GOZDARSKI INŠTITUT SLOVENIJE

SLOVENIAN FORESTRY INSTITUTE

70

# 30 LET SPREMLJANJA STANJA GOZDOV V SLOVENIJI

// DRUGA, DOPOLNJENA IZDAJA //

# 30 YEARS OF FOREST MONITORING IN SLOVENIA

// SECOND, REVISED EDITION //

Silva Slovenica

**Izdajatelj / Publisher:**
Gozdarski inštitut Slovenije, Založba *Silva Slovenica*, Ljubljana / Slovenian Forestry Institute, The *Silva Slovenica* Publishing Centre, Ljubljana

**Leto izida / Year of edition:** 2017

**Število natisnjenih izvodov / No. of printed copies:**
1000 izvodov / 1000 copies



**Naslov / Title:**
30 let spremljanja stanja gozdov v Sloveniji, Druga dopolnjena izdaja / 30 years of Forest monitoring in Slovenia, Second reviewed edition

**Recenzent / Reviewer:**
prof. dr. Franc Batič

**Glavna urednika / Editors-in-Chief:**
dr. Urša Vilhar, Daniel Žlindra

**Tehnična urednica / Technical editor:**
dr. Urša Vilhar

**Lektor / Language editor:**
Henrik Ciglič

**Oblikovanje / Design:**
Sonja Rutar - Škrlat

**Fotografije na platnicah / Cover page photos:**
Iztok Sinjur

**Tisk / Printed by:**
Grafični studio K, d.o.o.

**Cena / Price:**
brezplačno / free of charge

**Izdaja - 2. izdaja / Edition - 2nd Edition:**
*Studia Forestalia Slovenica*, 156
ISSN zbirke 0353-6025

**Izdaja / Edition:**
Druga prenovljena izdaja / Second, revised edition

*a Forestalia Slovenica*, 156
ISSN zbirke 0353-6025

**Sofinanciranje / Co-financing:**
Rezultati raziskav, objavljeni v publikaciji, so bili financirani iz različnih finančnih programov Republike Slovenije, pod okriljem Ministrstva za kmetijstvo, gozdarstvo in prehrano RS, Ministrstva za okolje in prostor RS, Ministrstva za kmetijstvo in okolje RS, Javne agencije za raziskovalno dejavnost in finančni programi Evropske unije, med najpomembnejšimi Life+.

Published research results were financed by financial programmes of Republic of Slovenia, within Ministry of Agriculture, Forestry and Food, Ministry of the Environment and Spatial Planning, Ministry of Agriculture and Enviroment, Slovenian Research Agency and European financial programmes, especially by Life+.

Izdajanje publikacije je sofinanciral EUFORINNO, European Forest Research and Innovation, 7. OP Capacities programme, RegPot No. 315982

The publication was co-financed by EUFORINNO, European Forest Research and Innovation, 7th FP EU Capacities programme RegPot No. 315982

This project is funded by the European Union

**Elektronski izvod / Electronic issue:**
https://doi.org/10.20315/SFS.156



# DOPOLNJENA IZDAJA NA POT OB 70-LETNICI GOZDARSKEGA INŠTITUTA SLOVENIJE

## // THE REVIEWED EDITION AT THE 70TH ANNIVERSARY OF THE SLOVENIAN FORESTRY INSTITUTE

**Urša Vilhar, Daniel Žlindra, Mitja Skudnik**

**V letošnjem letu Gozdarski inštitut Slovenije obeležuje 70 let znanstveno-raziskovalnega delovanja na področju gozdov. Ta jubilej se časovno ujema s prav toliko leti univerzitetnega izobraževalnega dela Biotehniške fakultete Univerze v Ljubljani, v okviru katere deluje tudi Oddelek za gozdarstvo in obnovljive gozdne vire.**

Za gozdni ekosistem 70 let ni pretirano dolgo obdobje, saj naravni procesi v gozdu potekajo počasi, v primeru nenadnih obsežnejših sprememb pa v gozdu obstajajo mehanizmi, ki njihove posledice po naravni poti ublažijo. Za boljše razumevanje teh naravnih mehanizmov in procesov je potrebno dolgoletno spremljanje gozdnih ekosistemov, kar vključuje poglobljene raziskave tako na terenu kot kasneje v laboratorijih in pisarnah. Vsemu pa sledi še poseben pomemben proces prenosa znanja, saj omogoča medgeneracijski prenos in nadgradnjo pridobljenega znanja in razumevanja v določeni stroki, na raziskovalnem področju in v družbi na splošno.

Le dolgoletno spremljanje gozdnih ekosistemov omogoča zaznavanje sprememb zdravstvenega stanja gozdov, ki pa ga v okviru trajnostnega, sonaravnega in večnamenskega gospodarjenja z gozdovi moramo razumeti. Današnje zdravje gozdov namreč pomembno vpliva na prihodnjo podobo gozdov. Samo na podlagi jasne slike stanja gozdov in z ustreznimi usmeritvami v okviru gozdnogospodarskega načrtovanja ter kasneje uresničevanje teh usmeritev v praksi bo mogoče predati našim zanamcem stabilne in vitalne gozdove.

Obratno kot za gozdove pa je z vidika človeka 70 let dolgo obdobje, saj dandanes potrošniško usmerjena družba hlepi po hitrem napredku, kratkoročnih učinkih inovacij in raziskavah z danes na jutri. Gozdni ekosistemi pa delujejo v drugačnih časovnih dimenzijah in v drugačnem etičnem kontekstu. Za človeško

**// This year, the Slovenian Forestry Institute celebrates 70 years of its scientific research work in forestry. This jubilee coincides with as many years of the academic work of the Biotechnical Faculty at the University of Ljubljana, within the framework of which the Department of Forestry and Renewable Forest Resources is functioning as well.**

For a forest ecosystem, 70 years do not present an excessively long period, given that natural processes in forests unroll at a slow rate, while in case of sudden and extensive events there are mechanisms in forests that mitigate their effects in a natural way. For a better understanding of these natural mechanisms and processes, a prolonged monitoring of forest ecosystems is necessary, including a thorough research both in the field, labs and later in offices. All this is followed by a special significant process of knowledge transfer, for it enables an intergenerational transfer and upgrading of the acquired knowledge in a profession, in the sphere of research and within a society in general.

Only long-term monitoring of forest ecosystems can enable us to detect changes in the forests' health status which, however, simply must be understood within the framework of sustainable, nature-friendly and multipurpose forest management. For the fact is that the forests' current health has significant effect on the forests' future image. It is only on the basis of a clear picture of the forests' status and through suitable policies within the forest management planning and, later on, implementation of these policies in practice that we shall be able to pass stable and vital forests on to our descendants.

From the human aspects, on the other hand, 70 years present a long period in view of the fact that nowadays the consumer-oriented society yearns for a rapid progress, short-term effects of innovations and družbo so gozdovi pomemben vir obnovljivih naravnih virov, hkrati pa opravljajo pomembne ekološke in socialne funkcije. Nekatere izmed njih smemo zajemati le z majhno žlico, spet druge z nekoliko večjo.

Želimo si, da bi ob letošnjem jubileju lahko ugotovili, da je delovanje Gozdarskega inštituta Slovenije pomembno pripomoglo k znanstveni uspešnosti naše družbe ter strokovnemu razvoju gozdarske stroke v Sloveniji in Evropi. Pred nami pa so številni izzivi, tako podnebna spremenljivost in z njo vse pogostejše velikopovršinske motnje v gozdovih kot tudi družbeno-ekonomske spremembe. Upajmo, da bo delovanje Gozdarskega inštituta Slovenije tudi v prihodnosti uspešno in da bomo lahko ponosno obeležili še kakšno okroglo obletnico delovanja!

research from today to tomorrow. Forest ecosystems, however, act in different time dimensions and in different ethical context. For the human society as a whole, forests present a significant source of renewable natural resources and, at the same time, perform important ecological and social functions. Some of them can be scooped up only with a small spoon, others with a somewhat larger spoon.

We dearly wish that at this year's jubilee we'll be able to conclude that the Slovenian Forestry Institute has significantly contributed to the scientific success of our society and to the professional development of the forestry in Slovenia and Europe. At this very moment, we are facing numerous challenges, such as climate change, ever increasing large-scale disturbances in the forests closely associated with it, as well as socio-economic changes. Let's hope that the Slovenian Forestry Institute will be successful in the future, too, and that we shall be able to proudly celebrate yet another round anniversary!

Foto: Roman Šipič
// Photo: Roman Šipič

## UVODNIK // PREFACE

# POMEN GOZDOV V SLOVENIJI

## // THE SIGNIFICANCE OF FORESTS IN SLOVENIA

**Miha Marenče**

Gozd prekriva približno 60 % površine Slovenije in je v Republiki Sloveniji simbol prepoznavnosti države ter odsev njenega odnosa do trajnostnega razvoja, s katerim poskušamo zagotoviti trajno in optimalno delovanje gozda kot ekosistema, življenjskih združb rastlin in živali in njihovih življenjskih prostorov. V Sloveniji smo upravičeno ponosni na naravne danosti, na gozdove in vodne vire. Tradicija in znanje v gozdarstvu in lesnopredelovalni industriji sta kljub trenutnemu zastoju predvsem lesne industrije nadvse pomembna, saj prispevata k dodani vrednosti, ustvarjeni v državi.

Razumevanje razvoja naravnega in gospodarjenega gozda in uporaba teh zakonitosti pri gospodarjenju z njim so osnova za njegovo ohranitev in uspešen razvoj v prihodnosti, kljub povečanim pritiskom glede rabe lesa, onesnaževanja, rabe prostora, uporabe novih tehnologij z namenom povečanja učinkovitosti izkoriščanja gozdov idr. Gozd v R Sloveniji je izrednega okoljskega, ekosistemskega, biotskega, kulturnega, zgodovinskega, asociativnega, krajinskega in zdravstvenega pomena, zato je nujno, da to bogastvo varujemo.

Zagotavljanje stabilnosti gozda in usmerjanje njegovega razvoja je in mora ostati pomemben dolgoročni cilj naše države. Les je sicer najpomembnejša obnovljiva surovina v Sloveniji.

// Forest covers about 60% of Slovenia and is a symbol of the country's recognition as well as reflection of its attitude towards sustainable development, providing a continuous and optimal functioning of the forest as an ecosystem, associations of animals and their habitats. In Slovenia, we are justifiably proud of our natural resources, forests and water resources. The tradition and knowledge of forestry and woodworking industry are of utmost importance, as they greatly contribute to the added value created in the country, in spite of the current impasse in wood industry in particular.

Understanding the development of natural and managed forests and application of these processes in their management constitute a basis for their preservation and successful development in the future, in spite of the ever greater pressures regarding the use of wood, environmental pollution, land-use as well as use of new technologies aimed at an increased effectiveness of forest utilization, etc. As forests are of exceptional environmental, ecosystem, biotic, cultural, historical, associative, landscape and health significance in Slovenia, it is implicit that we protect this great wealth.

Providing for the stability of forest and guidance of its development is and has to remain an important compound of the country's long-term objectives, for wood is the most significant renewable resource in Slovenia.

Foto: Iztok Sinjur
// Photo: Iztok Sinjur

Ena izmed osnovnih podlag za razumevanje stanja in bodočega ravnanja z gozdovi je informacija o stanju gozdov danes in v preteklosti, kar nam omogočajo različni monitoringi gozdov. Tudi na tem področju ima Slovenija tradicijo z uvajanjem kontrolne metode v snežniških gozdovih na prehodu iz 19. v 20. stoletje.

**PROGRAM SPREMLJANJA GOZDOV V SLOVENIJI NA PODLAGI KONVENCIJE O DALJINSKEM TRANSPORTU ONESNAŽENEGA ZRAKA (CLRTAP)**

Program spremljanja stanja gozdov v Sloveniji s poskusnimi snemanji poteka že od leta 1986 v okviru programa ICP Forests in na podlagi konvencije o daljinskem transportu onesnaženega zraka (CLRTAP), v zadnjih letih v skladu s Pravilnikom o varstvu gozdov (2009).

Poleg opravljanja aktivnosti na veliko površinski ravni (Raven I), poteka delo od l. 2003 tudi na Ravni II., t. i. procesni ravni (v Sloveniji t.i. intenzivno spremljanje stanja gozdnih ekosistemov). S pomočjo Kraljevine Nizozemske, ki je sofinancirala projekt implementacije EU zakonodaje, se je vzpostavila terenska infrastruktura (postavitev 11 objektov) ter se ustrezno opremila (laboratoriji), organizirala in usposobila skupina strokovnjakov na Gozdarskem inštitut Slovenije (GIS) za spremljanje stanja gozdov na Ravni II.

Podatki, pridobljeni s spremljanjem stanja gozdov, so pomembna osnova za pripravo nacionalnih in mednarodnih poročil za področje gozdarstva. Rezultati se deloma ali v celoti vključujejo v letna ali periodična nacionalna, EU in mednarodna poročila (poročilo o stanju gozdov v skladu s Pravilnikom o varstvu gozdov, FAO-GFRA, Forest Europe, Konvencija LRTAP, ICP Forests, letna nacionalna poročila (NIR), Konvencija (UNFCCC), Kjotski protokol itn.) in sestavljajo pomemben del gozdarskega in gozdarsko-okoljskega informacijskega sistema Slovenije.

Program ICP Forests v Sloveniji zaradi svoje narave povezuje Ministrstvo za kmetijstvo, gozdarstvo in prehrano (MKGP), Ministrstvo za okolje in prostor (MOP) z Gozdarskim inštitutom Slovenije (GIS), Zavodom za gozdove Slovenije (ZGS) ter strokovnjake Biotehniške fakultete Univerze v Ljubljani in Agencije RS za okolje (ARSO) na nacionalni ravni, na mednarodni pa omogoča hiter prenos znanja in spodbuja sodelovanje s tujimi strokovnjaki znotraj Ekspertnih skupin programa ICP Forests (Expert panels) iz številnih evropskih gozdarskih institucij. V zadnjem desetletju so se slovenski strokovnjaki aktivneje vključili v delovanje strokovnih skupin.

One of the primary bases for understanding the future forest management is the information on the state of forests today and in the past, which is enabled by various types of forest monitoring. In this sphere, too, Slovenia has a long tradition with the introduction of control method in Snežnik forests at the turn of the 20th century.

**THE PROGRAMME OF FOREST MONITORING IN SLOVENIA ON THE BASIS OF THE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION (CLRTAP)**

The program of forest monitoring in Slovenia with trial recordings has been taking place since 1986 within the framework of the ICP Forests Programme, on the basis of the Convention on Long-range Transboundary Air Pollution (CLRTAP) and, in the last few years, in compliance with the Regulations on forest protection (2009).

Apart from implementing various activities at the large-scale Level I, work has also been carried out since 2003 at Level II, at the so-called process level (in Slovenia called intensive monitoring of forest ecosystems). With the aid of the Kingdom of Holland, which co-financed the implementation of EU legislation project, terrain infrastructure (11 facilities) was set up and a group of experts suitably equipped (laboratories), organized and trained at the Slovenian Forestry Institute to implement the monitoring at Level II.

The data acquired through forest monitoring are important grounds for the preparation of national and international reports for the field of forestry. The results are partially or fully included in annual or periodical EU and international reports (report on forest condition in compliance with the Regulations on the protection of forests UN/GFRA, Forest Europe, LRTAP Convention, ICP Forests, NIR annual reports, Convention (UNFCCC), Kyoto Protocol, etc.) and constitute an important part of the forestry and forestry-environmental information system of Slovenia.

The ICP Forests Programme in Slovenia is due to its characteristics linking the Ministry of Agriculture, Forestry and Food, Ministry of Environment and Spatial planning to Slovenian Forestry Institute, Slovenian Forestry Service and experts from Biotechnical Faculty at the University of Ljubljana and Slovenian Environment Agency on national level. At the same time the Programme enables fast knowledge transfer on international level, fostering cooperation among international experts in the frame of Expert panels form various European forestry institutions. In the last decade the Slovenian experts were actively involved in Expert panel activities.



**NOVI IZZIVI ZA ZDRAVJE, STANJE GOZDOV IN KAKO NAPREJ**

Gozdarska stroka se zaveda usodne povezave med naravo in družbo. Gozd kot naravna danost ima v tem odnosu izjemno pomembno vlogo; podvržen je različnim interesom in obenem življenjski prostor, v katerem potekajo in bodo potekali številni, ne vedno tudi zaželeni procesi. Naša dolžnost je, da bomo to bogastvo, ki nam ga daje gozd, zapustili našim zanamcem.

Zavedamo se, da bo treba navkljub nenaklonjenem času za financiranje spremljanja stanja gozdov skrbeti za kontinuiteto in trajno nadaljevati z aktivnostmi; prilagojen pristop k monitoringu gozdov mora biti most med preteklostjo in prihodnostjo, most med informacijami, ki smo jih pridobivali zadnjih trideset let, in tistimi, ki prihajajo. Kljub težavam ne smemo izgubiti rdeče niti glede informacij o stanju in delovanju gozdov v Sloveniji in širše, v evropskem prostoru.

Slovenska gozdnata krajina je nenadomestljiv del evropskega prostora in je z vidika ekosistemske pestrosti vroča točka. Prepletanje ekosistemskih tipov, ki le izjemoma dosegajo površinsko izrednost, sicer ne daje velikih možnosti za veliko površinsko ekstenzivno gospodarjenje, zato pa je porok ekološki stabilnosti in gozdarstvo dobesedno sili v trajnostno, ekološko naravnano gospodarjenje. Vsebinsko in informacijsko zadostna inventarizacija gozda je prvi korak k takemu gospodarjenju, saj je poznavanje dejanskih razmer osnova za vse nadaljnje odločitve. Poleg inventarizacije pa nas mora zanimati poznavanje procesov, zakonitosti in odzivnosti gozda na okoljske spremembe ter na stres, kot so npr. vetrolomi, žledenje, suša in drugi ekstremni vremenski dogodki, bolezni in insekti, onesnaževala in drugo.

**NEW CHALLENGES FOR HEALTH, STATE OF FORESTS, AND LOOK TO THE FUTURE**

Forestry sector is aware of essential connection between nature and the society. Forest as natural wealth is extremely important in this relationship. subjected to the various interests and at the same habitat, where numerous processes are taking place, not always desirable. It is our duty to bequeath this wealth to our future generations.

We are aware that in spite of present situation, adverse to financing forest monitoring, we will have to take care of continuity and permanently carry on with the activities of forest monitoring; a tailored approach to forest monitoring should be a bridge between the past and future, a bridge between information gained in the last thirty years and the years to follow. In spite of the problems we should not lose the thread concerning information on the condition and functioning of forests in Slovenia and wider, in Europe.

The Slovenia forested landscape is an irreplaceable part of Europe and a true "hot spot" from the aspect of the ecosystem diversity. The interwinning of ecosystem types, which reach surface extraordinariness only exceptionally, indeed does not vouch for large-scale extensive management, but certainly is a guarantor for ecological stability, for it literally forces forestry into sustainable, ecologically oriented management. Substantively and informationally sufficient forest inventory is the very first step towards such management, given that knowledge of the actual conditions is a basis for all further decisions. Apart from inventory making, however, the knowledge about processes, rules and responses of forests to environmental changes and stress is needed, such as wind-storms, ice-storms, drought and other extreme weather events, diseases, insects, pollutants, etc.

# TRIDESET LET (1985-2015) SPREMLJANJA STANJA GOZDOV V SLOVENIJI

## // THIRTY YEARS (1985-2015) OF FOREST MONITORING IN SLOVENIA

**Marko Kovač, Primož Simončič**

### IZHODIŠČA

**Slabo stanje okolja v 70. letih prejšnjega stoletja, ki se je večkrat kazalo v obliki uničenih gozdov, je narekovalo oblikovanje in ratifikacijo Konvencije o onesnaževanju zraka na velike razdalje prek meja (CLRTAP). V okviru te Konvencije, zavezujoče od l. 1983 naprej, je Ekonomska komisija pri Združenih narodih za Evropo (UNECE) l. 1985 ustanovila mednarodni program ICP Forests, katerega cilj je bil spremljanje stanja gozdov in učinkov na gozdne ekosisteme. Program je sprva zajemal pet ekspertnih področij (depoziti, gozdna tla, stanje krošenj, rast drevja, mineralna prehrana rastlin). V desetletjih se je Program vsebinsko in institucionalno razširil in danes obsega osem področij ter vključuje 42 držav.**

Čeprav je bila Slovenija v 80. letih del Jugoslavije, ki v Programu ni sodelovala do ratifikacije Konvencije l. 1987, je slovenska gozdarska stroka na lastno pest v Programu sodelovala od l. 1985 naprej. Po vsebinski in formalni plati je ta Program sledil usmeritvam Konvencije. Močan vpliv nanj so imele države zahodne Evrope, predvsem ustanovne članice današnje Evropske unije (EU), ki so v povezavi z njim sprejele dve Uredbi Sveta EGS (EEC št. 3528/86 in 2158/92). Po osamosvojitvi je Slovenija v Programu sodelovala v skladu s Konvencijo, ki jo je nasledila l. 1992. Z vstopom v EU je poleg te zanjo postala zavezujoča še Uredba Forest Focus (Regulation EC št. 2152/2003; Uredba), ki je veljala do l. 2006.

