ENVIRONMENTAL MONITORING IN MEDITERRANEAN FOREST ECOSYSTEMS OF CROATIA

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Croatia in numbers

- Population: 4,290,612 inhabitants
- Coastline: 6,278 km
- Highest peak: 1,831 m (Dinara)
- Number of islands, islets, stacks, and reefs: 1,244
INTRODUCTION

- almost half of Croatian total forest area - highly significant
- provide multiple goods and services
  (water-related services, soil protection, and an exceptional richness in terms of biodiversity and unique non-wood forest products like aromatic plants, truffles, mushrooms, etc.) largely related to their environmental and social functions
ICP FORESTS

International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests

launched in 1985 under the Convention on Long-range Transboundary Air Pollution (CLRTAP) of the UN Economic Commission for Europe (UNECE)

in response to wide public and political concern over extensive forest damage in Europe in the beginning of the 1980s.
ICP Forests

HARMONIZATION

ICP FORESTS MANUALS DEVELOPED

EU

Standing Forestry Committee

Scientific Advisory Group (SAG)

Joint Research Centre (JRC)

Programme Co-ordinating Centre (PCC)

Lead Country (Germany)

Task Force of ICP Forests

ICP Forests

Programme Co-ordinating Group (PCG)

Expert Panel on Soil and Soil Solution

Forest Soil Co-ordinating Centre (FSCC)

Expert Panel on Foliage

Forest Foliar Co-ordinating Centre (FFCC)

Expert Panel on Forest Growth

Expert Panel on Deposition

WG Ambient Air Quality

WG Biotic Damage

Expert Panel on Litterfall, Meteorology and Phenology

Expert Panel on Ground Vegetation

WG Biodiversity
field visual observations of defoliation included two Mediterranean Croatian regions: Istria and Central Dalmatia showed that in Istria situation is alarming, the the percentage of damages is high, as for all types of total and for individual types

- in Aleppo pine, starting with 2001, there has been a steady rise of significant damage, which in 2006 reached 41.6%

- the research also established links between annual diameter growth and the degree of damage to the pubescent oak (Seletković and Potočić, 2011)

- Our Mediterranean region is ecologically very sensitive, because of its geographic position, complex orthography, specific meteorological conditions and number of pollution sources.
the emission of ammonia in Croatia in 2015 was 44.2 thousand tons, which is more than Limit Values defined EMEP protocol, which is 30 thousand tons

the biggest contributor is agriculture sector, 91 % as a result of the application and handling of natural fertilizers

trend transboundary pollution by sulphur compounds is reduced, and nitrogen oxides increases slightly.

by measuring the chemical composition of precipitation it was determined that the percentage of pollutants came by remote pollution are as follows: sulphur 80%, nitrogen 70% and ammonia about 50%

these large amounts of pollutants to our area mostly come from neighboring countries Italy, Slovenia, Hungary, Serbia, Montenegro and Bosnia and Hercegovina
up to today only the simplest methods that include various visual indices based on foliage colour, degree of leaf damage and the degree of crown defoliation were used in monitoring Mediterranean forest of Croatia

the project is to establish and develop forest monitoring that will give for the first time the unique possibility to analyse the biogeochemical cycle of elements, at local scale, but also the assessment of the environmental impact of pollutants on forest ecosystems compartments, following the uptake and the fate, from the sources to the receptors.

The processing of data resulting from monitoring in selected Mediterranean forests, will give the necessary information on the status of the environment and ecosystem services provided by these forests and the reaction of these forests to climate change.
Project objectives are strictly related to the European policy and governance acts, especially to

**Mediterranean Forest Research Agenda** for the period 2010-2020

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*the monitoring of the environmental status of the forests within the EU territory*

*promote new forest monitoring and data collection activities, and therefore contribute to sustainable forest management by data collecting of the ecosystem services*
OBJECTIVES

O1 Establishment of forest environmental monitoring in Mediterranean forest ecosystems

Defining study sites

the main broadleaved and conifer tree species/forests of sub-Mediterranean and eu-Mediterranean area

ISTRIAN PENINSULA
Quercus pubescens Wild.
Quercus ilex L.

