least 50% of the observed buds on the crown achieved the corresponding phase (Meier U., 2001)

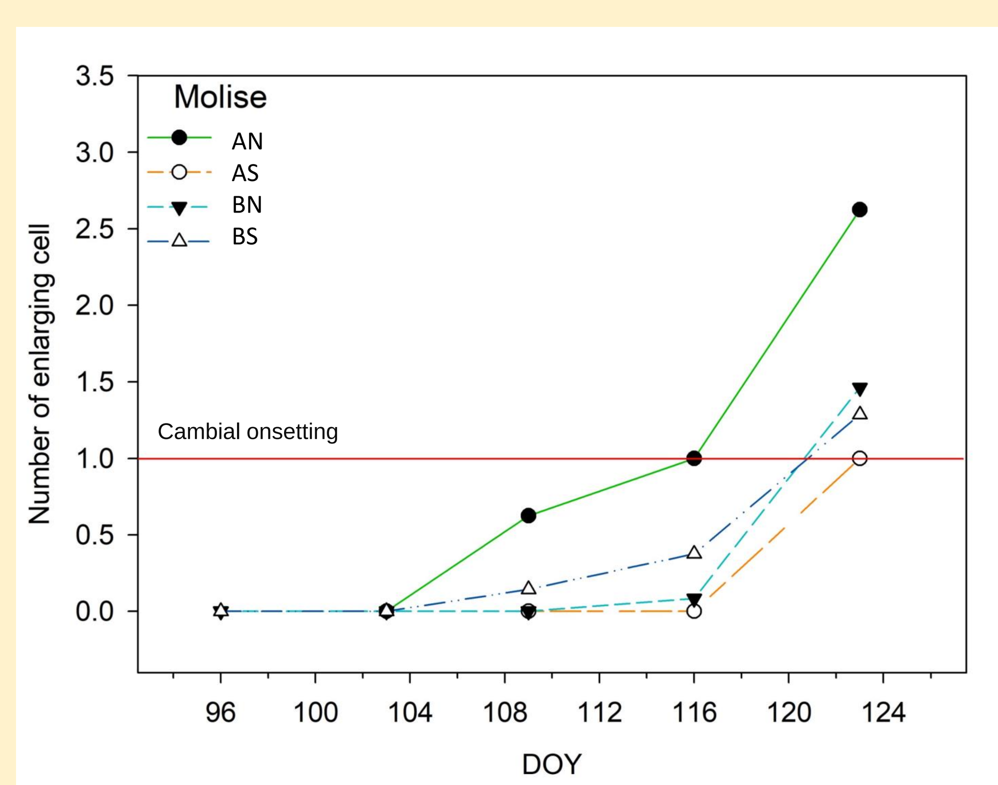


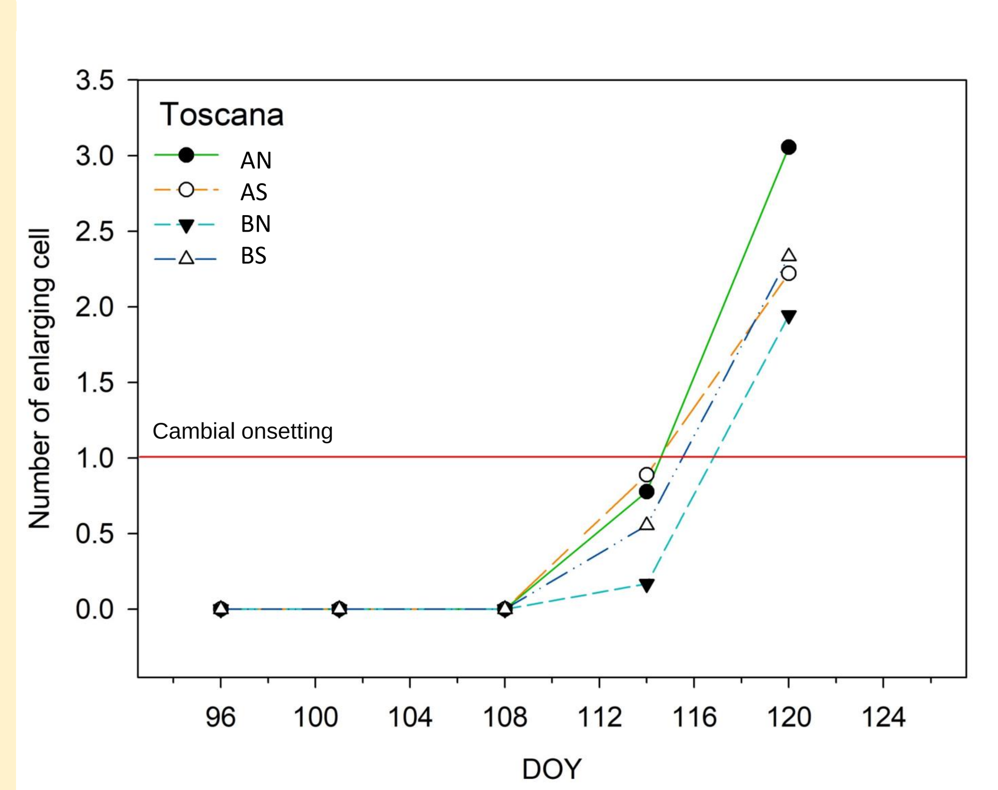






MT: Mature cells of previous year – CC: Cambial cells
EC: Enlarging cells – PF: Phloem fibers