Vsebinsko gledano Program ločeno obravnava dva različna sklopa. Prvi (Raven I, Level I), ki je v veljavi od l. 1985 naprej, obsega velikoprostorsko statistično inventuro zdravstvenega stanja gozdov in je njegova naloga preučevanje obsega, površinske porazdelitve in tendence razvoja stanja gozdov. Vse do prenehanja veljavnosti uredbe Forest Focus je ta inventura tekla na sistematični mreži 16 x 16 km, položeni prek vseh držav EU in tudi drugih evropskih držav. Od l. 2007 naprej inventarizacija ni več enotna; v nekaterih državah še naprej poteka tako

### // BASELINE

**The poor state of the environment in the 1970s, which was often reflected in forest degradation, called for preparation and ratification of the Convention on Long-range Transboundary Air Pollution (CLRTAP). Under the auspices of this Convention, binding from 1983 onwards, the United Nations Economic Commission for Europe (UNECE) founded in 1985 the International ICP Forests Programme, the objective of which was monitoring of forests and impacts on forest ecosystems. Initially, the Programme embraced five expert spheres (deposits, forest floor, crown condition, tree growth, mineral nutrition of plants). Through decades, the Programme was extended institutionally as well as in terms of its contents; today it embraces eight spheres and includes 42 countries.**

Although Slovenia was part of Yugoslavia in the 1980s and did not take part in the Programme until the Convention was ratified in 1987, the Slovenian forestry profession participated in the Programme at its own initiative from 1985 onwards. From the substantive and formal aspects, the Programme followed the Convention's guidelines. It was strongly influenced by the Western European countries, primarily founding members of the present-day European Union (EU), which in connection with it adopted two Council Regulations EGS (EEC No. 3528/86 and 2158/92). After gaining its independence, Slovenia participated in the Programme in accordance with the Convention, which it succeeded in 1992. With its entry into EU, the Forest Focus (Regulation EC No. 2152/2003; Regulation) also became binding for Slovenia and remained in force till 2006.

As to its contents, the Programme deals separately with two different complexes. The first (Level I), which has been running since 1985, embraces a large-scale statistical inventory of the forests' health condition, its main task being to study the extent, surface distribution and tendencies of the forests' condition development. Until the expiry of the Forest Focus Regulation' validity, this inventory was implemented in a systematic 16 x 16 km

kot prej, v nekaterih je ukinjena, v nekaterih državah pa je združena z nacionalnimi gozdnimi inventurami. Drugi sklop (Raven II, Level II), imenovan "intenzivni monitoring gozdnih ekosistemov", se je začel uresničevati l. 1994. V dopolnilo prvemu je njegova naloga izboljšanje znanja in boljše razumevanje učinkov onesnaženega zraka in drugih stresorjev (suša, depoziti) na gozdne ekosisteme. Tudi ta del raziskovanja je od l. 2007 zaradi prenehanja veljavnosti Uredbe v državah EU izpostavljen krčenju.

Vse od l. 1985 do l. 2000 uresničevanje Programa v Sloveniji ni bilo podprto s pravnimi podlagami. Te so bile prvič ustvarjene s Pravilnikom o varstvu gozdov iz l. 2009 (PVG 2009).

### SPREMLJANJE STANJA GOZDNIH EKOSISTEMOV V SLOVENIJI

Prva inventura propadanja gozdov v Sloveniji je bila v domeni domače gozdarske stroke opravljena l. 1985. Njen statistični model je temeljil na vzorčenju v grozdih, pri čemer so grozd tvorile 4 ploskve s po 6 drevesi (M6; metoda stalnega števila drevja). Inventura je bila organizirana na ravni države in je praviloma potekala na sistematični mreži 4 x 4 km. Poleg kazalcev zdravstvenega stanja gozdov so se ocenjevali in merili še sestojni in dendrometrijski znaki in bolezni. Druga inventura na mreži 4 x 4 km je bila v Sloveniji opravljena l. 1987, ko je prvič stekla tudi vsejugoslovanska inventarizacija gozdov.

Opisani inventurni model je bil v Sloveniji v rabi do l. 2000, v njegovem okviru pa sta periodično tekla še pedološko snemanje in odvzem foliarnih vzorcev za analize mineralne prehrane rastlin. L. 2000 je bil inventurni model izpopolnjen; v grozd je bila vključena še stalna vzorčna ploskev z odmerjenimi koncentričnimi krogi, na katero se je preneslo snemanje vseh kazalcev. Do te spremembe je prišlo zaradi nereprezentativnosti ploskev M6, na katerih se je gospodarilo drugače kot v bližnjih sestojih. M6 ploskve pa niso bile opuščene v celoti; ohranjene so na mreži 16 x 16 km in zaradi kontinuiranosti časovne serije rabijo poročanju Konvenciji, na mreži 4 x 4 km pa sta ohranjeni le po dve.

Delo na Ravni II oz. na intenzivnem monitoringu gozdnih ekosistemov je steklo ob koncu l. 2003. Pred tem časom je potekal program na Ravni II na izbranih testnih ploskvah. S pomočjo Kraljevine Nizozemske, ki je so-financirala projekt implementacije EU zakonodaje, vzpostavitev intenzivnega monitoringa gozdov v Sloveniji, je bila v državi v naslednjih dveh letih vzpostavljena in infrastrukturno opremljena mreža 11 objektov velikosti 1 ha z osrednjimi 50 m x 50 m velikimi ploskvami. Na teh

grid, placed across all EU countries and other European states. From 2007 onwards, the inventory has not been uniform any longer; in some countries it is still implemented in the same manner as before, in some it was abolished, while in some of them it has been combined with national forestry inventories. The second complex (Level II), also known as »intensive forest ecosystems monitoring«, began to be implemented in 1994. As a complement to the first complex, its task is to improve the knowledge and a better understanding of the impacts of air pollution and other stressors (drought, deposits) on forest ecosystems. Owing to the expiry of the Forest Focus Regulation' validity in EU countries, this part of research has been curtailed since 2007 as well.

From 1985 to 2000, the Programme's implementation was no supported by any legal bases in Slovenia. These were adopted with the Regulations on forest protection in 2009 (PVG 2009).

### MONITORING OF FOREST ECOSYSTEMS IN SLOVENIA

The first inventory of forest degradation in Slovenia was carried out by forestry profession in 1985. Its statistical model was based on cluster sampling, where a cluster was composed of 4 plots with 6 trees each (M6; constant tree counting method).The inventory was organized at the national level and was, as a rule, implemented in the systematic 4 x 4 km grid. Apart from forests' health condition indicators, dendrometric and stand marks as well as presence of diseases were assessed. The second inventory in 4 x 4 km grid was carried out in Slovenia in 1987, when the all-Yugoslav inventarization was also initiated for the first time.

In Slovenia, the described inventory model was used till 2000. Within its framework, pedological recording and foliar sampling for analyses of the plants' mineral nutrition was periodically implemented as well. In 2000, the inventory model was improved; a cluster including a permanent sample plot with concentric circles, on to which recording of all indicators was transferred. This change was made owing to the non-representativeness of M6 plots, where management differed from that in the nearby stands. M6 plots, however, were not abandoned in full; they have been preserved on the 16 x 16 km grid and serve, owing to the continuity of time series, for reporting to the Convention, while in 4 x 4 km grid only 2 plots have been preserved.

The work at Level II (or intensive monitoring of forest ecosystems) began at the end of 2003. Previously, the programme had been conducted at Level II on selected test plots. With the aid of the Kingdom of Holland, which co-financed the implementation of EU legislation proploskvah od l. 2004 teče spremljanje sprememb kazalcev in procesov, kot so osutost krošenj in porumenelost listja drevja, zdravstveno stanje drevja, indeks listne površine, rast drevja, sprememba vegetacije, fenologija, stanje gozdnih tal, mineralna prehrana drevja, vnos onesnaževal v gozdne ekosisteme, vnos in iznos snovi (količina in kakovost padavin, dinamika opada, kakovost talne raztopine), meteorološki znaki, pojav in znaki poškodovanosti vegetacije zaradi ozona ($O_3$).

ject, i.e. establishment of intensive forest monitoring in Slovenia, the infrastructurally equipped network with 11 1 ha large facilities with central 50 x 50 m large plots was set up in the country in the ensuing two years. On these plots, monitoring of the changes in indicators and processes, such as crown defoliation and discolouration of tree leaves, health condition of trees, leaf area index, tree growth, vegetation changes, phenology, forest soil condition, mineral nutrition of trees, input of pollutants into forest ecosystems, input and output of matter (quantity and quality of precipitation, leaf-litter dynamics, quality of soil solution), meteorological parameters, presence and signs of vegetation damage owing to ozone ($O_3$), has been carried out.

**Foto: Iztok Sinjur**
**//Photo: Iztok Sinjur**

# PROGRAM IN METODOLOGIJA ICP FORESTS V SLOVENIJI

## // THE PROGRAMME AND METHODOLOGY OF ICP FORESTS IN SLOVENIA

**Matjaž Čater, Mitja Ferlan, Milan Kobal, Marko Kovač, Lado Kutnar, Tom Levanič, Aleksander Marinšek, Matej Rupel, Primož Simončič, Iztok Sinjur, Mitja Skudnik, Mihej Urbančič, Urša Vilhar, Daniel Žlindra**

**Zakonodaja**

V Sloveniji smo od leta 1986 stanje gozdnih ekosistemov spremljali v skladu z mednarodnim programom ICP Forests, od leta 1986 do 2003 v skladu z evropsko zakonodajo, v letih 2003–2006 v okviru projekta Forest Focus, 2007-2008 v lastni iniciativi, 2009-2015 pa v skladu s Pravilnikom o varstvu gozdov, ki se sklicuje na CLRTAP oz. program ICP Forests. Razvoj in spremljanje stanja gozdnih ekosistemov v Sloveniji sta bila skozi leta deležna različnega financiranja: Javne gozdarske službe Ministrstva za kmetijstvo, gozdarstvo in prehrano, predpristopne pomoči KraljevineNizozemske in v okviru nalog EU; npr. sofinanciranje na osnovi domače (Pravilnik o varstvu gozdov; 2009) in EU zakonodaje (1986, 1994, 1999, 2003) ter projekta FutMon Life+ (2009-2011). Po letu 2011 je financiranje programa prepuščeno presoji vladam in pristojnim ministrstvom držav članic EU. V Sloveniji so bili ravno podatki, pridobljeni v okviru mreže ICP Forests, pomemben vir podatkov za poročanje po Kjotskem protokolu (obdobje 2008-2012), še zlasti za spremljanje zalog ogljika v gozdnih tleh in opadu.

**Glavni cilji**

Cilj programa je pridobiti vpogled v prostorske in časovne spremembe stanja gozdov in ugotoviti vpliv stresnih dejavnikov, vključno z onesnaženostjo zraka, na gozd. S tem namenom je bil v državah, ki so pri programu ICP Forest sodelovale, vzpostavljen monitoring poškodovanosti gozdov, ki se spremlja prek kazalca osutosti in popisa poškodb drevja.

Cilji spremljanja poškodovanosti gozdov na ploskvah Raven I so:

- periodične informacije o prostorskem in časovnem gibanju vitalnosti dreves na ravni države in EU,
- ugotoviti trend zdravstvenega stanja drevesnih vrst ter propadanja gozdov,

**Legislation**

Since 1986, forest ecosystems have been monitored in Slovenia in compliance with the international ICP Forests programme: from 1986 to 2003 in accordance with European legislation, in the years 2003-2006 within the Forest Focus programme, from 2007 to 2008 according to our own initiative, and from 2009 to 2015 in compliance with the Regulations on the protection of forests which refers to CLRTAP (ICP Forests). The development and monitoring of forest ecosystems in Slovenia was financed through years by the Public Forestry Service of the Ministry of Agriculture, Forestry and Food, pre-accession aid by Kingdom of Holland, and within the framework of EU tasks, e.g. co-financing on the basis of domestic legislation (Regulations on the protection of forests, 2009), EU legislation (1986, 1994, 1999, 2003) and the FutMon Life+ Project (2009-2011). After 2011, the financing of the programme was left to the governments and competent ministries of EU member states. In Slovenia, it was the very data acquired within the ICP Forests network that constituted an important source of data for reporting in accordance with the Kyoto Protocol (2008-2012 period), particularly for the monitoring of carbon stocks in forest soil and leaf-litter layer.

**Main objectives**

The objective of the programme is to gain insight into spatial and temporal changes of the forests' condition and to ascertain the impacts of stress factors, including air pollution, on forests. To this end, monitoring of forest damages, which are followed via defoliation indicators and inventory of tree damages, was introduced in the countries taking part in the ICP Forests programme.

The objectives of forest damage monitoring at level I plots are:

- periodic information on spatial and temporal trends of tree vitality at the levels of the country and EU;
- to ascertain the trend of health condition of tree species and forest degradation;

- poročati o stanju gozdov na različnih prostorskih ravneh, kot so npr. državna poročila, ki jih določa Pravilnik o varstvu gozdov, in poročila na mednarodni ravni, za katere se je država obvezala ob podpisu listin, resolucij in protokolov (poročilo ICP Forests, UN-FAO/ECE, MCPFE).

Namen intenzivnega spremljanja stanja gozdnih ekosistemov je podrobnejše seznanjanje z ekološkimi procesi, razvojem gozdnih sestojev, identificiranje vzročno-posledičnih mehanizmov, ocenjevanje sposobnosti prilagajanja gozdnih ekosistemov vnosom onesnaževal in nenazadnje priprava ukrepov za zmanjševanje tveganj glede okoljskih vplivov in stabilnosti gozdnih ekosistemov danes ter v prihodnosti.

**Uresničevanje**

Program ICP Forests se v Sloveniji uresničuje na dveh intenzivnostnih ravneh, in sicer na Ravni I in Ravni II. Raven I obsega 44 ploskev (sistematična vzorčna mreža 16 x 16 km) (slika 1), na katerih se letno spremlja stanje gozdov prek kazalca osutosti in poškodovanosti drevja. Periodično, na 5 do 10 let, se je v Sloveniji poškodovanost gozdov spremlja še dodatno na zgoščeni vzorčni mreži 4 x 4 km (cca. 780 ploskev). Za izbiro dreves na ploskvi je uporabljena metoda M6. Na mreži 16 x 16 km vsako ploskev sestavljajo štiri pod-ploskve M6. Tako se na vsaki ploskvi oceni zdravstveno stanje 24 dreves.

V okviru intenzivnega spremljanja stanja gozdnih ekosistemov (Raven II) je bilo v letu 2003 vzpostavljenih 11 ploskev po vsej Sloveniji (Slika 1), kjer poteka sistematično zbiranje informacij o vremenskih spremenljivkah, zračnih usedlinah, vsebnostih hranil v iglicah, listju in opadu, onesnaženosti in rodovitnosti gozdnih tal, kemijski sestavi talne raztopine, fenološkem razvoju dreves, kakovosti zraka, rasti drevja, osutosti krošenj, stanju pritalne vegetacije (Slika 2) v skladu z navodili ICP Forests (http://icp-forests.net/page/icp-forests-manual).

Zaradi različnih vzrokov smo nekaj ploskev deloma ali popolnoma opustili, nekaj pa na novo osnovali, predvsem kot nadgradnjo obstoječih. Tako imamo danes štiri t. i. »core« ploskve, kjer opravljamo vse aktivnosti, ter šest ploskev z nižjo intenziteto spremljanja gozdnih ekosistemov, kjer je poudarek na neposrednem monitoringu zdravja, prehranjenosti in osutosti drevja.

- and to report on condition of forests at different spatial levels, such as national reports as stipulated by the Regulations on forest protection and reports at the international level, for which the country committed itself when signing documents, resolutions and protocols (ICP Forest report, UN-FAO/ECE, MCPFE).

The purpose of intensive monitoring of forest ecosystems is a more detailed familiarization with ecological processes, development of forest stands, identification of cause-effect mechanisms, assessment of the capability of forest ecosystems adapting to the input of pollutants and, last but not least, preparation of measures to reduce risks regarding the environmental impacts and stability of forest ecosystems today and in the future.

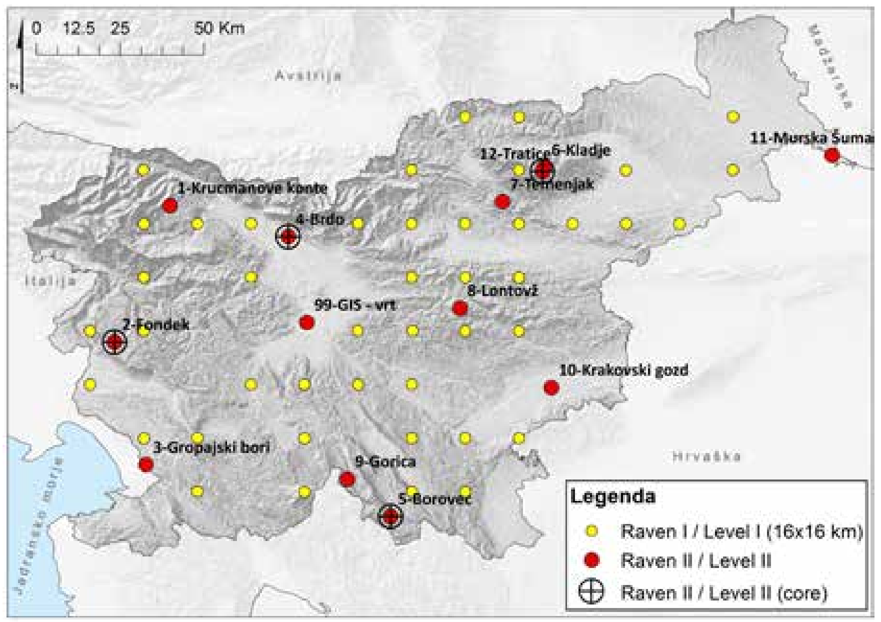
**Implementation**

The ICP Forests programme is being implemented in Slovenia at two intensity levels, i.e. at Levels I and II..

Level I embraces 44 plots (16 x 16 km systematic sample grid (Figure 1), on which the condition of forests is annually monitored via defoliation indicator and damages to trees . Periodically, at 5 to 10 years, tree damage is additionally monitored in 4 x 4 km condensed grid (ca. 780 plots). For the selection of trees on a plot, the M6 method is used, which means that 6 trees nearest to the plot centre are inventoried. Each plot In the 16 x 16 km grid is composed of 4 sub-plots M6. In this way, health condition of 24 trees is assessed.

Within the framework of intensive monitoring of forest ecosystems (Level II), 11 plots were set up in 2003 all over Slovenia, where a systematic gathering of information on weather variables, air sediments, contents of nutrients in needles, leaves and leaf-litter, pollution and fertility of forest soil, chemical structure of soil solution, phenological development of trees, air quality, tree growth, crown defoliation, condition of ground vegetation (Figure 2) is carried out in compliance with the instructions of ICP Forests (http://icp-forests.net/page/icp-forests-manual.

For various reasons, some plots were partially or fully abandoned, while some were set up anew, especially as a superstructure of the existing plots. Thus we currently have four core plots, where all activities are carried out, and six plots with lower intensity of forest ecosystem monitoring, where emphasis is laid on direct monitoring of tree health, nutrition and defoliation.