Dalmatia Region
Pinus halepensis Mill.
Pinus nigra L.
OBJECTIVES

O2 Estimation of atmospheric inputs to forest ecosystems and identification of the possible impact of acid deposition and ozone on crown condition, tree nutrition, growth, soil and water availability, estimation of the present deposition loads and calculation of the critical load for nutrient N and acidity

MEASUREMENTS

A2.1 Atmospheric deposition (THR, BOF) estimation of present loads and calculation of the critical load for nutrient N and acidity
A2.2 Evaluation of ozone (passive samplers, visual assessment)

A2.3 Soil condition
A2.4 Tree nutrition
A2.5 Tree growth and crown condition
PLOTS
DEPOSITION AND OZONE MEASUREMENTS
ISTRIAN OAK PLOTS

Critical N amount
15-20 kg/Nhay

Quercus ilex
Quercus pubescens
FIRST YEAR RESULTS

Dalmatian pine plots

Critical N amount 10-15 kg/Nhay

Pinus nigra
Pinus halepenis
“Bad” ozone can be distinguished from “good” ozone, which is present at high altitudes in the atmosphere and beneficial because it protects the earth from excessive ultraviolet radiation. But bad, or ground-level, ozone—the primary component of smog—is harmful to health. Human activities such as driving cars and generating electricity are major sources of the ingredients that form smog.

NO$_x$ + VOC + Heat & Sunlight = Ozone

Ground-level or “bad” ozone is not emitted directly into the air, but is created by chemical reactions between NO$_x$ and VOCs in the presence of heat and sunlight.

Emissions from industrial facilities and electric utilities, motor vehicles, gasoline, and chemical solvents are some of the major sources of oxides of nitrogen (NO$_x$) and volatile organic compounds (VOCs).

Source: Adapted from EPA 2010.
Tropospheric ozone (O3)

- Increased by warming
- Toxic to human health
- Toxic to plant health
- A greenhouse gas (GHG)

Ground level OZONE GHG

- SMOG
- CO2
- Fossil fuel combustion

NITROGEN OXIDES + VOLATILE ORGANIC COMPOUNDS

GLOBAL WARMING

CROP damage

Forest damage carbon feedback
Results of calculations of ground-level ozone concentrations show that the daily mean values of ozone can be high and that there is a gradient of increasing concentration going from continental to Mediterranean because the highest ozone risk as ozone formation occurs at high temperatures in presence of solar radiation, which is elevated in the Mediterranean-type ecosystems.

Fig. VIII.6 The 26th highest maximum daily 8-hour average of O₃ concentration in Europe, 2012

Note:
Red and dark red areas correspond to exceedances of the limit value 120 µg.m⁻³.
OZONE 2017

ISTRIAN PENINSULA

GROWING SEASON
From April to October
Every 2 weeks
GROWING SEASON
From April to October
Every 2 weeks
The impact of ground level ozone on vegetation – 2017

Ozone-induced symptoms on **1st plot in Istria** LESS (Light Exposed Sampling Site) in 2017 (validated by the ICP Forests Expert Panel on Ambient Air Quality). Symptoms suggesting oxidative stress caused by high ground-level ozone concentrations found in *Ligustrum vulgare, Pinus halepensis, Cornus mas*.

Symptoms recorded on LESS in 1st plot in **Dalmatia** (*Clematis vitalba*) and **2nd plot in Istria** (*Fraxinus ornus, Laurus nobilis, *); no symptoms found on LESS 2nd plot in Dalmatia.
Less information is gathered about the response of biochemical plant characteristics on longer-term exposure to multiple ambient air pollution sources in field conditions.

Changes in physiological and biochemical parameters are useful as an early test to detect the first stages of pollution before the appearance of any visual signs of damage, providing a basis for determining the long-term impact of even relatively low levels of air pollution.
Estimation of the extent of oxidative stress caused by combination of air pollutants (ozone, acid and nitrogen deposition) and climatic variables

The oxidative stress induced by air pollutants exposure along with that derived from the Mediterranean conditions during summer months might exceed the plant ability to react to both pollutant and climatic stress.