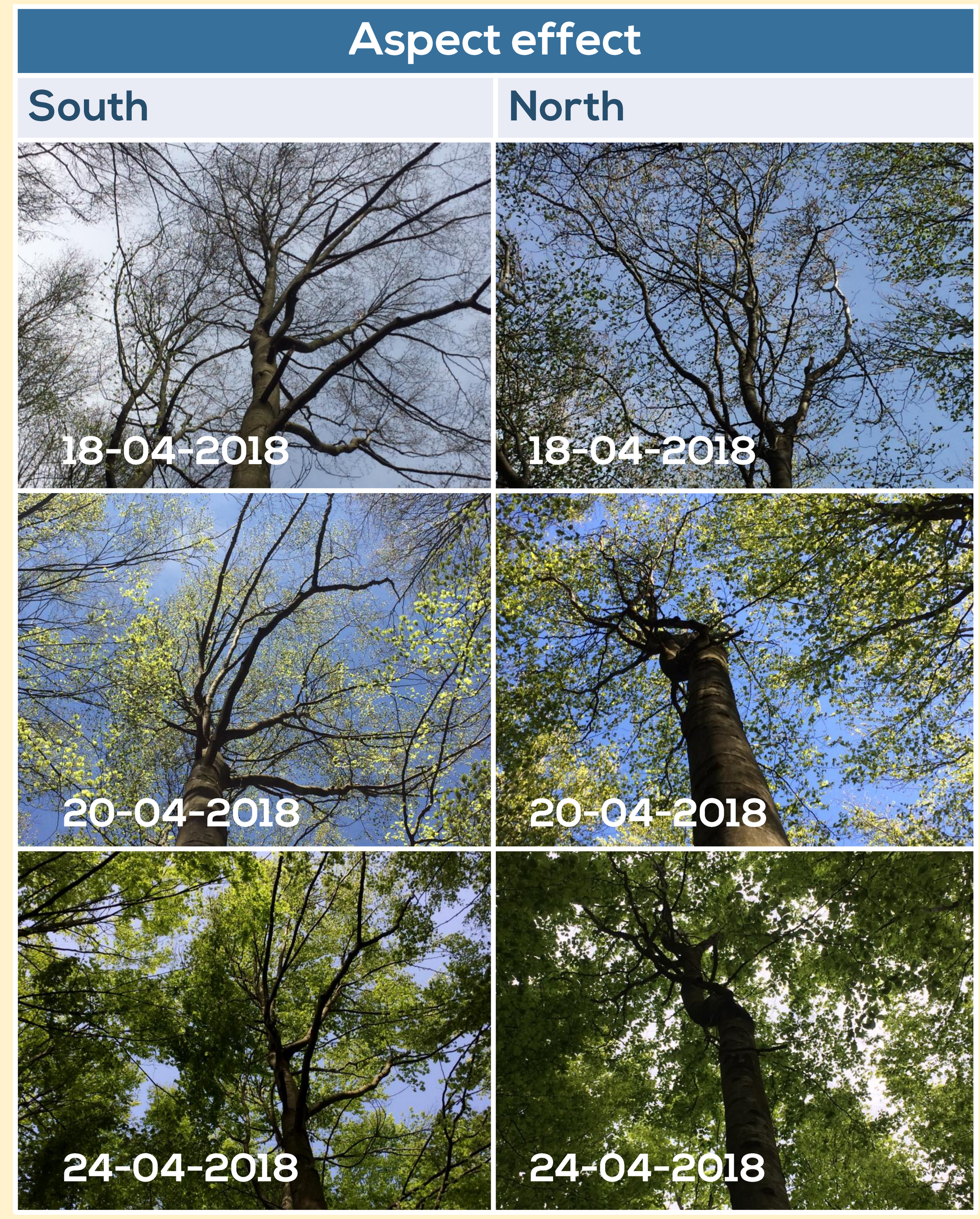


Leaves flashing

Dates in Day Of the Year (DOY)

Aspect	Altitude	ID	Bud break (Score 3)		Leaves unfolding (Score 5)	
			Toscana	Molise	Toscana	Molise
North	High	AN	108	116	113	123
	Low	BN	106	109	110	116
South	High	AS	110	120	114	126
	Low	BS	108	109	112	117

Aspect effect



Highlights

- Lower altitudinal belt showed to be phenologically synchronised due to similar adaptive traits in similar ecological condition (contact with the Turkey oak higher belt).
- Higher altitudinal belt showed an early onsetting at the northern aspect compared with the southern one. This difference fade off until the complete leaves unfolding which tends to be synchronised.
- Wood radial increment (presence of enlarging cells - EC) starts with the complete leaves unfolding (Score 5).
- Microwave remote sensing from Sentinel 1 proved to be an operative detection tool for leaves unfolding phase (Score 5) with a 6 days temporal accuracy and 10 m geometric resolution.
- It is necessary to link the complete flashing activity to environmental features and parametrize specific models. These models can be coupled with remote sensing data to realize a continuous remote monitoring of phenological phases.