**Slika 1: Ploskve spremljanja stanja gozdnih ekosistemov v Sloveniji (Raven I in Raven II)**
**// Figure 1: Forest monitoring plots in Slovenia (Levels I and II)**


**Slika 2: Dejavnosti intenzivnega spremljanja stanja gozdnih ekosistemov v Sloveniji**
**// Figure 2: Activities of intensive forest monitoring in Slovenia**

**Preglednica 1: Geografska lokacija in glavne značilnosti ploskev intenzivnega spremljanja gozdnih ekosistemov (Raven II) ("core" ploskve označene s krepko pisavo)**
**// Table 1: Geographic locations and main characteristics of forest monitoring plots (Level II) in Slovenia (core plots in bold)**

| Ime ploskve | Zemljepisna dolžina* | Zemljepisna širina* | Nadmorska višina* | Ekološka regija | Glavna drevesna vrsta | Št. opazovanih dreves | Obdobje spremljanja |
|---|---|---|---|---|---|---|---|
| Plot name | Longitude (°) | Latitude (°) | Elevation (m) | Ecological region | Main tree species | No. of observed trees | Monitoring period |
| 1 - Krucmanove konte | +13°56´ | +46°22´ | 1397 | Alpska / *Alpine* | Smreka (*Picea abies*) | 19 | 2003 - present |
| **2 - Fondek** | **+13°43´** | **+45°59´** | **827** | **Dinarska / *Dinaric*** | **Bukev (*Fagus sylvatica*)** | **20** | **2003 - present** |
| 3 - Gropajski bori | +13°51´ | +45°40´ | 420 | Submediteranska / *Sub-Mediterranean* | Črni bor (*Pinus nigra*) | 19 | 2003 - 2013 |
| **4 - Brdo** | **+14°24´** | **+46°17´** | **471** | **Predalpska / *Pre-Alpine*** | **Rdeči bor (*Pinus sylvestris*)** | **20** | **2003 - present** |
| **5 - Borovec** | **+14°48´** | **+45°32´** | **705** | **Dinarska / *Dinaric*** | **Bukev (*Fagus sylvatica*)** | **20** | **2003 - present** |
| 6 - Kladje | +15°23´ | +46°28´ | 1304 | Pohorska / *Pohorje* | Smreka (*Picea abies*) | 19 | 2003 - 2008 |
| 7 - Temenjak | +15°12´ | +46°21´ | 1000 | Predalpska / *Pre-Alpine* | Bukev (*Fagus sylvatica*) | 20 | 2003 - 2008 |
| 8 - Lontovž | +15°03´ | +46°05´ | 950 | Predalpska / *Pre-Alpine* | Bukev (*Fagus sylvatica*) | 20 | 2003 - present |
| 9 - Gorica | +14°38´ | +45°38´ | 955 | Dinarska / *Dinaric* | Bukev (*Fagus sylvatica*), jelka (*Abies alba*) | 20 | 2003 - 2014 |
| 10 - Krakovski gozd | +15°24´ | +45°52´ | 160 | Predpanonska / *Pre-pannonian* | Dob (*Quercus robur*), beli gaber (*Carpinus betulus*) | 20 | 2003 - 2013 |
| 11 - Murska šuma | +16°30´ | +46°29´ | 170 | Predpanonska / *Pre-pannonian* | Smreka (*Picea abies*), bukev (*Fagus sylvatica*) | 19 | 2003 - 2013 |
| **12 - Tratice** | **+15°23'** | **+46°27˝** | **1289** | **Pohorska / *Pohorje*** | **mešano (mixed)** | | **2009 - present** |
| 99 – GIS-vrt** | +14°29' | +46°03˝ | 310 | Predalpska / *Pre-Alpine* | | | 2009 - present |

*** Center ploskve** **// plot centre**

****Dodatna, testna, ploskev, namenjena preizkušanju naprav, metod, tudi demonstraciji strokovni in laični javnosti**
**// Additional plot, serves as a test plot for pilot devices, methods, as demonstration plot for professional and lay public**

# STANJE KROŠENJ IN POŠKODBE DREVJA

## // TREE CROWN CONDITION AND DAMAGE CAUSES

**Mitja Skudnik, Špela Planinšek, Saša Vochl in Jure Žlogar**

**Stanje krošenj in poškodbe drevja v Sloveniji spremljamo že od leta 1985. Stanje krošenj ocenjujemo s pomočjo kazalnika osutost, poškodbe drevja pa na podlagi videnega simptoma poškodbe posameznega dela drevesa. Rezultati kažejo, da se v Sloveniji zdravstveno stanje dreves od leta 2008 dalje izboljšuje, stanje iglavcev ostaja slabše od stanja listavcev. Najpogostejši vzroki poškodb drevja so biotski (defoliatorji in podlubniki) in v zadnjih letih vse pogostejši tudi abiotski dejavniki, kot so žledenje, vetrolomi, snegolomi in požari.**

**// Tree crown condition and damage causes in Slovenia have been monitored since 1985. The crown condition is assessed using the indicator defoliation, while damage of trees is assessed with visible damage symptoms for each part of the tree. The results for Slovenia show that from 2008 the state of health of trees has improved, while the state of conifers remains slightly worse compared to broadleaves. The commonest causes of tree damages are biotic factors (like defoliators and bark beetles), Increasingly common in recent years, however, have also been abiotic factors such as sleet, snowbreaks, windthrows and fires.**

Popis stanja krošenj v Sloveniji poteka že od leta 1985. Cilj programa je pridobiti vpogled v prostorske in časovne spremembe zdravstvenega stanja gozdov in ugotoviti vpliv stresnih dejavnikov, vključno z onesnaženostjo zraka.

S tem namenom je bil v državah, ki so sodelovale pri programu ICP Forests, vzpostavljen monitoring poškodovanosti gozdov. Glavna indikatorja za spremljanje poškodovanosti gozdov sta spremljanje stanja krošenj (osutost krošenj) in ocena poškodb drevja. Osutost je na oko ocenjeni delež (v odstotkih) manjkajočih asimilacijskih organov (listov, iglic) izbranega drevesa v primerjavi z normalno olistanim primerkom iste drevesne vrste. Pri vsakem drevesu se ocenijo tudi vidne poškodbe - mesto poškodbe na drevesu, obstoječi simptomi in potencialni povzročitelj poškodbe.

V Sloveniji stanje krošenj spremljamo na 44 ploskvah Ravni I (sistematična vzorčna mreža 16 x 16 km) (Slika 1) in 10 ploskvah intenzivnega spremljanja stanja gozdov (Raven II), ki so bile v Sloveniji osnovane leta 2004. Namen popisa poškodb drevja je spremljanje različnih stresnih dejavnikov, ki vplivajo na poškodovanost gozdnega drevja, in hkrati tudi delno pojasniti vzroke osutosti dreves. Cilj spremljanja stanja krošenj pa je ugotoviti trend zdravstvenega stanja drevesnih vrst ter propadanja gozdov.

Prednost spremljanja stanja gozdov na dveh ravneh (Raven I in Raven II) je predvsem v tem, da je prvi namenjen spremljanju stanja gozdov na državni ravni, medtem ko je namen monitoringa na ploskvah Raven II predvsem boljše razumevanje odvisnosti med vitalnostjo drevja in vzroki ter posledicami faktorjev stresa. Dodatno rezultati monitoringa na ploskvah Raven II rabijo tudi kot kontrola dolgoročnih trendov propadanja gozdov in zaznavanje trenutnega stanja osutosti drevesnih vrst.

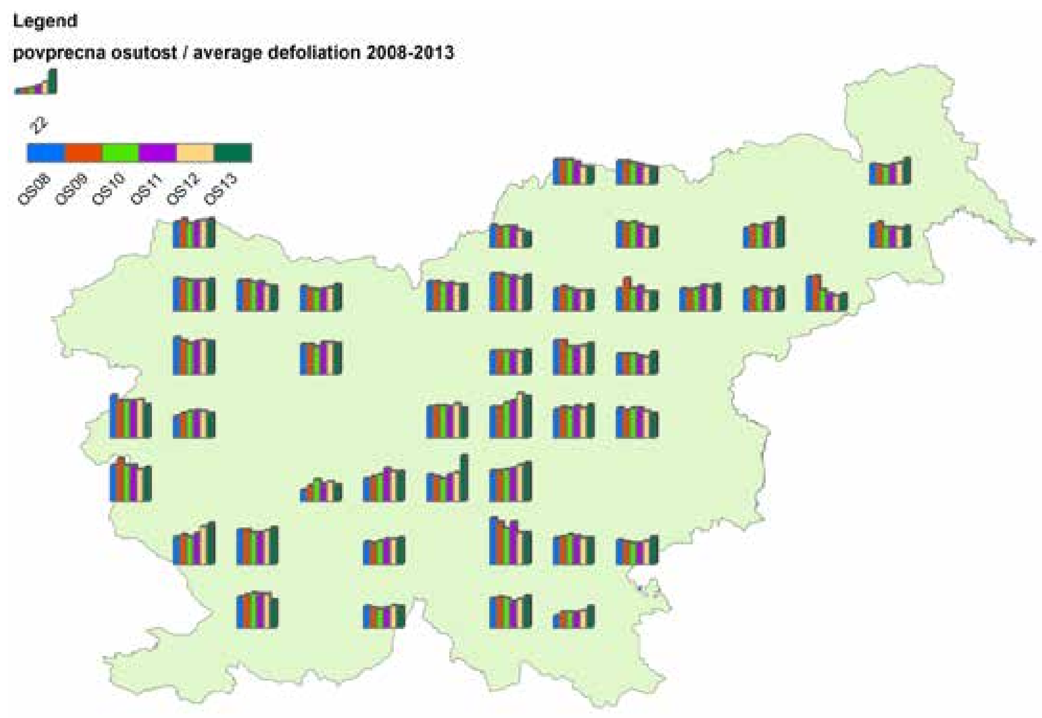
Tree crown monitoring has been carried out in Slovenia since 1985. The aim of the program is to gain insight into the spatial and temporal changes in forest health condition and to determine the effect of stress factors, including air pollution on forests.

For this reason, the countries participating in the ICP Forest program established a monitoring of tree health. The main indicators were the monitoring of crown condition (defoliation) and assessment of damage causes. Defoliation is the estimated proportion of missing assimilation organs (leaves, needles) for selected trees compared with normal foliage of the same tree species. For each tree, visible damages are also assessed - damaged part of the tree, damage symptoms and the potential cause of injury.

In Slovenia, the crown condition is monitored on 44 Level I plots (systematic sampling 16 x 16 km grid) (Figure 1) and on 10 intensive monitoring plots (Level II), which were established in Slovenia in 2004. The purpose of the damage cause assessment is to monitor the types of stress factors that affect the damage of forest trees and also to partially explain the causes of tree crown defoliation. The aim of crown condition monitoring is to determine the trend of the health status of tree species and forest degradation.

Benefits of forest monitoring designed at two levels (Level I and Level II) lie mainly in the fact that the first is designed to monitor the condition of forests at the national level, while the purpose of the second level is a better understanding of the interdependence between the vitality of trees and causes and consequences produced by stress factors. In addition, the results of monitoring plots at Level II serve also as a control for long-term trends in forest degradation and perception of the current state of defoliation of tree species.






**Slika 1. Povprečna osutost za obdobje 2008-2013 po posameznih ploskvah Ravni I v Sloveniji**
**// Figure 1. Average defoliation for the period 2008-2013 for Slovenian Level I plots**

Rezultati kažejo, da se je v Sloveniji zdravstveno stanje gozdov nekoliko izboljšalo. Predvsem se je zmanjšal delež poškodovanih listavcev. Kljub temu pa je delež poškodovanih dreves v Sloveniji še vedno nad povprečjem držav članic EU. Najpogostejši vzroki so biotski (defoliatorji in podlubniki) in v zadnjih letih tudi abiotski dejavniki, kot so žledenje in vetrolomi.

Popis stanja krošenj in povzročiteljev poškodb je pomemben zato, ker zaobjema celotno nacionalno ozemlje v enem trenutku oz. v enem letu. V okviru rednega monitoringa gozdov se pogosto poleg poškodovanosti ocenjujejo in merijo tudi drugi znaki, kot so npr. debelinski in višinski prirastek drevja, količina odmrle biomase itd., zaradi česar ti podatki oblikujejo pomembno ekološko zbirko o gozdnem prostoru. Kot celota je popis pomemben tudi z mednarodnega vidika - program ICP Forests je namreč globalno uveljavljen in ga uresničujejo v večini evropskih dežel, Kanadi, ZDA ter nekaterih azijskih državah.

The results show that Slovenia forest health condition has improved. In particular, proportion of damaged broadleaves trees decreased. Nevertheless, the proportion of damaged trees in Slovenia is still above the EU average. The commonest causes are biological (causes like defoliators and bark beetles) and, in recent years, the abiotic factors such as sleet and windthrows.

Crown condition and damage causes survey gives important information on the state of forests in the entire national territory at one time or in one year. Within the framework of regular forest monitoring, monitoring of other characteristics of trees like DBH and height of trees, the amount of dead biomass, etc. is often included as well. These pieces of information jointly constitute an important ecological collection of data for forest areas. As a whole, the survey is also important from an international perspective.

The ICP Forest program is widely spread and implemented in most European countries as well as in Canada, the US and some Asian countries.

# SPREMLJANJE STANJA PRITALNE VEGETACIJE GOZDOV

## // MONITORING OF FOREST GROUND VEGETATION

**Lado Kutnar**

### SPREMLJANJE PRITALNE VEGETACIJE V EVROPI IN SLOVENIJI

Spremljanje stanja pritalne vegetacije gozdov poteka v okviru mednarodnega programa ICP Forests. V okviru tega programa je bila oblikovana posebna ekspertna skupina, ki razvija mednarodno usklajene metode za spremljanja stanja biotske raznovrstnosti gozdov in pritalne vegetacije. Spremljanje stanja in sprememb pritalne vegetacije v Evropi in pri nas poteka na dveh različnih ravneh: (i) Raven I temelji na sistematično razvrščenih ploskvah na mreži 16 x 16 km; (ii) Raven II pa vključuje ploskve za intenzivno spremljanje stanja gozdnih ekosistemov in učinkov različnih stresnih dejavnikov.

Cilj spremljanja pritalne vegetacije je pridobivanje informacij o spremembah rastlinske vrstne pestrosti zaradi naravnih sprememb (npr. naravna sukcesija gozda) in motenj (npr. onesnaženje okolja, podnebne spremembe, gospodarjenje z gozdom). S tem namenom se ugotavljajo (i) vrstna sestava, (ii) stopnja zastiranja vrst (pokrovnost, obilje) in (iii) vertikalna struktura vegetacije.

### ZGODOVINA SPREMLJANJE PRITALNE VEGETACIJE V SLOVENIJI

Začetki spremljanja pritalne vegetacije v Sloveniji v skladu s programom ICP Forests segajo že v leto 1994, ko smo popisali del ploskev na mreži 16 x 16 km (Raven I). Prve raziskave pritalne vegetacije na Ravni II (intenzivno spremljanje gozdov) smo poskusno napravili v letu 1996 na dveh ploskvah v bližini Kočevske Reke.

Začetek sistematičnega spremljanja pritalne vegetacije sega v leto 2004, ko smo v okviru evropskega programa Forest Focus (2004-2006) napravili popis vegetacije na 11 izbranih ploskvah za intenzivno spremljanje stanja gozdov (Raven II). Celostnejši popis pritalne vegetacije na 39 ploskvah mreže 16 x 16 km (Raven I) je bil opravljen v okviru evropskega demonstracijskega projekta BioSoil (Biodiverziteta) v letih 2006 in 2007.

### RASTLINSKA PESTROST GOZDOV V SLOVENIJI

Dogovorjena popisna površina za vrednotenje rastlinske vrstne pestrosti na obeh ravneh znaša 400 $m^2$. V Sloveniji na Ravni I spremljamo pritalno vegetacijo na popisni ploskvi krožne oblike z radijem 11,3 metra. Na ploskvah Ravni II dobimo to popisno površino z združevanjem štirih vegetacijskih podploskev velikosti 10 x 10 metrov. Za oceno stopnje zastiranja rastlinskih vrst na ploskvah obeh ravni uporabljamo metodo po Barkman et al (1964).

Popis vegetacije na ploskvah obeh ravni je pokazal razmeroma visok nivo vrstne pestrost gozdov v Sloveniji. Na Ravni II smo popisali v povprečju 61 vrst praprotnic in semenk na ploskev (preglednica 1). Celotno število popisanih vrst praprotnic in semenk na vseh ploskvah Ravni II je bilo 295.

V vseh vertikalnih plasteh (drevesna, grmovna in zeliščna) ploskev Ravni I in II smo na površini 400 $m^2$ v povprečju popisali 8,3 drevesnih vrst (razpon od 2 do 17 vrst na ploskev) in 6,4 grmovnih vrst (razpon od 0 do 20 vrst). Največkrat popisane drevesne vrste v vseh vertikalnih plasteh so bile *Fagus sylvatica, Picea abies, Acer pseudoplatanus, Quercus petraea, Prunus avium, Abies alba, Carpinus betulus, Fraxinus excelsior, Sorbus aucuparia* in *Sorbus aria*. Od grmovnic in olesenelih vzpenjavk pa smo največkrat določili naslednje vrste: *Rubus hirtus, Hedera helix, Corylus avellana, Daphne mezereum, Clematis vitalba, Sambucus nigra, Rosa arvensis, Euonymus europaea* in *Rubus idaeus.*

Spremljanje stanja rastlinske vrstne sestave, zastiranja vrst in vertikalne strukture vegetacije je razmeroma dobro izhodišče za zaznavanje sprememb v gozdnih ekosistemih. Na osnovi kontinuiranega monitoringa pritalne vegetacije gozda lahko ugotavljamo in sledimo spremembam gozdnih ekosistemov in njihovega širšega okolja ter učinkom različnih stresnih dejavnikov.

### MONITORING OF GROUND VEGETATION IN EUROPE AND SLOVENIA

Monitoring of forest ground vegetation is part of the International ICP Forests Programme. Within this Programme, the Expert Panel on Biodiversity and Ground Vegetation has been given the task to develop harmonised monitoring methods in the fields of forest biological diversity and ground vegetation. Monitoring of ground vegetation in Europe and Slovenia is carried out on two different levels: (i) Level I is based on a systematic 16 x 16 km gridnet; (ii) Level II comprises plots for the intensive monitoring of conditions in forest ecosystems and effects of different stress factors.

The main objective of the assessment of diversity in ground vegetation is to get information on changes in biodiversity due to natural dynamics (e.g. natural successional development of forest) and disturbances (e.g. air pollution, climate changes, forest management). The aim of the vegetation survey through continuous monitoring is to obtain information on changes (i) in species composition, (ii) in species cover (abundance), and (iii) in vertical vegetation structure.

### HISTORY OF GROUND VEGETATION MONITORING IN SLOVENIA

In Slovenia, first test phase of ICP Forests ground vegetation monitoring started in 1994, when part of the plots on 16 x 16 km gridnet (Level 1) were surveyed. In 1996, the test survey of ground vegetation on Level 2 (intensive monitoring of forests) was carried out on two plots near Kočevska Reka village.

In Slovenia, the systematic ground vegetation monitoring started in 2004. Within the European Forest Focus Programme (2004-2006), a vegetation inventory of 11 selected intensive monitoring plots (Level II) was done. As a part of the European BioSoil demonstration project (Biodiversity), the comprehensive survey of ground vegetation on 39 plots of the 16 x 16 km gridnet (Level I) was performed in 2006 and 2007.

### FOREST PLANT DIVERSITY IN SLOVENIA

At both two levels, the harmonised sampling area for the evaluation of plant species diversity covers 400 $m^2$. In Slovenia, monitoring of ground vegetation at Level I is carried out on the circular plot with a radius of 11.3 meters. At Level II, the sampling area is obtained by combining four vegetation subplots of 10 x 10 meters. For the estimation of plant cover at both two levels, method by Barkman et al. is used (1964).

A relatively high level of forest plant species diversity was established on the plots of both levels. On average, 61 vascular plant species per Level II plot were documented (Table 1). A total of 295 vascular plant species were recorded on these plots.

In all vertical layers (tree, shrub and herb layer) of Level I and Level II plots measuring 400 $m^2$ in size on average, 8.3 tree species (range 2 to 17 species per plot) and 6.4 shrub species (range 0 to 20 species) were identified. The most frequently assessed tree species in all vertical layers were *Fagus sylvatica, Picea abies, Acer pseudoplatanus, Quercus petraea, Prunus avium, Abies alba, Carpinus betulus, Fraxinus excelsior, Sorbus aucuparia* and *Sorbus aria*. Among shrub species and woody climbers, *Rubus hirtus, Hedera helix, Corylus avellana, Daphne mezereum, Clematis vitalba, Sambucus nigra, Rosa arvensis, Euonymus europaea* and *Rubus idaeus* prevailed.

Assessment of the plant species composition, plant cover and vertical structure of vegetation is a relatively good starting point for detecting changes in forest ecosystems. On the basis of continuous monitoring of forest ground vegetation, the changes of forest ecosystems and their environment and the effects of various stress factors can be identified and followed.