Responses of plants to oxidative stresses include a number of physiological and biochemical changes
To estimate the extent of oxidative stress following biochemical stress indicators will be measured in leaves and needles:
- contents malondialdehyde (MDA; cytotoxic product of lipid peroxidation),
  - H2O2 (non-radical ROS)
  - soluble protein
- photosynthetic pigments (chlorophyll and carotenoids)

To better understand the role of antioxidant defense system of tree against oxidative stress caused by air pollution and climatic conditions following alternations will be also determined:
- non-enzyme antioxidant contents (e.g. ascorbate and glutathione, total phenols)
  - antioxidant enzyme activities
  (e.g. superoxide dismutase, guaiacol peroxidase, catalase and ascorbat-peroxidase)
Leaves and needles will be collected _every year during the second half of growing season_. The leaves and needles will be harvested from ten dominant healthy trees (same as for the foliar nutrient analyses) as well as from trees with observed damage symptoms at a height of 2-4 m from half shade.
OBJECTIVES

Identification of the cause-effect relationships between physiological and biochemical parameters of trees, forest condition, meteorological parameters and atmospheric inputs by using different statistical tools

ANALYSES

A3.1 Analyses and processing the collected data by using different statistical tools

- Relationships between individual deposition, soil, foliar and tree growth variables will be described by single factor regression

- An individual tree growth model with measured basal area increment of each individual tree as responding growth factor and tree size, tree competition, site factors (soil C/N ratio, temperature), and environmental factors as influencing parameters will be developed

- Acid and N deposition from plots will be used for calculation of critical loads. Only steady state Simple Mass Balance model will be considered
Random Forest Analysis - meteorological parameters, soil water content, solar radiation and nitrogen deposition, ozone concentration and ozone uptake as data to estimate the predictor importance on the insurgence of the main symptoms directly measured into the forests (i.e. defoliation, visible injury occurrence, crown discoloration, biochemical parameters etc).

Impacts of ozone will be estimated as relationship between both ozone concentration and uptake into leaves and needles by DO3SE model-Deposition of O3 for stomatal exchange. It estimates O3 flux to vegetated surfaces as a function of O3 concentration, meteorology and plant-specific characteristics (including phenological, physiological and structural characteristics)
To assess the integrated effects of changes in N deposition, ozone pollution, and climate change on tree growth, wood production and forest carbon budget, we will use the **process- and individual-based model NOTG**. The model incorporates the main biophysical processes involved in the water, carbon, and nitrogen cycles in trees and soil.

- Comparing simulations **with and without N deposition and ozone damage** with tree ring data will provide information on the respective roles of N deposition and ozone damage.
For example, data from passive samplers have so far not been compared with modeled data from e.g. EMEP. Yet, **ozone risk maps** that are based on different methodologies have already been **produced for Croatia**.

According to **EMEP models risk of damage from ozone to Mediterranean forests** of Croatian growing season from April to September levels is high. In Istria even higher than the critical level for forest damage of 5000 ppb/h.

These maps of ozone correspond to regional background levels and they are not representative of **local point measurements**, where these values can be much higher and it is crucial to be investigated in forest ecosystems.
The models will be applied to future scenarios for climate change and air pollution in the future. In particular for climate change **RCP-Representative Concentration Pathways** scenarios will be used, with different severity degrees (RCP 2.5, 4.5, 8.5).

The severity degrees refer to radiative forcing values measured in W/m² by the year 2100. Radiative forcing values include the net effect of all anthropogenic **greenhouse gases and other forcing agents** (van Vuuren et al., 2011).
A better understanding of the cause-effect relationships between crown defoliation and environmental, biochemical, deposition and ozone parameters is needed.

The results of this research and collaboration with Italian and French scientific institutions will contribute to the wider overview on impacts of atmospheric inputs in Mediterranean forests ecosystem of Eastern Adriatic coast at the regional and European level.

The role of meteorological conditions and atmospheric inputs on forest health status is a key task at European level in order to identify the best policies able to counteract and mitigate the impacts of future climate and air pollution.
Thank you for your attention!

National park Kornati

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