**Preglednica 1. Pestrost rastlinskih vrst na ploskvah ravni II // Table 1. Diversity of plant species on Level II plots**

| Številka in ime Ploskve Number & plot name | Vegetacijski tip Vegetation type |
|---|---|
| 1-KRUCMANOVE KONTE | Aposerido-Piceetum var. geogr. Helleborus niger |
| 3-GROPAJSKI BORI | Ostryo-Quercetum pubescentis |
| 6-KLADJE | Avenello flexuosae-Piceetum var. geogr. Aposeris foetida |
| 7-TEMENJAK | Lamio orvalae-Fagetum var. geogr. Dentaria pentaphyllos |
| 9-GORICA | Omphalodo-Fagetum var. geogr. Calamintha grandiflora |
| 10-KRAKOVSKI GOZD | Pseudostellario europaeae-Quercetum roboris |
| 2-FONDEK | Seslerio autumnalis-Fagetum var. geogr. Anemone trifolia |
| 4-BRDO | Vaccinio myrtilli-Pinetum var. geogr. Castanea sativa |
| 5-BOROVEC | Lamio orvalae-Fagetum var. geogr. Dentaria polyphyllos |
| 8-LONTOVŽ | Lamio orvalae-Fagetum var. geogr. Dentaria pentaphyllos |
| 11-MURSKA ŠUMA | Querco roboris-Carpinetum s. lat. |

| Številka in ime Ploskve Number & plot name | Ograjena ploskev Fenced plot | Št. 10X10 m Podploskev N 10x10 m Subplots | Povp. Št. Vrst praprotnic in semenk/podploskev mean n vascular species/subplot | Št. Vrst praprotnic in semenk N vascular species | Št. Vrst mahov N bryophte species |
|---|---|---|---|---|---|
| 1-KRUCMANOVE KONTE | ne/no | 4 | 42 | 70 | 33 |
| 3-GROPAJSKI BORI | ne/no | 4 | 27 | 49 | 23 |
| 6-KLADJE | ne/no | 4 | 12 | 16 | 19 |
| 7-TEMENJAK | ne/no | 4 | 44 | 62 | 31 |
| 9-GORICA | ne/no | 4 | 57 | 77 | 36 |
| 10-KRAKOVSKI GOZD | ne/no | 4 | 43 | 71 | 27 |
| 2-FONDEK | da/yes | 8 | 27 | 59 | 26 |
| 4-BRDO | da/yes | 8 | 12 | 25 | 13 |
| 5-BOROVEC | da/yes | 8 | 45 | 90 | 37 |
| 8-LONTOVŽ | da/yes | 8 | 53 | 89 | 33 |
| 11-MURSKA ŠUMA | da/yes | 8 | 32 | 63 | 24 |

**Slika 1. Dinarski jelovo-bukov gozd na ploskvi Gorica v Loškem potoku (Foto: Lado Kutnar)**
**// Picture 1. Dinaric silver fir-common beech foreston the Gorica plot near Loški potok (Photo: Lado Kutnar)**

**Slika 2. Spomladanski aspekt pritalne vegetacije na ploski v Murski šumi pri Lendavi (Foto: Lado Kutnar)**
**// Picture 2. Spring aspect of ground vegetation on the plot in Murska šuma near Lendava (Photo: Lado Kutnar)**



# RAST IN PRIRASTEK DREVES

## // GROWTH AND YIELD

**Tom Levanič, Mitja Skudnik**

**V okviru intenzivnega spremljanja stanja gozdnih ekosistemov v Sloveniji od leta 2004 spremljamo tudi rast in prirastek dreves na 10 ploskvah Ravni II. Spremembam v debelinskem priraščanju dreves sledimo v skladu z navodili ICP Forests - Growth na dva komplementarna načina: (1) s pomočjo periodičnih dendrometrijskih meritev istih dreves vsakih 5 let in (2) s pomočjo ročnih dendrometrov, nameščenih na izbrano število dreves.**

**// Within the framework of intensive monitoring of forest ecosystem, tree growth and increment has been monitored on 10 level II monitoring plots since 2004. The monitoring of growth and increment, which is carried out in accordance with ICP Forests Manual on Growth, is performed in two ways: (1) by forest inventory every 5 years and (2) by manual girth bands installed on a selected number of trees.**

S SPREMLJANJEM RASTI IN PRIRAŠČANJA DREVES V GOZDU DOBIMO VPOGLED V DINAMIKO SPREMINJANJA PRIRASTKA IN LESNE ZALOGE SESTOJEV V LUČI SPREMINJAJOČIH SE OKOLJSKIH RAZMER.

BY MONITORING GROWTH AND YIELD OF FOREST TREES WE GAIN INSIGHT INTO DYNAMICS OF INCREMENT AND GROWING STOCK IN CHANGING ENVIRONMENTAL AND CLIMATIC CONDITIONS.

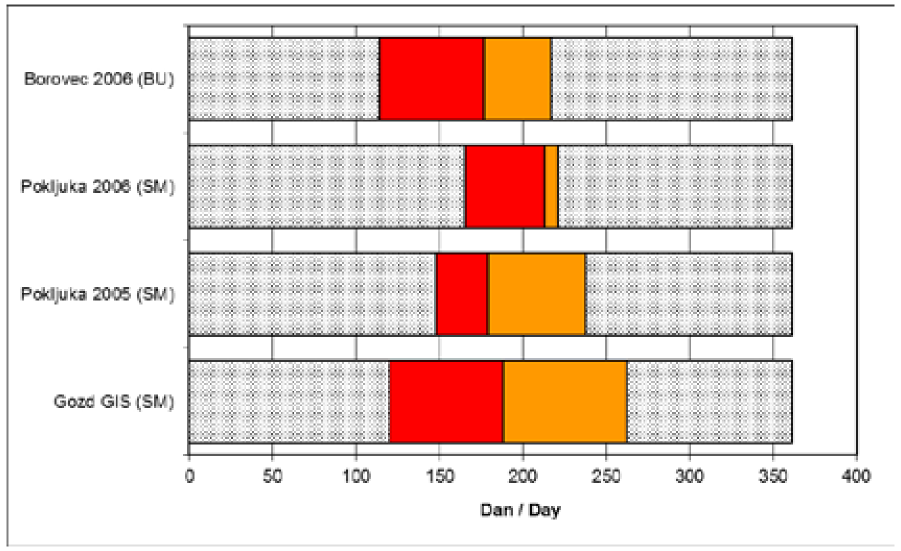
Na desetih ploskvah (0,25 ha) intenzivnega spremljanja stanja gozdnih ekosistemov smo v letu 2004 opravili dendrometrijske meritve 1250 dreves (prsni premer, višina, socialni položaj…), ki smo jih ponovili še v letih 2009 in 2014. Ugotavljamo, da ima največjo temeljnico, dominantno višino in lesno zalogo starejši smrekov debeljak na Krucmanovih kontah, Pokljuka (ploskev št. 1). Ploskve mlajših razvojnih faz dosegajo manjše lesne zaloge. Največji prirastek lesne zaloge in s tem tudi akumulacijo nadzemne in podzemne biomase in ogljika smo ugotovili na ploskvah Lontovž, Draga, Krakovski gozd in Murska šuma. Največji prirastki so 13 m$^3$ ha$^{-1}$ leto$^{-1}$ (Draga), najmanjši pa 6,2 m$^3$ ha$^{-1}$ (Gropajski bori, Sežana). Podobno je z akumulacijo ogljika, ki je bila največja na ploskvi Krakovski gozd (6,9 t C ha$^{-1}$ leto$^{-1}$), na Krucmanovih kontah pa starejši smrekovi debeljaki akumulirajo le še 1,8 t C ha$^{-1}$ leto$^{-1}$.

Na vseh desetih ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov smo namestili tudi ročne dendrometre na skupno 229 dreves. Z ročnimi dendrometri dobimo vpogled v t.i. intra-anualno dinamiko priraščanja drevja. Slednjega ne moremo dobiti s periodičnimi meritvami na pet let. Prednost takšnih meritev je, da ne dobimo samo podatka o letnem debelinskem prirastku, marveč tudi vpogled v dinamiko nastajanja letnega debelinskega prirastka, kdaj se rast začne in kdaj je naj-

On ten forest monitoring plots (0.25 ha each), a forest inventory was carried out in 2004 and repeated in 2009 and 2014. Radial increment, basal area increment, dominant height and growing stock for each of the ten plots were calculated. Plot Krucmanove konte, Pokljuka (No. 1) turned out to be the most productive site due to the highest basal area, dominant tree height and growing stock. Plots with younger trees have smaller growing stock compared to plots with older trees. The highest increase of the growing stock and, accordingly, the highest accumulation of aboveground and belowground biomass and carbon were measured on plots Lontovž, Draga, Krakovski gozd and Murska šuma. The highest increment was 13 m$^3$ ha year$^{-1}$ (Draga), the lowest 6.2 m$^3$ ha$^{-1}$ (Gropajski Bori, Sežana). The highest accumulation of carbon was measured at plot Krakovski gozd – 6.9 t C ha$^{-1}$ year$^{-1}$, the smallest on Krucmanove konte 1.8 t C ha$^{-1}$ year$^{-1}$.

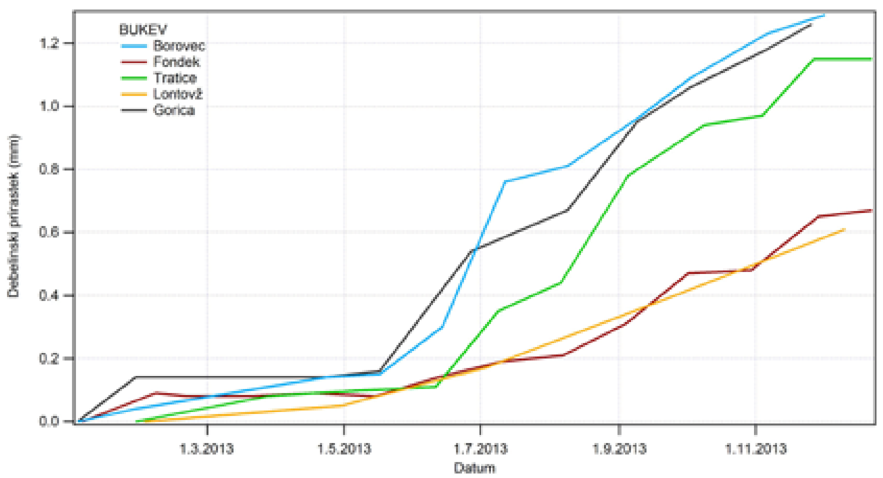
On all ten forest monitoring plots, manual girth bands were installed (N=229 trees). With these bands we are able to gain insight into intra-annual growth dynamics, which cannot be observed with the forest inventory every five years. Additionally, data on temporal dynamics of radial increment are assessed, information when growth starts and ends and also when the growth is most intensive. These pieces of information are imporbolj intenzivna. Te informacije so pomembne zato, ker lahko prek njih ugotavljamo odzive dreves na okoljske in klimatske dražljaje, hkrati pa tudi vidimo, kako konkretna mikroklima (v povezavi s samodejnimi vremenskimi postajami na ploskvah) vpliva na rast drevesa in druge parametre, ki jih spremljamo.

tant for acquiring an understanding of tree's response to environmental and climatic stressors, to see tree's response to microclimatic conditions (in connection with automated weather stations installed on forest monitoring plots) and the influence of microclimate on tree growth and other monitored parameters.





**Slika 1: Spremembe v premeru debla odčitavamo na desetinko milimetra natančno, kar omogoča nonijska skala. Drevo na fotografiji v premeru meri 44,27 cm. (Foto: Tom Levanič)**
**// Figure 1: Changes in stem diameter are detected with the accuracy of 0.1 millimetres. This is enabled by the nonium scale. Tree diameter in Figure 1 is 44.27 cm. (Photo: Tom Levanič)**




**Graf 1: Letni debelinski prirastek bukve na petih ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov – Trnovski gozd (Fondek), Kočevska Reka (Borovec), Zasavje (Lontovž), Pohorje (Tratice) in Loški Potok (Gorica) v letu 2013**
**// Graph 1: Annual radial increment of beech trees on five intensive forest monitoring plots – Trnovski gozd (Fondek), Kočevska Reka (Borovec), Zasavje (Lontovž), Pohorje (Tratice) and Loški Potok (Gorica) in 2013**



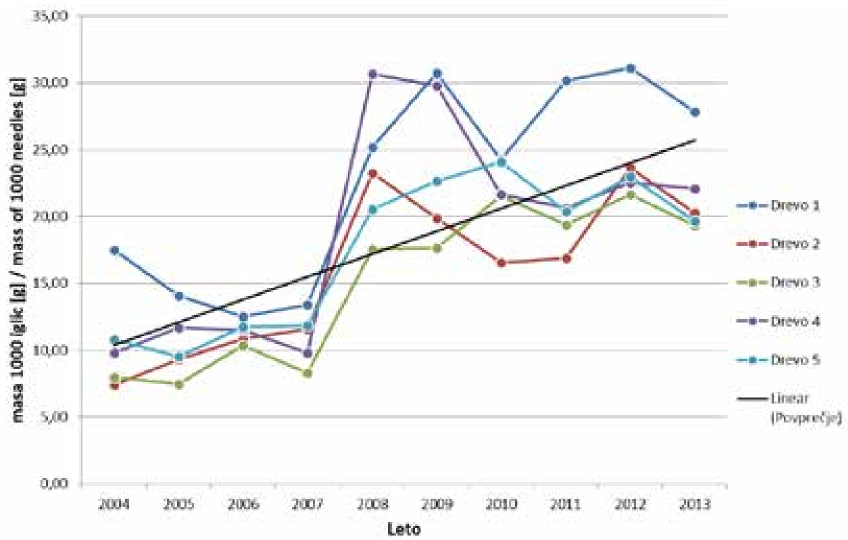
# HRANILA V FOLIARNIH VZORCIH

## // NUTRIENTS IN FOLIAGE

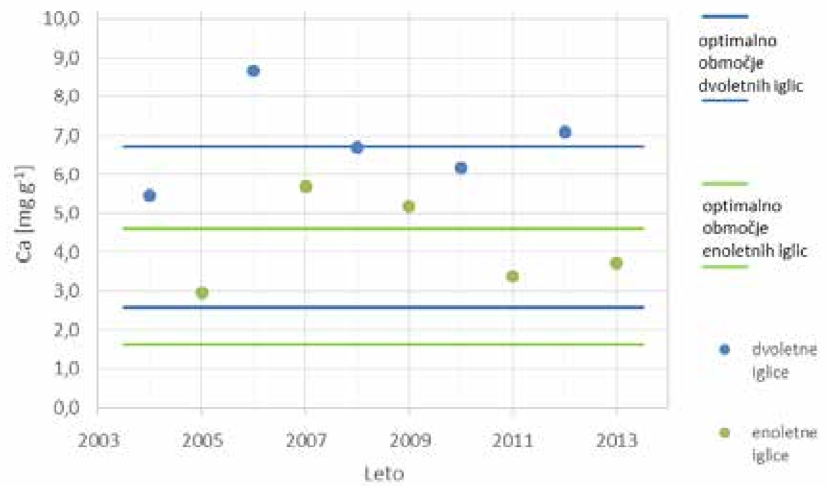
**Daniel Žlindra**

S spremljanjem mase listov oziroma iglic in vsebnostjo hranil ocenimo stopnjo prehranjenosti drevja. Z rednim spremljanjem lahko določimo tudi prevladujoče trende in, če so ti neugodni, sprejemamo potrebne odločitve za njihovo izboljšanje.

//The nutrition status of trees can be estimated with the aid of monitoring the nutrients in foliage. With regular monitoring, the prevailing trends can be detected, and if they are adverse we take the measures to improve them.




**Slika 1: Mase 1000 iglic (suha masa) rdečega bora (*Pinus sylvestris* L.) na ploskvi Brdo petih preučevanih dreves in trend povprečja**
**// Fig. 1: Mass of 1000 needles (dry weight) of Scots pine (*Pinus sylvestris* L.) on the plot Brdo from 5 monitored trees and trend of the average**




**Slika 2: Vsebnosti kalcija v iglicah rdečega bora (*Pinus sylvestris* L.) na ploskvi 4 – Brdo tekočega (zelena) in preteklega (modra) leta z optimalnim območjem**
**// Fig. 2: Calcium content of Scots pine (*Pinus sylvestris* L.) needles on the plot Brdo in the current year (green) and previous year (blue) with the optimal range**

**Foto: Iztok Sinjur**
**//Photo: Iztok Sinjur**

# BOLEZNI IN POŠKODBE GOZDNEGA DREVJA

## // DISEASES AND DAMAGES ON FOREST TREES

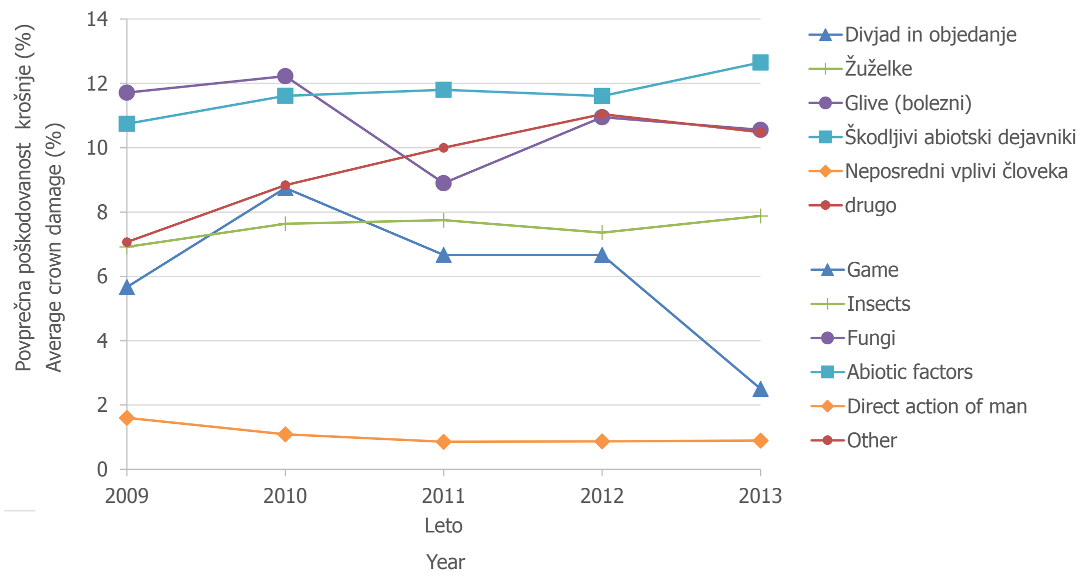
**Nikica Ogris**

Popis povzročiteljev poškodb drevja se opravlja tako na ploskvah Ravni I kot Ravni II. V obdobju 2009–2013 so krošnjo najbolj poškodovali abiotski dejavniki (slika 1). Na drugem mestu so bili drugi (neznani) vzroki, zaradi kateri narašča povprečna poškodovanost krošnje že vse od leta 2009. Sledijo parazitske glive, ki so med letoma 2009 in 2013 povzročile 8,9–12,2-odstotno povprečno poškodovanost krošnje. Žuželke so pogost povzročitelj poškodb krošnje, saj v povprečju povzročijo od 6,9–7,9-odstotno poškodovanost krošnje. Povprečna poškodovanost krošnje zaradi divjadi in objedanja je v letu 2013 močno padla glede na prejšnja leta (s 6,7 na 2,5 % povprečno). K poškodovanosti krošnje najmanj prispevajo neposredni vplivi človeka (v zadnjih treh letih 0,8 %).

**Popis povzročiteljev poškodb pojasnjuje osutost krošnje.** Najpogostejši vzrok osutosti v zadnjih nekaj letih so defoliatorji in med njimi bukov rilčkar skakač (*Rhynchaenus fagi*), ki je povzročil približno tretjino osutosti krošnje. Na drugem mestu po pogostosti navedbe vzroka poškodovanosti je bila sušica najmlajših borovih poganjkov, ki jo povzroča gliva *Diplodia pinea*. Med vzroki poškodovanosti dreves so bili v 2013 najpogosteje navedeni še *Heterobasidion* spp., glive, ogenj, raki, mraz, konkurenca zaradi gostote, veter.

// Damage agents of trees are surveyed on both monitoring levels, i.e. Level I and Level II. In the 2009-2013period, the most damaging agent of crown were harmful abiotic factors (Figure 1). The next most damaging were other (unknown) reasons, due to which the average damage of crown has been increasing since 2009. These were followed by parasitic fungi, which caused 8.9% to 12.2% crown damage on average between 2009 and 2013. Insects are a common cause of crown damage, as they cause from 6.9 to 7.9% damage on average. The average damage of the crown due to game in 2013 fell sharply compared to the previous year (from 6.7% to 2.5% on average). Direct human impacts contribute least to the crown damages (0.8% in the last three years).

**Monitoring causal agents explains crown defoliation.** The commonest defoliation inducers in the last few years have been defoliators, especially *Rhynchaenus fagi*, which has been responsible for about a third of crown defoliation. In the second place in terms of frequency was the pathogenic fungus *Diplodia pinea*. Other most frequently recorded causal agents were: *Heterobasidion* spp., other fungi, fire, canker, cold damage, competition due to density, and wind.




**Slika 1: Povprečna poškodovanost krošnje za glavne kategorije povzročiteljev 2009–2013**
**// Figure 1: Average crown damage for the main categories of damage agents 2009–2013**



# GOZDNA TLA

## // FOREST SOILS

**Mihej Urbančič, Milan Kobal, Aleksander Marinšek, Daniel Žlindra, Primož Simončič**

Gozdna tla so temeljni sestavni del gozda. S svojimi lastnostmi, kot so založenost s hranili, sposobnostjo nevtralizacije negativnih atmosferskih in drugih vplivov, sposobnostjo zadrževanja vode, ogljika, zadrževanja težkih kovin in drugih onesnaževal, poglavitno vplivajo na razvoj in spremembe gozdnega ekosistema. Vseskozi v tleh potekajo procesi njihovega nastajanja (humifikacija, mineralizacija, preperevanje) in siromašenja (izpiranje, zakisovanje, evtrofikacija, oglejevanje). Gozdna tla lahko degradirajo zaradi škodljivih vplivov neposrednega gospodarjenja z gozdovi in gozdnimi tlemi (npr. kot posledica zasmrečenosti, steljarjenja, onesnaženosti, različnih ujm, erozije idr.) ali vplivov daljnosežnih okoljskih dejavnikov (daljinski transport onesnaževal).

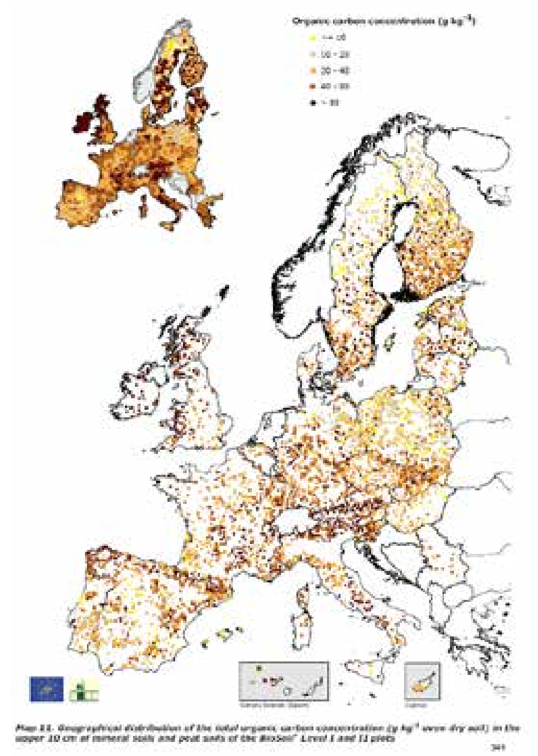
V okviru načrtnega spremljanja tal v gozdnih ekosistemih po Evropi je predvideno njihovo vzorčenje s časovnim razmikom 10 let (1995, 2005), v katerem je možno tudi že zaznati posamezne trende.

Šele redno periodično spremljanje potrjuje pravilnost ukrepov za zmanjšanje ogroženosti tal v preteklosti, hkrati pa omogoča ugotavljanje možnih trendov in daje priložnost za ukrepanje na mikro in makro nivoju za prihodnost.

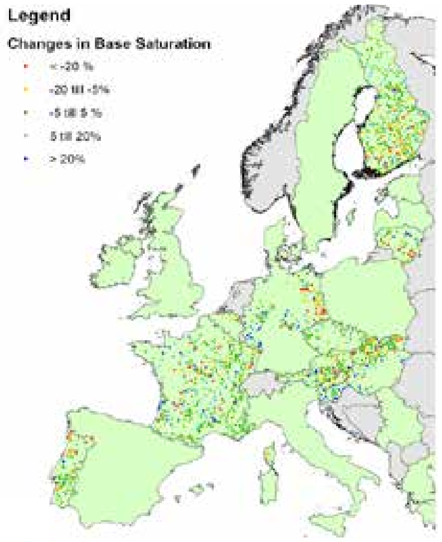
// Forest soils are the basic component of the forest. They influence the development and changes of the forest ecosystems with their properties such as nutrient availability, availability of neutralisation od negative atmospheric and other influences, water retention capability, capacity of carbon stock, retention of heavy metals and other pollutants. In the forest soils,  processes of their formation (humification, mineralization, weathering) and depletion (washout, acidification, eutrophication, formation of gley soil) are continually taking place. Forest soils can be degraded due to adverse impacts of direct forest and forest soil managing (sprucing, litter gathering, pollution, natural disaster, erosion …) or long range environment factors (long range air pollution).

Within the framework of systematic soil monitoring in forest ecosystems throughout Europe, sampling in time window of 10 years (1995, 2005) is foreseen, in which some trends can be detected.

It is only the periodic monitoring that can confirm the right decisions taken for reducing threats to soils in the past. At the same time, it enables us to detect possible trends, which serve as basis for taking appropriate measures  on the micro and macro scales for the future.



**Slika 1. Geografska razporeditev celotnega organskega ogljika (v g kg$^{-1}$ na suho maso) v zgornjih 10 cm mineralnega dela tal in šotnih tleh na BioSoil$^{+}$ ploskvah nivoja Ravni I in II (Nathalie Cools & Bruno De Vos)**
**// Fig. 1. Geographical distribution of the total organic carbon concentration (g kg$^{-1}$ oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil$^{+}$ Level I and II plots (Nathalie Cools & Bruno De Vos)**




**Slika 2. Geografska razporeditev sprememb nasičenosti z bazami na BioSoil+ ploskvah nivoja Ravni I (Nathalie Cools & Bruno De Vos)**
**// Fig. 2. Geographical distribution of changes in base saturation on the BioSoil+ Level I plots (Nathalie Cools & Bruno De Vos)**

# SVETLOBNE RAZMERE V SESTOJU IN STANJE KROŠENJ

## // MONITORING LIGHT AND CROWN CONDITIONS IN FOREST STANDS

**Matjaž Čater**

Svetlobne razmere so osnovni pogoj za večino življenjskih procesov kopenskih ekosistemov. Med sklepom krošenj, strukturo in razpoložljivo svetlobo pod krošnjami obstaja tesna povezava, ki se kaže v različnih strategijah preživetja rastlin, prilagoditvah rastlin različnim svetlobnim razmeram in njihovem razvoju.

Spremembe stanja listne površine zaradi defoliacije, načina gospodarjenja ali vremenskih ekstremov se posledično kažejo v spremenjeni produktivnosti sestoja. Zaradi strukturne heterogenosti in sprememb v času je ocena sklepa krošenj ali deleža svetlobnih razmer velikokrat težavna. V spremenljivih okoljskih razmerah je tako poznavanje stanja svetlobnih razmer ključno za uspešno pomlajevanje ter uravnavanje tekmovalne moči različnih drevesnih vrst. Sestojne svetlobne razmere in stanje krošenj dobro ovrednotimo z analizo sferičnih posnetkov.

// Light conditions constitute essential requirements for most life processes. A strong correlation exists between the canopy characteristics, structure and below-canopy light availability, which is reflected in different survival strategies of plants, their adaptation and development.

Changes of light conditions owing to defoliation, way of management, or weather extremes are consequently reflected in the changed stand productivity. Because of structural heterogeneity and temporal changes, an estimation of crown conditions or light availability below them is very challenging indeed. In the changing environmental conditions, the knowledge about light availability is therefore crucial for the successful regeneration and regulation of competitive strength between different tree species. Light conditions below canopies may be well evaluated with hemispherical photo analysis.

**Slika: Analizirana hemisfera krošenj (levo), poletne (sredina) in zimske razmere (desno) (Foto: Matjaž Čater)**
**// Figure 1: Analysed hemispherical image of crowns (left), summer (middle) and winter (right) stand conditions (Photo: Matjaž Čater)**

Primerjava stanja krošenj in mortalitete odraslih dreves na stalnih ploskvah nižinskih dobrav je za zadnjih 20 let potrdila ujemanje med razpoložljivostjo vode (podtalnico) in ekstremnimi razmerami (povečano T zraka).

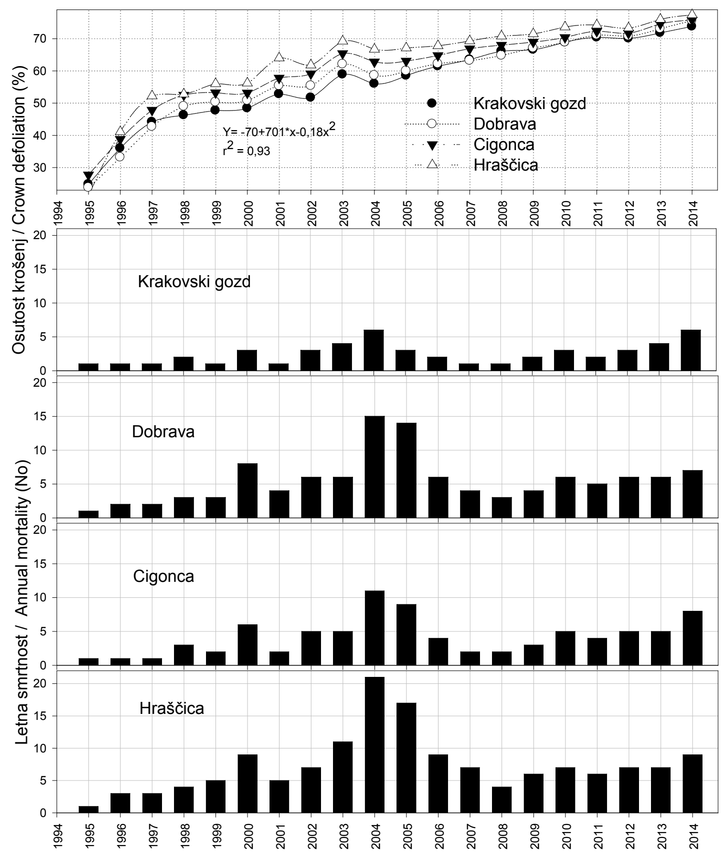
Prednosti metode:

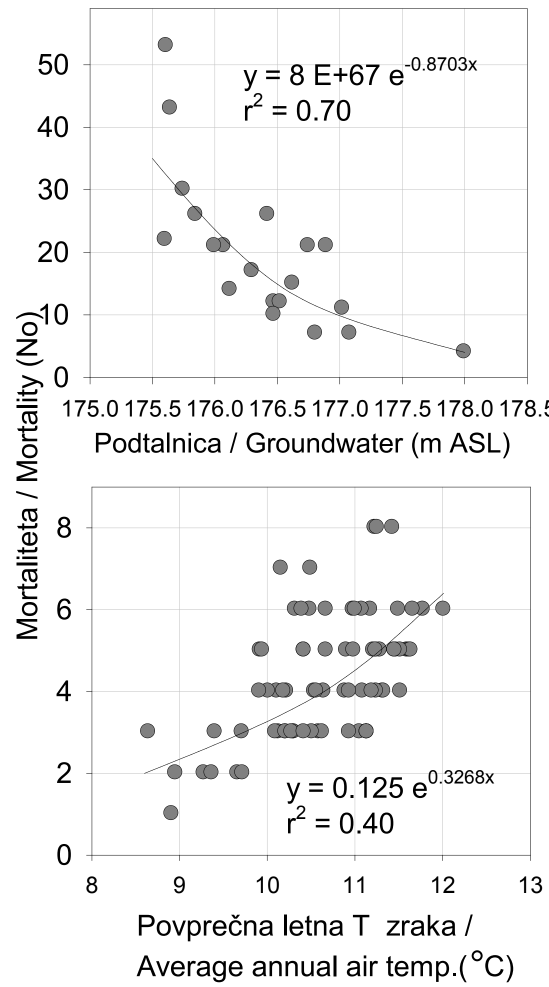
- hitrost in ovrednotenje v razmeroma kratkem času omogoča primerjavo več izbranih objektov;
- primerjava z izpeljanimi podatki sevanja (razlike poletje - zima) omogoča boljše ujemanje;
- ocene posameznih parametrov so realne in niso obremenjene s sistematično napako;
- metoda je objektivna, ponovljiva in ponuja natančen vpogled v dogajanje sklepa krošenj;
- nabor parametrov se lahko uporablja za primerjavo drugih kazalnikov ali deleža sevanja v pritalni plasti, npr. pri študiju ekologije pomlajevanja;
- zaradi sledljivosti postopka je metoda preverljiva in primerna za oceno stanja širšega prostorskega območja.

Comparison between crown conditions and mortality of adult trees on permanent pedunculate-oak plots for the last 20 years confirmed a good agreement between water availability (groundwater table) and extreme site conditions (increase in average air T).

Advantages of the presented method:

- processing and evaluation performed in relatively short temporal window enable comparisons between more selected facilities;
- better agreement is achieved with processed images that take into account differences between summer and winter conditions;
- parameter estimates are reliable, without systematic error;
- method is objective, non-destructive and repeatable;
- obtained parameters can be used for further analysis, e.g. regeneration ecology, etc.;
- as the procedure is traceable, the method is verifiable and suitable for estimating the condition of the wider area.




**Slika 2: Stanje krošenj na dobovih ploskvah s stopnjo mortalitete in ujemanjem s podtalnico in letnimi temperaturami zraka**
**// Figure 2: Crown conditions on pedunculate oak plots (n = 192) (top, left) with corresponding annual mortality rate (No/ha) below and agreement with groundwater and annual air temperature**

# SPREMLJANJE KAKOVOSTI ZRAKA

## // MONITORING OF AMBIENT AIR QUALITY

**Urša Vilhar, Daniel Žlindra, Matej Rupel, Primož Simončič**

Spremljanje kakovosti zraka v gozdovih je namenjeno oceni ogroženosti gozdne vegetacije zaradi onesnaževal v zraku ter za ugotavljanje prostorske razporeditve, časovne spremenljivosti ter trendov na območjih, ki niso vključena v obstoječe mreže za spremljanje kakovosti zraka. V zadnjih desetletjih je večji del zračnih usedlin v evropskih gozdovih povzročalo onesnaževanje zraka na velike razdalje, na primer z žveplovim dioksidom ($SO_2$), dušikovimi oksidi ($NO_x$), amoniakom ($NH_3$), ki nastaja pri zgorevanju fosilnih goriv in biomase ter v industrijskih in kmetijskih procesih. Onesnaževanje v Evropi je bilo najbolj intenzivno od leta 1950 do 1990, v zadnjem obdobju pa naj bi se zmanjševalo. Zračne usedline so pomemben vir makro- in mikrohranil za gozdne ekosisteme, ki pomembno vplivajo na rast dreves in na zdravstveno stanje gozda. Po drugi strani pa lahko večji vnosi hranil v obliki anorganskega dušika (N) povzročijo evtrofikacijo vodnih in kopenskih ekosistemov.

// The purpose of air quality monitoring in forests is to evaluate threats to forest vegetation due to air pollutants, to determine spatial distribution, time variability and trends in areas that are not included in the existing networks of air quality monitoring. In the last few decades, air pollution in European forests has been caused primarily by long range pollution with sulphur dioxide ($SO_2$), nitrogen oxides ($NO_x$) and ammonia ($NH_3$) released from fossil and biomass fuels combustion and during industrial and agricultural processes. The most intensive period of pollution in Europe lasted from 1950 to 1990, but allegedly declined in the last couple of decades. Deposition is important source of micro and macro nutrition for forest ecosystems, which plays an important role in tree growth and the health status of the forest. On the other hand, the significant import of the nutrition in the shape of inorganic nitrogen (N) can lead to eutrophication of water and terrestrial ecosystems.

Gozd s krošnjami dreves, listnim opadom in tlemi deluje kot naravni filter za onesnaževala v zraku, tleh in vodi, zato je pomembno vedeti, v kolikšni meri gozd ohranja ali izboljšuje kakovost zraka v primerjavi z drugimi rabami tal. Spremljanje onesnaževal v zraku, predvsem dušikovih in žveplovih spojin, ki so posledica antropogenega onesnaževanja zraka, omogoča neposredno oceno vnosa snovi v gozd in izračun kritičnih obremenitev, ki jih gozd in rastline v njem še prenesejo.

The forest with its tree canopies, leaf-litter and soil acts as a natural filter for the pollutants in the air, water and soil, therefore it is important to know to what extent the forest preserves or improves the air quality compared to other land uses. Monitoring of air pollutants, in particular nitrogen and sulphur compounds, which are the result of the anthropogenic air pollution, enables us to directly estimate the import of these compounds in the forest and to calculate critical loads, which can still be withstood by forest and its vegetation.

Troposferski ozon ($O_3$) je za gozdove najbolj nevarno plinasto onesnaževalo v zraku. Na drevesne vrste vpliva na različne načine, vključno z vidnimi poškodbami listov, zmanjšanjem in prerazporeditvijo biomase ter povečano občutljivostjo za patogene mikroorganizme. Amonijak ($NH_3$) je zdravju škodljiv plin, ki povzroča bolezni dihal, prispeva k zakisanju tal, evtrofikaciji in tvorbi sekundarnih prašnih delcev. Dušikov dioksid ($NO_2$) je škodljiv za vsa živa bitja. Poleg tega je vključen pri tvorbi kislega dežja in ozona. Vnosi žveplovega dioksida ($SO_2$) v evropske gozdove se zmanjšujejo zaradi uspešnih političnih ukrepov za zmanjševanje izpustov v zadnjih letih.

Tropospheric ozone ($O_3$) presents the most dangerous air pollutant for the forests. It affects tree species in different ways, causing visible injuries to leaves, lowering and translocation of the biomass and increased sensitivity to pathogenic microorganisms. Ammonia ($NH_3$) is the health hazardous gas, causing respiratory diseases, contributing to the acidification of the soil, eutrophication and formation of the secondary dust particles. Nitrogen dioxide ($NO_2$) is harmful to all living beings. Besides, it participates in acid rain and ozone formation. The imports of sulphur dioxide ($SO_2$) in the European forests are decreasing due to the successful political measures for reducing emissions in the last few years.

Za našteta onesnaževala v zraku so bile določene kritične obremenitve z vidika varstva rastlin. Kritične obremenitve so opredeljene kot »mejna vsebnost, kumulativna izpostavljenost ali kumulativni stomatalni tok onesnaževala v rastline, nad katero obstaja verjetnost pojava neposrednih škodljivih učinkov na občutljivo vegetacijo«. Kritične obremenitve za žveplov dioksid, dušikov dioksid in amoniak so izražene kot povprečne vsebnosti v določenem časovnem obdobju, medtem ko se pri ozonu uporabljajo tudi kumulativne vsebnosti nad določeno vrednostjo (AOT40).

For these pollutants, critical loads in terms of plant protection have been determined. Critical loads have been defined as "threshold cumulative exposure or cumulative stomatal flow of the air pollutant above which the occurrence of the direct adverse effects to sensitive vegetation is probable". Critical loads for sulphur dioxide, nitrogen dioxide and ammonia are expressed as average concentrations in the specified time period, while in ozone cumulative contents have been in use (AOT40).

**Slika 1. Vidne poškodbe po ozonu na listih bukve (*Fagus sylvatica* L.) (Foto: Matej Rupel)**
**// Figure 1. Visual ozone damages to the European beech leaf (*Fagus sylvatica* L.) (Photo: Matej Rupel)**

### NEPOSREDNE MERITVE KAKOVOSTI ZRAKA

Vsebnost plinastih onesnaževal v gozdu lahko spremljamo z različnimi merilnimi napravami, kot so običajni analizatorji kakovosti zraka ali pasivni vzorčevalniki. Vsebnost onesnaževal pa se lahko oceni tudi s pomočjo modeliranja ali prostorske interpolacije merjenih vrednosti z bližnjih merilnih postaj. Na gozdnih območjih so običajni analizatorji zraka neuporabni, zato se je na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov v Evropi uveljavila uporaba pasivnih vzorčevalnikov, ki pomenijo cenovno ugodno in zanesljivo metodo za spremljanje vsebnosti plinastih onesnaževal v gozdovih. Spremljanje vsebnosti onesnaževal v zraku poteka s pasivnimi vzorčevalniki za dušikove in žveplove spojine ter ozon, ki jih primerjamo z meritvami samodejnih kontinuiranih merilnih postaj ARSO ter s popisi poškodb zaradi ozona na rastlinah, ki potekajo v skladu z metodologijo ICP Forests.

### DIRECT MEASUREMENTS OF THE AIR QUALITY

The air pollutant concentrations can be monitored in the forest with different measuring devices, such as regular air quality analyzers or passive samplers. The concentration of the pollutants can be estimated also with the help of modelling or space interpolation of values measured at measuring stations. In the forest areas the regular air quality analyzers are inoperable, therefore the use of passive samplers was implemented on the intensive forest monitoring plots throughout Europe. They present low-cost and efficient method for air pollutants monitoring in the forests. Simultaneously, surveys of the ozone injuries on the vegetation according to the ICP Forests methodology are conducted.

**Slika 2. Pasivni vzorčevalniki za spremljanje vsebnosti dušikovega dioksida, žveplovega dioksida, amonijaka ter ozona v zraku. Zaščita zanje je bila razvita in izdelana na Gozdarskem inštitutu Slovenije v letu 2013 v okviru projekta Life+ EMoNFUr. (Foto: Matej Rupel)**
**// Figure 2. Passive samplers for monitoring nitrogen dioxide, sulphur dioxide, ammonia and ozone ambient air concentrations. They were developed and manufactured by the Slovenian Forestry Institute in 2013 within the frame of Life+ project EMoNFUr. (Photo: Matej Rupel)**

## POSREDNE MERITVE KAKOVOSTI ZRAKA S SPREMLJANJEM USEDLIN

Spremljanje usedlin na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov poteka na prostem in v sestoju pod krošnjami dreves v skladu s priročnikom ICP Forests ter obsega merjenje količine padavin, pH, elektroprevodnosti, alkalitete, raztopljenega organskega ogljika (DOC), skupnega dušika (Tot N), $Cl^-$, $NO_2^-$, $NO_3^-$, $PO_4^{3-}$, $SO_4^{2-}$, $Na^+$, $NH_4^+$, $K^+$, $Mn^{2+}$, $Ca^{2+}$ in $Mg^{2+}$. Izmerjene količine usedlin (padavine v obliki dežja, snega in trdnih delcev, odtok vode po deblu, prepuščene padavine) in rezultati analiz vzorcev usedlin skupaj omogočajo izračun vnosa snovi v gozdne ekosisteme za izbrana merilna mesta.

## INDIRECT MEASUREMENTS OF THE AIR QUALITY WITH DEPOSITION MONITORING

Deposition monitoring is conducted on the intensive monitoring plots in the open (bulk) and under the canopies (throughfall, stemflow) according to the ICP Forests manual and includes measurements of quantity, pH, electroconductivity, alkalinity, dissolved organic carbon (DOC), total nitrogen (Tot N), $Cl^-$, $NO_2^-$, $NO_3^-$, $PO_4^{3-}$, $SO_4^{2-}$, $Na^+$, $NH_4^+$, $K^+$, $Mn^{2+}$, $Ca^{2+}$ in $Mg^{2+}$. The measured amounts of the deposition (rain, snow, solid particles, stemflow and throughfall) and the results of the analyses jointly enable calculation of the emitted compound in the forest ecosystems for the defined measuring sites.

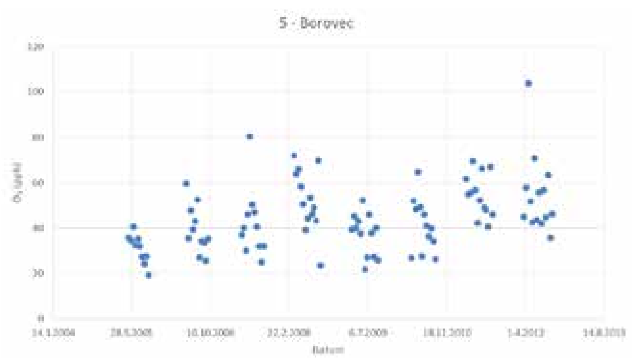
a)

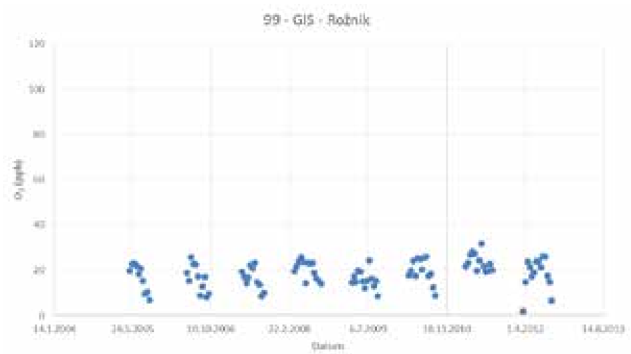
b)

**Slika 3. Vzorčevalniki za usedline na ploskvi Brdo a) na prostem in b) v sestoju (Foto: Daniel Žlindra)**
**// Figure 3: Deposition samplers at forest monitoring plot Brdo a) in the open and b) in the forest stand (Photo: Daniel Žlindra)**

Vsebnosti ozona na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov v Sloveniji ter v urbanih gozdovih Ljubljane sodijo med najmanjše v primerjavi s ploskvami v evropskih gozdovih. Z nekaj posameznimi izjemami na ploskvah nismo ugotovili vidnih poškodb zaradi ozona na rastlinah.

The ozone concentrations at intensive forest monitoring plots in Slovenia and urban forests in Ljubljana are lower comparing to plots in European forests. With few exceptions, no visible ozone injuries on vegetation at forest monitoring plots were found.



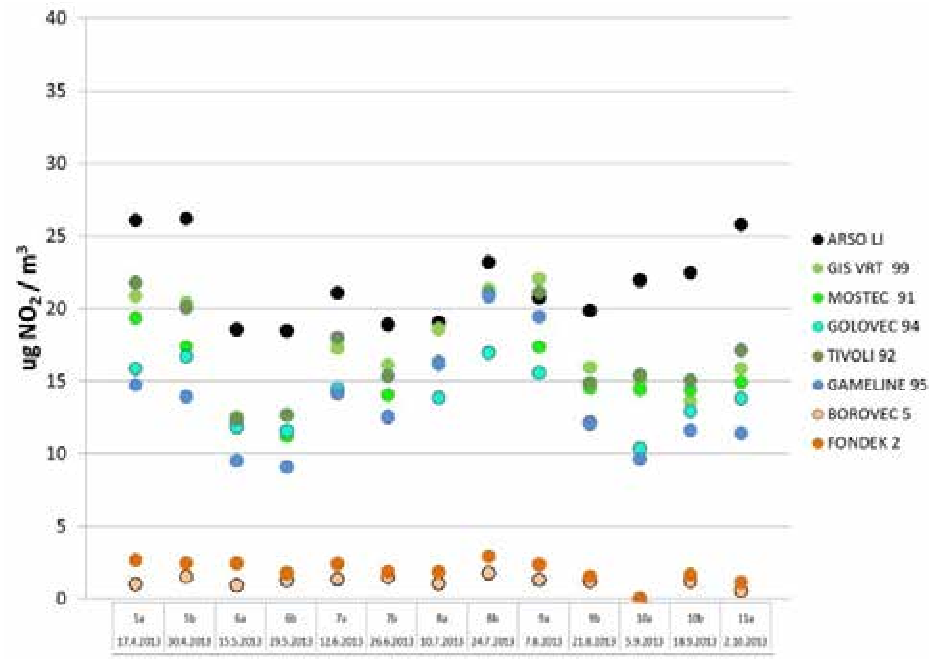




**Slika 4. Povprečne 14-dnevne vsebnosti ozona ($O_3$) v zraku (ppb) na a) ploskvi intenzivnega spremljanja stanja gozdnih ekosistemov Borovec in b) ploskvi Rožnik v urbanem gozdu v Ljubljani**
**// Figure 4: Average 14-day ambient air ozone ($O_3$) concentration at a) forest monitoring plot Borovec and b) at urban forest monitoring plot Rožnik in Ljubljana**



Vsebnosti dušikovega dioksida v zraku so na ploskvah v gozdovih zunaj urbanih središč precej manjše od tistih v urbanih gozdovih. Največje vsebnosti dušikovega dioksida v zraku smo izmerili v središču mesta. Nato vsebnosti dušikovega dioksida padajo v smeri urbani gozd, periurbani gozd, gozd zunaj poseljenih območij.

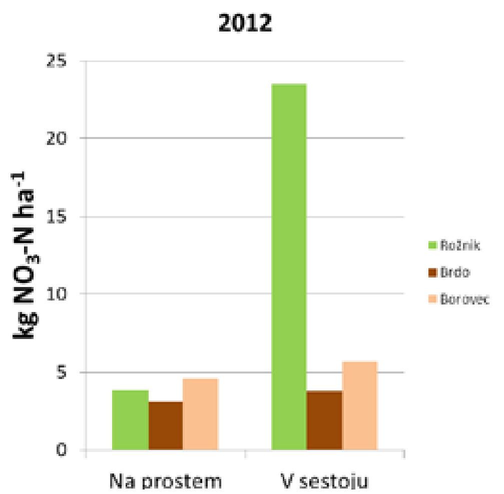
Nitrogen dioxide concentrations are much lower on plots in forests outside urban areas than in urban forests. We detected the highest levels of nitrogen dioxide in the city centre. The level of nitrogen dioxide eventually falls in direction of urban forest, periurban forest and rural forest.



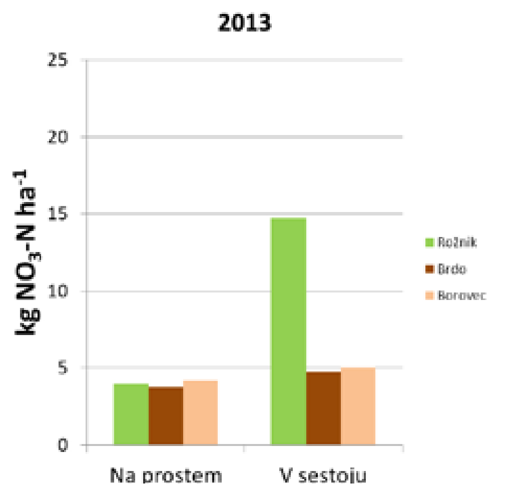

**Slika 5. Povprečne 14-dnevne vsebnosti dušikovega dioksida ($NO_2$) v zraku na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov zunaj urbanih središč ter urbanih gozdov Ljubljane. Na osi x so prikazani končni datumi 14-dnevih intervalov od aprila do oktobra 2013.**
**// Figure 5: Average 14-day ambient air nitrogen dioxide ($NO_2$) concentration at forest monitoring plots and urban forest monitoring plots in Ljubljana. On X-axis, final dates of the 14-day sampling periods from April to October 2013 are shown.**

Letni vnosi onesnaževal v padavinah so na ploskvah v urbanem gozdu nekajkrat večji v primerjavi z gozdovi zunaj urbanih središč. Glavni vzrok so najverjetneje suhe usedline prašnih delcev, bogate z amonijevi, nitratnimi in žveplovimi ioni, ki jih je v mestu Ljubljana precej več kot v gozdnatih območjih, oddaljenih od urbanih središč.

Annual pollutant deposits are several times higher on urban forest plots compared to rural forest. The main cause could be dry deposition of dust particles, rich with ammonia, nitrate and sulphate ions, which are much more common in cities than in forest areas, far from urban centres.




a)

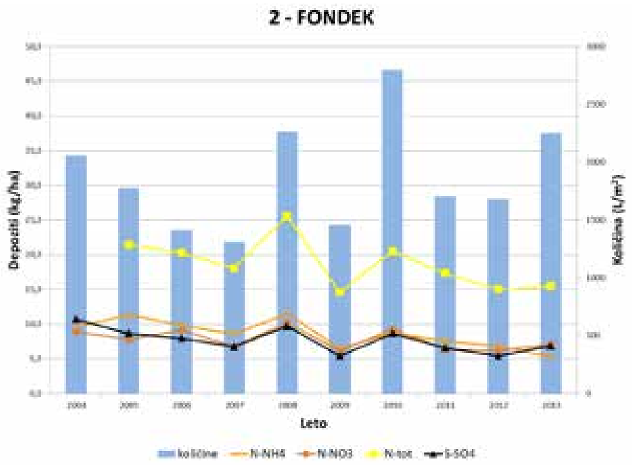


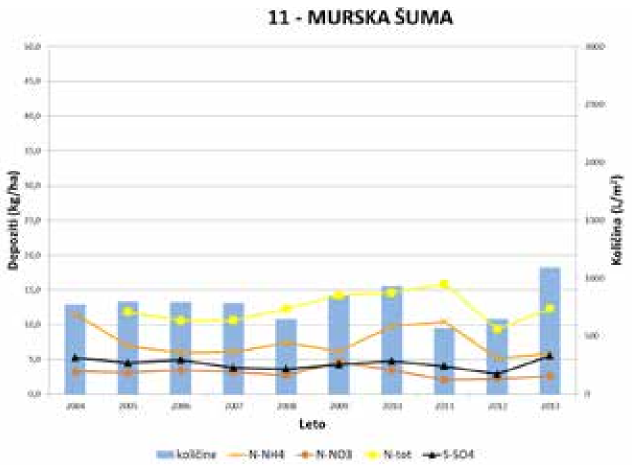

b)

**Slika 6. Primerjava letnih vnosov nitratnega dušika med urbanim gozdom (Rožnik) in ploskvami intenzivnega spremljanja stanja gozdnih ekosistemov zunaj urbanih središč (Brdo, Borovec) v letih a) 2012 in b) 2013**
**// Figure 6: Comparison of annual deposition of nitrate nitrogen at urban forest monitoring plot Rožnik in Ljubljana and forest monitoring plots Brdo and Borovec in a) 2012 and b) 2013**

Na nekaterih ploskvah intenzivnega spremljanja gozdnih ekosistemov smo v letih od 2004 do 2014 opazili zmanjšanje usedlin, predvsem za sulfatno žveplo in amonijev dušik. Na ploskvi Murska šuma pa se usedline amonijevega dušika od leta 2006 dalje večajo. Tudi na evropski ravni je opazno upadanje vnosa onesnaževal v zadnjih letih, predvsem za žveplove spojine. Za dušikove spojine trend upadanja v Sloveniji ni bil ugotovljen, na nekaterih ploskvah pa je vnos dušikovih spojin v letih od 2008 do 2010 celo narasel.

On some of the intensive forest monitoring plots we detected a decline of deposits between 2004 and 2014, especially as far as sulphate sulphur and ammonia nitrogen are concerned. On the plot Murska šuma, however, the ammonia nitrogen depositions have been increasing from 2006 onwards. Decreasing of sulphur compounds deposition has been detected in the last few years at the European level as well. In Slovenia, such trend for nitrogen compounds has not been detected; on some plots, the deposition of nitrogen compounds in the years from 2008 to 2010 even increased.




**Slika 7. Primerjava letne količine padavin (modri stolpci) ter posameznih onesnaževal na prostem na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov a) Fondek (JZ Slovenija) in b) Murska šuma (SV Slovenija)**
**// Fig. 7: Comparison of annual precipitation (blue bars) and bulk deposition at forest monitoring plots a) Fondek (SW Slovenia) and b) Murska šuma (NE Slovenia)**



# FENOLOŠKE FAZE DREVES V ODVISNOSTI OD VREMENSKIH SPREMENLJIVK IN OSUTOSTI KROŠENJ

## // TREE PHENOLOGY IN RELATION TO METEOROLOGICAL CONDITIONS AND CROWN DEFOLIATION

**Urša Vilhar, Mitja Ferlan, Mitja Skudnik, Primož Simončič**

**Dolgoletno spremljanje fenoloških faz dreves je pomemben kazalnik globalne podnebne spremenljivosti in z njimi povezanih bioloških odzivov dreves. Razumevanje teh povezav je ključno za napovedovanje odziva ekosistemov na podnebno spremenljivost, a tudi za določanje obdobja vezave ogljika v gozdovih ter preučevanje sezonske izmenjave vode in energije med zemeljskim površjem in ozračjem.**

**// Long-term studies of phenological phases of trees are of increasing importance as an indicator of global climate change and associated biological responses in forests. Understanding these relationships is crucial, not only for predicting ecosystems responses to climate change, but also identifying the carbon-uptake period of forests and examining the seasonal exchanges of water and energy between the land surface and the atmosphere.**

Namen fenoloških opazovanj dreves na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov je:

- pridobiti vedenje o stanju in poteku fenoloških faz različnih drevesnih vrst med letom;
- primerjati letni potek fenoloških faz dreves v odvisnosti od lokalnih (meteoroloških in rastiščnih) razmer, vključno s poškodbami;
- beleženje in razlaga morebitnih sprememb v času pojavljanja fenoloških faz dreves zaradi okoljskih dejavnikov naravnega in / ali antropogenega izvora, kot so zračna onesnaževala in podnebna spremenljivost.

The main objectives of phenological observations at forest intensive monitoring plots are:

- to provide information on the status and development of forest trees over the course of the year;
- to determine the course of the annual development stages of forest trees and their dependence on local (e.g. meteorological and site) conditions including damaging events;
- to document and explain possible changes in the timing of these stages in relation to environmental factors of natural and/or anthropogenic origin such as air pollution and climate change.

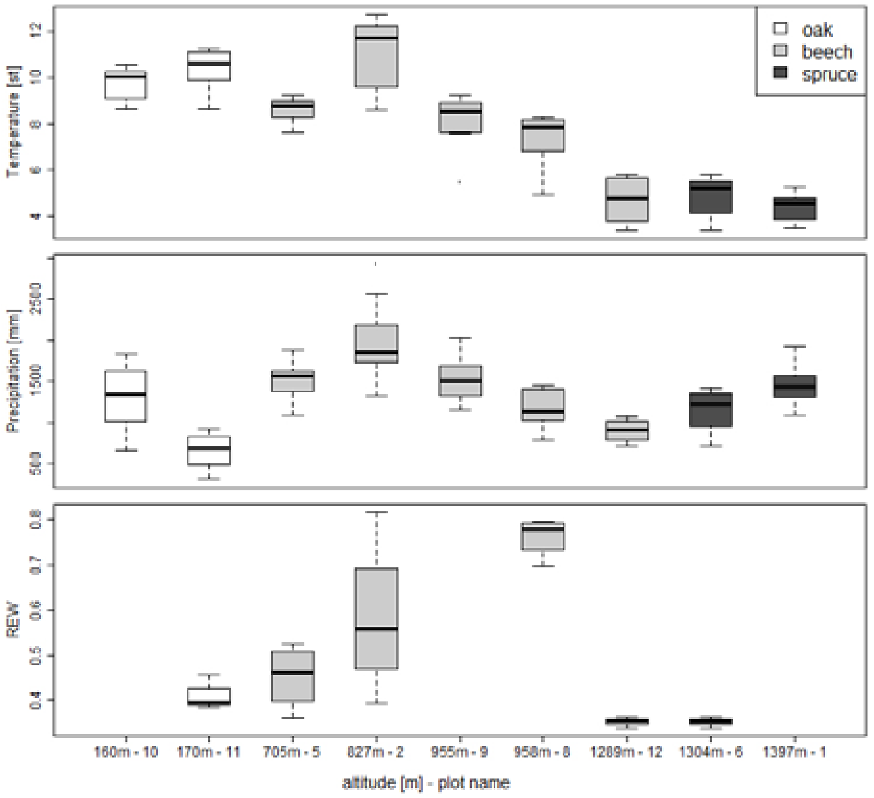
RAZUMEVANJE ODNOSA MED FENOLOŠKIMI FAZAMI DREVES, OSUTOSTJO KROŠENJ IN VREMENSKIMI RAZMERAMI JE KLJUČNEGA POMENA ZA SPREMLJANJE ZDRAVJA GOZDA IN DOLGOLETNIH SPREMEMB VITALNOSTI GOZDOV.

UNDERSTANDING THE RELATIONSHIP BETWEEN TREE PHENOLOGY, CROWN DEFOLIATION AND METEOROLOGICAL CONDITIONS IS CRUCIAL FOR A BETTER ASSESSMENT OF FOREST HEALTH AND LONG-TERM CHANGES OF FOREST VITALITY.


a)


b)

**Slika 1: Fenološka faza prvih listov in iglic: nastopi, ko so iglice in listi odgnali iz poganjkov in se razprli; a) *Picea abies* (L. ) Karst. in b) *Fagus sylvatica* L. (Foto: Urša Vilhar).**
**// Figure 1: Needle appearance and leaf unfolding starts when the fresh green needles or leaves become visible from the buds; a) *Picea abies* (L.) Karst. and b) *Fagus sylvatica* L. (Photo: Urša Vilhar).**




**Slika 2: Povprečne letne a) temperature zraka, b) padavine in c) relativna dostopna voda v tleh (REW) za devet ploskev intenzivnega spremljanja stanja gozdnih ekosistemov v Sloveniji v obdobju 2004–2013**
**// Figure 2: Average annual a) air temperature, b) precipitation and c) relative extractable soil water (REW) at nine Intensive forest monitoring plots in Slovenia in the 2004–2013 period**

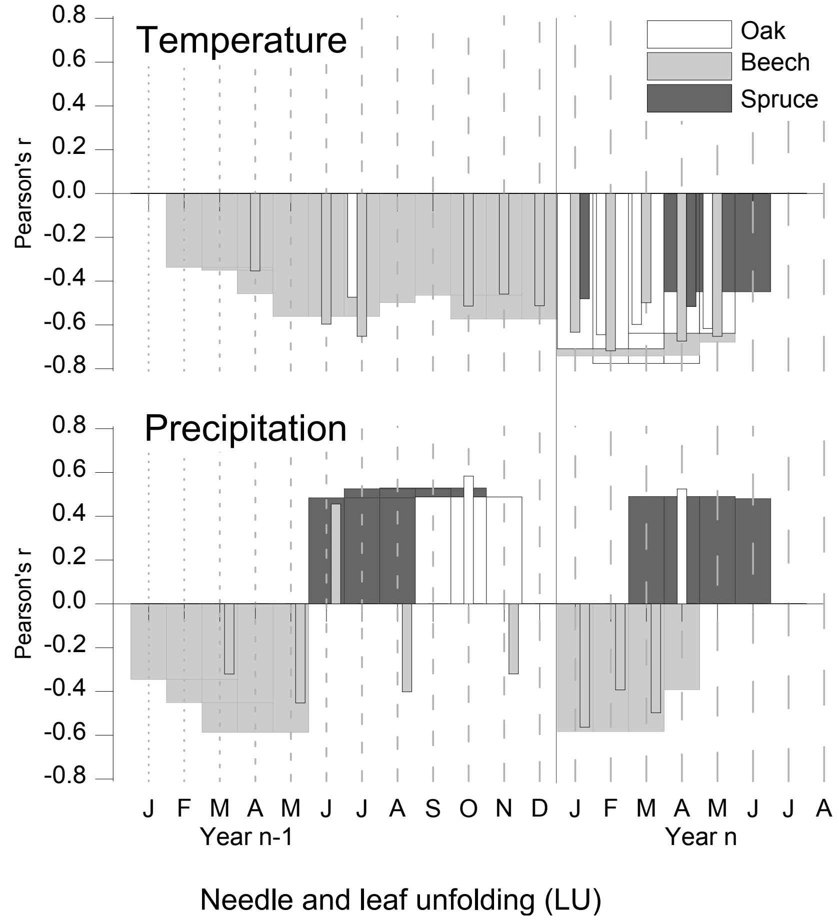
Na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov Gozdarskega inštituta Slovenije smo ugotavljali povezanost fenoloških faz z osutostjo krošenj doba *(Quercus robur* L.), bukve (*Fagus sylvatica* L.) in smreke (*Picea abies* (L.) Karst.) ter vremenskimi razmerami. Izbor dreves na ploskvah, ocena osutosti krošenj ter fenološka opazovanja smo opravljali v skladu z navodili ICP Forests. Vremenske podatke so beležile samodejne vremenske postaje na prostem v skladu z metodologijo ICP Forests. Mesečne vrednosti vremenskih spremenljivk smo primerjali z letnimi povprečji fenoloških faz ter osutosti krošenj dreves (%).

Na osnovi regionalnih podatkov iz razmeroma majhnega območja z veliko geografsko raznolikostjo ugotavljamo, da povezava med nastopom fenofaz doba, bukve in smreke ter osutostjo njihovih krošenj obstaja, vendar je vrstno specifična. Na osutost krošenj bukve niso vplivale temperature zraka, temveč padavine in relativna dostopna voda v tleh. Za osutosti krošenj doba in smreke smo zaznali šibko občutljivost za temperaturo zraka in samo za dob tudi za vsebnost vode v tleh. Vendar pa so bile te korelacije značilne samo za posamezne mesece, brez jasnih sezonskih vzorcev.

The Level II forest monitoring plots for the Intensive Monitoring of Forest Ecosystems by the Slovenian Forestry Institute were utilized to evaluate potential relationship between the observed tree phenology and tree crown defoliation in beech (*Fagus sylvatica* L.), pedunculate oak *(Quercus robur* L.) and Norway spruce *(Picea abies* (L.) Karst.) forests and their sensitivity to meteorological conditions. The selection of trees on monitoring plots, tree crown defoliation assessment and the phenological observations were made in accordance with the ICP Forests manuals. Meteorological data were collected using automated weather stations in the open area according to ICP Forests. Monthly meteorological datasets were compared to yearly means for phenological observations and tree crown defoliation (%).

Using sub-regional data from a relatively small area with high geographic variability showed that air temperature and precipitation sensitivity of tree phenology was highly species-dependent with beech, pedunculate oak and spruce exhibiting contrasting responses. Crown defoliation of beech was not sensitive to air temperature but to precipitation and relative extractable soil water. For spruce and pedunculate oak, only weak sensitivity of crown defoliation to air temperature, and only for pedunculate oak also to soil water conditions, was found for single months, without clear seasonal pattern.






**Slika 3: Značilni Pearsonovi koeficienti korelacije r (na 95-odstotni ravni), izračunani med mesečnimi (stolpci) in trimesečnimi (osenčeno) vsotami temperature zraka (T) in padavinami (P) in a) fenofazo prvih listov in iglic (LU) za dob, bukev in smreko na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov v Sloveniji v obdobju 2004–2013**
**// Figure 3: Significant Pearson's correlation coefficients r (at 95% level) calculated between the monthly (bars) and three-month (shadow) air temperature sums (T) and precipitation (P) and a) the first leaf and needle unfolding (LU) for pedunculate oak, European beech and Norway spruce at Intensive forest monitoring plots in Slovenia in the period 2004– 2013**

Večja osutost krošenj doba je prispevala k zgodnejšemu nastopu fenofaze prvih listov, splošnega rumenenja listja in daljšemu vegetacijskemu obdobju v sledečem letu. Nismo pa ugotovili povezanosti med osutostjo krošenj in fenofazami bukve ali smreke.

Ugotavljamo, da povezava med nastopom fenofaz izbranih drevesnih vrst ter osutostjo njihovih krošenj obstaja, vendar je vrstno specifična. Tudi lokalne rastiščne razmere imajo morda pri tem pomembno vlogo, predvsem razpoložljivost hranil.

Za natančnejšo razlago vpliva osutosti krošenj in vremenskih razmer na fenološke faze dreves v Sloveniji bodo potrebne nadaljnje raziskave na večjem številu ploskev in v daljših časovnih obdobjih.

Higher crown defoliation of pedunculate oak contributed to earlier leaf unfolding, later autumn leaf colouring and longer growing season in the ensuing year. Relation between tree phenology and crown defoliation was found neither for beech nor Norway spruce.

Results indicate that the correlation between defoliation and phenology is species-specific and we assume that site conditions also play an important role, in particular availability of nutrients.

Further investigations involving a larger number of sites and longer time series are therefore needed before any conclusions about the role of crown defoliation and meteorological conditions in tree phenology in Slovenia can be drawn.

# SPREMLJANJE STANJA URBANIH GOZDOV V OKVIRU PROJEKTA LIFE+ EMoNFUr

## // MONITORING OF URBAN FORESTS WITHIN THE FRAMEWORK OF LIFE+ PROJECT EMoNFUr

**Vilhar U., Božič G., de Groot M., Ferlan M., Flajšman K., Hauptman T., Japelj A., Jurc D., Kutnar L., Levanič T., Marinšek A., Ogris N., Sinjur I., Skudnik M., Verlič A., Vochl S., Žlindra D., Simončič P.**

**POVZETEK**
Urbani gozdovi opravljajo veliko funkcij (ekosistemskih storitev), ki igrajo pomembno vlogo pri zagotavljanju zdravja in kakovostnega življenja prebivalcev. Vendar pa podnebne spremembe znatno zmanjšujejo njihovo zmožnost za zagotavljanje zgoraj naštetih koristi za okolje. Namen projekta LIFE+ EMoNFUr je bil ustvariti trajno mrežo za spremljanje urbanih gozdov v Lombardiji in Sloveniji.

**// ABSTRACT**
Urban forests perform a number of functions (ecosystem services), which play an important role at insuring the health and quality life of the citizens. But climate changes notably reduce their ability of providing for the above mentioned benefits for the environment. The goal of the EMoNFUr project was to establish a permanent network for monitoring urban forests in the Lombardy region and in Slovenia.

V PROJEKTU »EMoNFUr - ZASNOVA MREŽE ZA SPREMLJANJE STANJA NIŽINSKEGA GOZDA IN POGOZDITEV V URBANEM PROSTORU V LOMBARDIJI IN URBANEGA GOZDA V SLOVENIJI« LIFE10ENV/IT 399 SO KOT PARTNERJI SODELOVALI GOZDARSKI INŠTITUT SLOVENIJE, ERSAF - REGIONALNA AGENCIJA ZA KMETIJSKE IN GOZDARSKE STORITVE, PARCO NORD MILANO IN ITALIJANSKA DEŽELA LOMBARDIJA. SOFINANCIRALI SO GA EVROPSKA UNIJA PREK PROGRAMA LIFE+ ENVIRONMENTAL, MINISTRSTVO ZA KMETIJSTVO IN OKOLJE TER MESTNA OBČINA LJUBLJANA.

IN THE PROJECT »EMoNFUr - ESTABLISHING A MONITORING NETWORK TO ASSESS LOWLAND FOREST AND URBAN PLANTATION IN LOMBARDY AND URBAN FOREST IN SLOVENIA«, LIFE10ENV/IT 399, THE FOLLOWING INSTITUTIONS COOPERATED AS PARTNERS: THE SLOVENIAN FORESTRY INSTITUTE, ERSAF - THE REGIONAL AGENCY FOR AGRICULTURAL AND FOREST SERVICES, PARCO NORD MILANO, AND THE LOMBARDY REGION. IT WAS CO-FINANCED BY THE EUROPEAN UNION THROUGH LIFE+ PROGRAM, MINISTRY OF AGRICULTURE AND ENVIRONMENT, AND THE MUNICIPALITY OF LJUBLJANA.

**UVOD**
Gozd, gozdno drevje, parki in druge zelene površine znotraj ali blizu urbaniziranih območjih so nenadomestljiv del narave in našega bivanjskega okolja ter so še posebej pomembni za meščane. Urbani gozdovi so pomembni zato, ker prebivalcem mest omogočajo neposreden stik z naravo, mir, sprostitev, estetski užitek, v Sloveniji pa so tudi pogosto obiskan rekreacijski prostor.

**NAMEN PROJEKTA LIFE+ EMONFUR**
V okviru projekta LIFE+ EMoNFUr je bila vzpostavljena trajna mreža za spremljanje urbanih gozdov v Lombardiji in Sloveniji. Spremljanje stanja urbanih gozdov je potekalo na petih študijskih območjih v italijanski deželi Lombardija in na dveh v Sloveniji. V urbanih gozdovih Mestne občine Ljubljana smo na osnovi pregleda različnih programov, projektov in monitoringov določili najpomembnejše kazalnike za merjenje vpliva urbanih gozdov na uravnavanje količine vodnih virov, ohranjanje kakovosti virov pitne vode ter zadrževalno sposobnost urbanih gozdov za presežke vode v času nalivov in taljenja snega; vpliva urbanega gozda na blažitev posledic podnebnih sprememb ter vpliv urbanega gozda kot naravnega filtra za onesnaževala. Drugi del spremljanja v Sloveniji je monitoring gozdov v ne-urbanih okoljih, ki ga Gozdarski inštitut Slovenije opravlja že od leta 1980. V okviru projekta smo: (1) spremljali izbrane živalske vrste, (2) popisali rastlinske vrste, (3) popisali bolezni in škodljivce gozdnega drevja ter ocenili zdravstveno stanje gozdnega drevja, (4) analizirali gozdna tla, (5) spremljali obiskanost, (6) spremljali kakovost zraka, (7) analizirali rast gozdnega drevja, (8) napravili gozdno inventuro ter (9) spremljali vpliv gozda na kakovost in količino vode, ki odteka iz gozda.

**INTRODUCTION**
Forest, forest trees, parks and other green areas inside or near urban areas are an irreplaceable part of nature and our environment and especially important for citizens. They enable them a direct contact with nature, peace, relaxation, aesthetics and are frequently visited for recreation in Slovenia.

**THE OBJECTIVES OF LIFE+ EMONFUR PROJECT**
Within the LIFE + EMoNFUr project, a network of monitoring plots for permanent monitoring of urban forests in Lombardy and Slovenia was established. Monitoring of urban forests was set up in five study areas in the Italian region of Lombardy and in two areas in Slovenia. In the urban forests of the City of Ljubljana, the most important indicators were chosen based on a review of various programs, projects and monitoring programs. Those were the indicators for measuring the impact of urban forests in regulating the quantity of water resources, preservation of the quality of drinking water sources and retention ability of urban forests overflow of water during rains and melting snow; the impact of urban forests in mitigating climate change and the impact of the urban forest as a natural filter for contaminants. Furthermore, the Slovenian Forestry Institute has been monitoring forests remote from urban areas since 1980. Monitoring activities include (1) monitoring of selected animal species, (2) inventory of plant species, (3) inventory of forest diseases and pests of forest trees and assess the state of health of forest trees, (4) analyses of forest soil, (5) visitor monitoring, (6) monitoring of air quality, (7) analyses of the growth of forest trees, (8) forest inventory, and (9) monitoring the influence of the forest on the quality and quantity of water that flows out of the forests.

**Slika 1. Krajinski park Tivoli, Rožnik, Šišenski hrib leži zahodno od središča Ljubljane. Leta 1984 je bilo območje z odlokom razglašeno za krajinski park, danes pa je večji del območja gozda opredeljen z Odlokom o gozdovih s posebnim namenom (GPN, 2010). (Foto: Iztok Sinjur)**
**// Figure 1. Tivoli, Rožnik and Šišenski hrib Nature Park in the city centre of Ljubljana. In 1984, the area was decreed a landscape park, but now the greater part of the forest area is defined by the Decree on forests with a special purpose (GPN, 2010). (Photo: Iztok Sinjur)**

**Slika 2. Primestni nižinski poplavni gozdovi ob reki Savi so pomembni zaradi ohranjanja avtohtonega črnega topola v nižinskih obvodnih logih, ki jih občasno še poplavljajo vode. Evropski črni topol (*Populus nigra* L.) je pionirska drevesna vrsta obvodnih ekosistemov in indikator ohranjenosti obrežnih in poplavnih logov. Čeprav ima velik naraven areal, je črni topol danes že ena najbolj ogroženih drevesnih vrst v Evropi. (Foto: Aleksander Marinšek)**
**// Figure 2. Peri-urban lowland floodplain forests along the Sava River are significant for preserving the indigenous black poplar in lowland riparian grounds that are occasionally flooded by the river. The European black poplar (*Populus nigra* L.) is a pioneer tree species and riparian ecosystems indicator of conservation status of riparian and floodplain forests. Although inhabiting a large natural area, the black poplar is today one of the most endangered tree species in Europe. (Photo: Aleksander Marinšek)**

PRI MONITORINGU JE BILO V GOZDOVIH ZNOTRAJ IN NA OBROBJU MESTA LJUBLJANA OPAŽENIH 1246 OSEBKOV PTIC, KI SO PRIPADALE 50 RAZLIČNIM VRSTAM. MED NAJBOLJ POGOSTIMI VRSTAMI PTIC, KI SO SE POJAVLJALE NA OPAZOVANEM OBMOČJU, SO: ŠČINKAVEC, VELIKA SINICA, TAŠČICA, SIVA VRANA IN KOS. NAJREDKEJŠE VRSTE SO BILE: KALIN, RJAVA PENICA IN SLAVEC. TU ŽIVITA TUDI VRSTI, KI STA Z DIREKTIVO O PTICAH ZAVAROVANI CELO NA EVROPSKI RAVNI, IN SICER PIVKA IN ČRNA ŽOLNA.

AS A RESULT OF THE MONITORING THAT 50 SPECIES WITH 1,246 INDIVIDUALS WERE OBSERVED IN THE FORESTS IN AND AROUND LJUBLJANA. THE MOST ABUNDANT SPECIES WERE THE CHAFFINCH, GREAT TIT, ROBIN, HOODED CROW AND BLACKBIRD. THE RAREST SPECIES WERE BULLFINCH, LESSER WHITETHROAT AND NIGHTINGALE. FURTHERMORE, TWO SPECIES, WHICH ARE PROTECTED AT THE EUROPEAN LEVEL BY THE BIRD DIRECTIVE, WERE OBSERVED IN THE FORESTS: THE GREYHEADED AND BLACK WOODPECKER.

**NAJPOMEMBNEJŠI REZULTATI PROJEKTA**

**1. Protokol spremljanja urbanih gozdov projekta EMoNFUr**
Protokol spremljanja urbanih gozdov projekta EMoNFUr vključuje širok nabor meril, ki nam pomagajo pri ustvarjanju natančnih opisov ekološke, okoljske in družbene vrednosti urbanih gozdov. Protokol vključuje obvezne, priporočene in izbirne podatke. Z obveznimi podatki zagotovimo osnovne informacije o različnih vidikih gozdnega ekosistema in ustvarimo enotno bazo podatkov. S priporočenimi in izbirnimi podatki opisujemo posebne vidike, ki so povezani z značilnostmi izbranega vzorčnega območja. (http://www.emonfur.eu/pagina.php?sez=86&pag=578&label=Deliverable+products)

**2. Vzpostavitev trajne mreže za spremljanje urbanih gozdov**
Vzpostavili smo trajno mrežo ploskev za spremljanje urbanih gozdov v italijanski deželi Lombardiji in v Sloveniji, ki jo bo mogoče pozneje razširiti, saj se bodo interesne skupine v obravnavanem območju lahko odločile za prostovoljno vključevanje v sistem ploskev.

**3. Inventura in popis urbanih in primestnih gozdov v Lombardiji**
(www.forestemonfur.eu)

**4. Spletni priročnik**
(www.emonfur.eu), ki podrobneje obravnava različne vidike urbanih in primestnih gozdov, kot so upravljanje, spremljanje ter določanje in ocenjevanje ekosistemskih storitev.

**5. Podatki, ki so rezultat triletnega spremljanja urbanih gozdov**

**THE MOST IMPORTANT RESULTS OF THE PROJECT**

**1. Protocol for monitoring urban forest**
The Protocol for monitoring urban forest developed within the EMoNFUr project includes a wide range of criteria to help us to create detailed descriptions of ecological, environmental and social values of urban forests. The Protocol includes mandatory, recommended and optional parameters. Mandatory data provide basic information on different aspects of the forest ecosystem and create a single database. The recommended and optional data describe specific aspects related to the characteristics of the sampled area. (http://www.emonfur.eu/pagina.php?sez=86&pag=578&label=Deliverable+products)

**2. Setting up a permanent monitoring network of urban forests monitoring plots**
We have established a network of permanent plots for monitoring urban forest in the Italian region of Lombardy and in Slovenia, which can later be expanded. Depending on the stakeholders present in an area, one can opt for voluntary participation in the network.

**3. Inventory and mapping of the urban and peri-urban forests in Lombardy**
(www.forestemonfur.eu)

**4. Web manual**
(www.emonfur.eu), which deals with in great detail with various aspects of urban and peri-urban forests, such as management, monitoring and identifying and assessing ecosystem services.

**5. Data are the result of the three-year of monitoring of urban forests**

**ŽIVALI SO POMEMBEN KAZALNIK STANJA BIODIVERZITETE V URBANEM GOZDU.**
Ptice so pomemben indikator biodiverzitete in imajo v gozdovih mnoge posredne in neposredne funkcije. So plenilci mnogih vrst insektov in tako preprečujejo prenamnožitev škodljivcev. Med drugim imajo velik pomen tudi za socialno in zdravstveno varstvo ljudi, saj opazovanje ptic in bivanje v okolju, ki ga naseljujejo ptice, pri ljudeh zmanjšuje stres. Dolgoročen monitoring stanja ptic v mestih je zelo pomemben, saj le tako lahko nadziramo, kaj se dogaja s populacijami različnih vrst ptic, in posledično tudi preprečimo, da ne bi nekoč morda prišlo do »neme pomladi«.

Muhe trepetavke so kljub velike številčnosti in pogostnosti sicer med manj znanimi vrstami žuželk, vendar so odrasli osebki pomembni opraševalci rastlin, medtem ko se ličinke prehranjujejo z drugimi žuželkami in se pogosto uporabljajo za biokontrolo. So zelo dobri bioindikatorji za spremembe v količini odmrlega lesa in drugih vplivov, ki jih ima gospodarjenje z gozdom na ugodno stanje habitatov.

**ANIMALS ARE IMPORTANT INDICATOR OF BIODIVERSITY STATUS IN URBAN FOREST.**
Birds are important indicators of the biodiversity and have many direct and indirect functions in the forests. They predate on many insects and therefore prevent insect outbreaks. Furthermore, they have also a strong impact on the social and health care level, for it is well known that bird watching lowers the stress level of people. Because of the important role of birds in cities, it is important to monitor the status of the birds over the years in order to avoid the day we shall suddenly be faced with a »silent spring«.

Although hoverflies are not that well known, they are very abundant around us and everyone observed them, although they fooled us by letting us think that they were bees, wasps or a bumblebees. Adults are important pollinators for plants, while larvae feed on other insects and are often used as biocontrol method. Furthermore, they are also good bio-indicators, as this insect group has different functions in the ecosystem.

**Slika 1: Ščinkavec, ena najpogostejših vrst ptic v urbanih gozdovih v Ljubljani (Foto: Tim Faasen) // Photo 1: Chaffinch, one of the commonest species in the urban forests of Ljubljana (Photo: Tim Faasen)**

**Slika 2: Zimska trepetavka: pomemben opraševalec in plenilec listnih uši (Foto: Tim Faasen) // Photo 2: Marmalade hoverfly (*Episyrphus balteatus*): an important pollinator and predator on aphids (Photo: Tim Faasen)**

## PESTROST RASTLINSKIH VRST V URBANIH GOZDOVIH

Rastline so ključna sestavina gozdnih ekosistemov, ki nam zaradi povezanosti z drugimi omogočajo ugotavljanje splošnega stanja v gozdnem in širšem okolju. Poleg bogastva rastlinskih vrst v urbanem gozdu so posebej zanimivi tudi pojavi invazivnih tujerodnih vrst, ki so predvsem posledica različnih človekovih dejavnosti.

Urbani gozdovi v Ljubljani so razmeroma bogati z rastlinskimi vrstami. Na treh izbranih ploskvah smo ugotovili 161 različnih vrst praprotnic in semenk. Posebno skrb, povezano s prihodnostjo urbanih gozdov v Ljubljani, zbujajo invazivne tujerodne rastlinske vrste.

Njihovo hitro širitev in prenamnožitev lahko opazujemo predvsem v različnih nižinskih gozdovih, še posebej ob rekah in potokih. Resno grožnjo za obstoj današnjih tipov gozdov smo zaznali predvsem na ploskvi v neposredni bližini reke Save in deloma tudi v središču mesta na pobočju Rožnika. V teh dveh gozdovih smo popisali večje število tujerodnih rastlinskih vrst, ki so večinoma invazivne, z deležem 8 % od vseh popisanih.

## DIVERSITY OF PLANT SPECIES IN URBAN FORESTS

Plants are among key components of forest ecosystems, and due to their interactions with other components they well indicate the ecological conditions in forests and the neighbouring ecosystems. Beside plant species richness of urban forest, the presence of invasive alien species, which are primarily the result of various human activities and impacts, is of special interest.

In the urban forests of Ljubljana area, a high number of plant species can be found. On three selected plots, 161 different fern and vascular species were documented. In view of the future perspective of the urban forests in Ljubljana, the invasive non-native plant species should be given special attention.

Their rapid expansion can be observed mainly in various lowland forests, especially along rivers and streams. A serious threat to the existence of today's forests was detected mainly on the plot along the bank of the Sava River in Ljubljana periurban area, and partly on the slopes of Rožnik hill in the urban area. In these forests, a larger number of non-native plant species representing 8% of all species recorded, and among them invasive species, prevail.

**Slika 1: Gozdna tla na obrežju reke Save preraščа gost zastor invazivnih tujerodnih vrst, kot so orjaška zlata rozga (*Solidago gigantea Aiton*), japonski dresnik (*Fallopia japonica (Houtt.)Ronse Decraine*) in deljenolistna rudbekija (*Rudbeckia laciniata L.*). (Foto: Lado Kutnar)**
**// Figure 1: Forest floor along the bank of the Sava River is overgrown by dense cover of invasive alien species like *Solidago gigantea Aiton, Fallopia japonica (Houtt.)Ronse Decraine* and *Rudbeckia laciniata L.* (Photo: Lado Kutnar)**

**Slika 2: Orjaška zlata rozga (*Solidago gigantea*) je invazivna tujerodna vrsta obrečnih, poplavnih in močvirnih gozdov v Sloveniji. (Foto: Lado Kutnar)**
**// Figure 2: *Solidago gigantea* is an invasive alien species of riverine, floodplain and swamp forests in Slovenia. (Photo: Lado Kutnar)**

## POPIS BOLEZNI GOZDNEGA DREVJA TER PREGLED ZDRAVJA DREVJA V URBANIH GOZDOVIH

Zdravje drevja je v urbanem okolju še posebno pomembno, saj so bolna in poškodovana drevesa lahko nevarna za človeka. Pri trohnečem drevesu se veje pogosto odlomijo, ali pa se drevo zaradi trohnečega debla ali korenin ob močnem vetru podre. Bolezni drevja povzročajo različne vrste škodljivih gliv. Številne žuželke lahko drevje poškodujejo, mu kvarijo videz ali zmanjšujejo vitalnost. Za zmanjševanje poškodb so proti njim razvili različne preventivne in kurativne ukrepe. Ugotavljali smo povzročitelje poškodb ter razvijali in preizkušali različne tehnike beleženja poškodovanega ali bolnega drevja. Razvoj in uporaba teh znanj bosta omogočila upravljanje z gozdovi tako, da bodo vitalnejši in varnejši za obiskovalce.

## SPREMLJANJE OBISKANOSTI URBANEGA GOZDA

Po vsakodnevnih obveznostih, ko ni vedno dovolj časa za daljše izlete v naravo, je urbani gozd v Ljubljani prostor za rekreacijsko dejavnost v naravi. Za trajnostno upravljanje z urbanimi gozdovi pa sta nujni vsaj okvirna informacija o številu obiskovalcev v gozdu in časovna dinamika obiska. Intenzivnost obiska namreč vpliva tako na gozd (npr. erozija poti) kot neposredno rekreacijsko izkušnjo (npr. željo po odmaknjenosti oziroma druženju). V ta namen smo območje raziskovanja opremili s sistemi za štetje obiskovalcev, ki smo jih izdelali v laboratoriju za elektronske naprave Gozdarskega inštituta Slovenije.

## ONESNAŽENOST GOZDNIH TAL IN VAROVANJE VODNIH VIROV V URBANIH GOZDOVIH LJUBLJANE

Gozdna tla z naravno ohranjeno rastlinsko sestavo in sestojno zgradbo gozda so pomemben filter za vnose onesnaževal iz okoliških kmetijskih površin, prometnic in urbanih površin v podtalnico in površinske vodotoke.

Vloga gozda v urbanih območjih je z vidika ohranjanja rodovitnih in neonesnaženih gozdnih tal predvsem ohranjanje stabilnosti gozdnih tal z močnimi koreninskimi sistemi drevesnih vrst, prestrezanje čim večje količine padavin in zadrževanje tal v erozijsko ogroženih območjih.

V okviru projekta EMoNFUr je bila vzpostavljena mreža stalnih vzorčnih ploskev za redno spremljanje stanja in onesnaženosti gozdnih tal v Krajinskem parku Tivoli, Rožnik in Šišenski hrib ter v nižinskem poplavnem gozdu ob reki Savi. Ugotovili smo, da so gozdna tla dobro ohranjena in neonesnažena in tako eno izmed najčistejših okolij v Ljubljani (slika 3).

## THE INVENTORY OF DISEASES OF FOREST TREES AND AN OVERVIEW OF THE HEALTH OF TREES IN URBAN FORESTS

Tree health is especially important in urban environment, since diseased or injured trees can pose a serious threat to humans. In decaying trees, the branches often snap off or the tree breaks in strong wind due to degraded wood or rotten roots. Tree diseases are caused by numerous pathogenic fungi. Many insects can harm trees, deteriorating their appearance or reducing their vitality. For reducing the damages caused by diseases and pests, numerous preventive and curative protection measures were developed. We identified the causes of the damages, and developed as well as tested different methods to monitor diseased and injured trees. The development and use of this knowledge will enable forest management to create healthier and safer forests for visitors.

## MONITORING VISITS TO THE URBAN FOREST

After all our daily obligations, when we often do not have enough time for longer trips to a natural area, an urban forest such as in Ljubljana serves as a perfect place for restorative activities in nature. To sustainably manage an urban forest, a manager must know at least indicative information on the number of visitors in the forest and temporal dynamics of the visits. The intensity of the visit has an impact both on the forest (e.g. erosion, soil compaction), as well as direct recreational experience (e.g. a desire for seclusion or socializing). To estimate the frequency of the visits, we have installed a system of visitor frequency counters that we developed at the Laboratory for electronic devices at the Slovenian Forestry Institute.

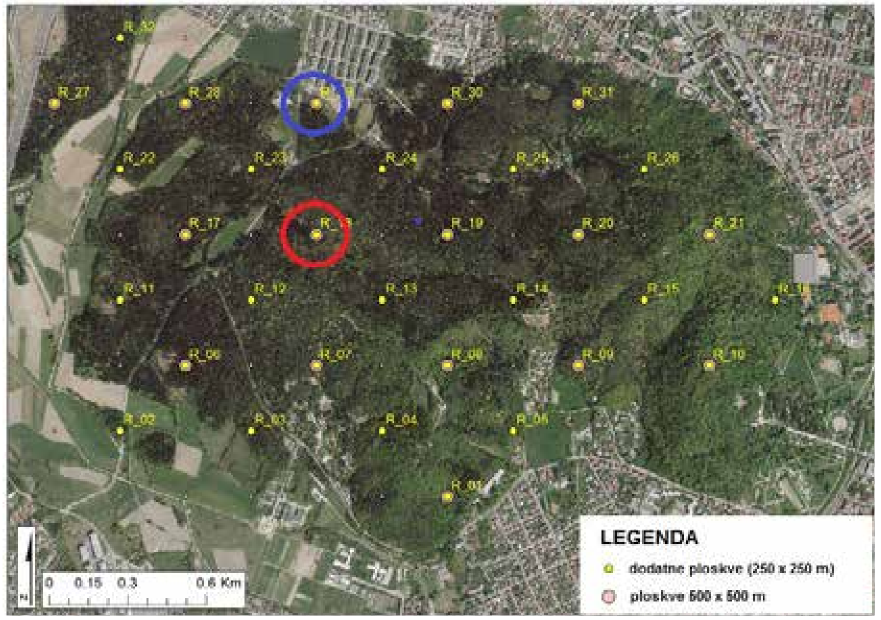
## POLLUTION OF FOREST SOIL AND PROTECTION OF WATER RESOURCES IN LJUBLJANA URBAN FORESTS

Forest soils are an important filter for inputs of pollutants from the surrounding farmland, roads and urban areas into groundwater and surface watercourses.

From the point of view of maintaining fertile and unpolluted forest soil, the role of forests in urban areas is especially in maximized interception of rainfall and retention of soil in erosion risk areas.

A network of permanent sample plots for regular monitoring and pollution of forest soils in the Tivoli, Rožnik and Šišenski hill Landscape Park and in the lowland floodplain forest along the Sava River was established within the EMoNFUr project. Forest soils have proved to be well preserved and are one of the cleanest environment in the city (Fig. 3).

**Slika 2. V Krajinskem parku Tivoli, Rožnik in Šišenski hrib prevladujejo globoka ter kisla distrična rjava tla. (Foto: Aleksander Marinšek)**
**// Fig. 2: In the Tivoli, Rožnik and Šišenski hrib Landscape Park, deep Dystric Cambisols prevail. (Photo: Aleksander Marinšek)**




**Slika 3. Vsebnost svinca (Pb) presega opozorilno vrednost (100 mg/kg) le na eni ploskvi v Mostecu (140 mg/kg, rdeči krog). Tudi mejna vrednost (200 mg/kg) cinka (Zn) je bila presežena le na ploskvi v bližini Koseškega bajerja (201,6 mg/kg, modri krog). Kritične vsebnosti težkih kovin v gozdnih tleh niso bile presežene na nobeni ploskvi.**
**// Figure 3: The content of lead (Pb) exceeds the warning value (100 mg/kg) only on a single location at Mostec (140 mg/kg) (red circle). The limit value (200 mg/kg) for zinc (Zn) has been exceeded only on the Koseze plot near the pond (201.6 mg/kg) (blue circle). The critical concentrations of heavy metals in forest soils are not exceeded on any of the plots.**

### SPREMLJANJE KAKOVOSTI ZRAKA

Merjenje in spremljanje usedlin predvsem dušikovih in žveplovih spojin, ki so antropogenega izvora in posledica onesnaževanja zraka (http://www.gozdis.si/za-radovedne/gozdarski-filmi/), omogoča neposredno oceno vnosa snovi v gozd in izračun kritičnih vrednosti, ki jih gozd in rastline v njem še prenesejo. Z razširitvijo spremljanja usedlin na urbane gozdove želimo ovrednotiti pozitivni vpliv gozda na življenje v mestu in njegovi okolici, ki ni omejen samo na področje zraka, marveč tudi kakovosti vode oziroma podtalnice in tal.

### AIR QUALITY MONITORING

Measuring and monitoring of deposition, especially of nitrogen and sulphur compounds of anthropogenic sources and consequence of the air pollution (http://www.gozdis.si/za-radovedne/gozdarski-filmi/), enables us to assess direct amounts of inputs into the forests and calculation of the critical loads, which are still tolerable by the forest and plants in it. By extending deposition monitoring to the urban forests we want to evaluate the positive influence of forest on the life in the city and its surroundings, which is not restricted to the sphere of air, but also on water, groundwater and soil.



Kakovost zraka lahko spremljamo tudi z analizo tkiv določenih vrst mahov. Večina mahov ima slabo razvit koreninski sistem in nimajo razvite kutikule, tako da sprejemajo večino hranil in vode prek celotne površine, neposredno iz tal pa le v manjšem obsegu. Spremljanje onesnaženosti zraka na posreden način prek drugih rastlinskih ali živalskih vrst imenujemo »biomonitoring«, ki je pomembna informacija o onesnaženosti naravnega okolja.

The quality of air could be monitored also through element measurements in moss tissue. Most of the moss species have a poorly developed rooting system and they lack the cuticle, which forces them to accept most of the mineral substances and water over the surface and not from the soil. Monitoring of air pollution indirectly via plants or animals is called "bio monitoring" and could be used as additional important information about the pollution of a natural environment.

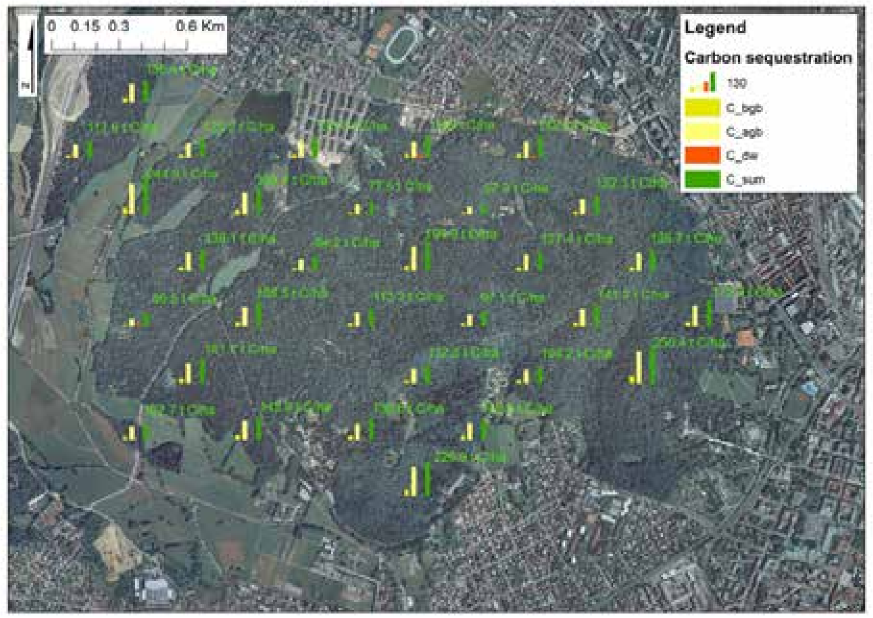
**Slika 4: Vzorčenje mahu na terenu (levo) in pogosto uporabljena vrsta mahu (*Hypnum cupressiforme*) za analize o vsebnostih onesnažil (desno) (Foto: Mitja Skudnik)**
**// Figure 4: Field sampling of moss (left) and example of commonly used moss species (*Hypnum cupressiforme*) for analysis of pollutants (right) (Photo: Mitja Skudnik)**

### GOZDNA INVENTURA IN ANALIZA RASTI DREVJA V URBANIH GOZDOVIH

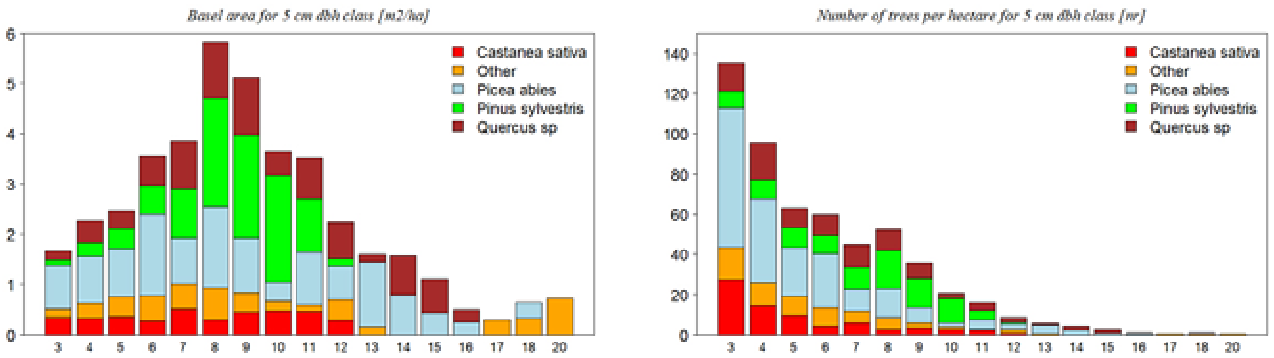
Cilj gozdne inventure je pridobiti informacije o stanju gozda. V okviru projekta EMoNFUr je bil na Rožniku vzpostavljen sistem 31 stalnih vzorčnih ploskev na mreži 250 x 250 m. Pripravljen je bil nabor znakov, s katerimi bi lahko spremljali informacije o urbanih gozdovih in ki bi bili zanimivi za različne interesne skupine (gozdarski strokovnjaki, lastniki gozdnih zemljišč, meščani, naravovarstveniki itd.). Gozdna inventura je tako dala odgovore na vprašanja, kakšna je količina vezanega ogljika v živi in odmrli lesni biomasi in kakšno je stanje mestnih gozdov z vidika biotske pestrosti. Pridobili smo tudi podatke o višini lesne zaloge v mestnih gozdovih, o višini dreves, njihovi debelinski strukturi, sliko o horizontalni in vertikalni zgradbi gozda in uspešnosti pomlajevanja mestnega gozda. Vsi ti podatki so potrebni za uspešno načrtovanje ukrepov v gozdu, katerih cilj je zagotavljati trajnost in mnogonamenskost mestnega gozda.

### FOREST INVENTORY AND GROWTH ANALYSIS OF TREES IN URBAN FOREST

The goal of urban forest inventory is to define the state of the forest. In the EMoNFUr project, 31 permanent sampling plots on the 250 x 250 m grid were established. The list of indicators that could potentially be used by different users (forest experts, forest owners, citizens and environmentalists etc.) was presented for monitoring the urban forest's condition. The forest inventory of urban forest of Rožnik gave us some answers on biodiversity and the amount of carbon in live and dead wood biomass. We also obtained data on growing stock, height of trees, dbh structure, horizontal and vertical structure and forest regeneration in urban forest. All these data are essential for planning measurements that help us to pursue the goal of sustainable and multidisciplinary urban forests.




**Slika 5: Zemljevid, ki prikazuje lokacije stalnih vzorčnih ploskev in količine vezanega ogljika v nadzemni, podzemni in odmrli lesni biomasi. V povprečju je bilo v raziskanih mestnih gozdovih vezanega 138 ton C ha$^{-1}$.**
**// Figure 5: Map of the newly established permanent sampling plots and the amount of sequestrated C in aboveground, belowground and dead wood biomass. On average, 138 tons C ha$^{-1}$ were sequestrated within the urban forests of Ljubljana.**




**Slika 6: Temeljnica za glavne drevesne vrste po 5 cm debelinskih razredih (levo) in število dreves za glavne drevesne vrste po 5 cm debelinskih razredih (desno) prikazuje razmeroma visoke vrednosti za smreko in rdeči bor.**
**// Figure 6: Basal area for the main tree species for 5 cm DBH class (left), and number of trees for main tree species for 5 cm DBH class (right) show relative high values for Norway spruce and Scotch pine.**

## ODZIV RASTI DREVES V URBANEM GOZDU NA OKOLJSKE DEJAVNIKE

V okviru projekta merimo debelinski prirastek dreves na dva različna načina – z elektronskimi dendrometri in s pomočjo izvrtkov, ki jih s posebnim votlim svedrom vzamemo iz debla. Z elektronskimi dendrometri merimo majhne (< 0,1 mm) spremembe v debelinskem priraščanju dreves v intervalih od 15 do 30 minut v eni rastni sezoni. Z dendrometri te spremembe zaznamo in povežemo z okoljskimi razmerami, ki vplivajo na rast (npr. suša). Z izvrtki preučujemo debelinsko priraščanje dreves v preteklosti in njihov odziv na vplive okolja na letni ravni. S poznavanjem odziva dreves lahko predvidimo odziv drevesa in vpeljemo gojitvene ukrepe, ki bodo pripomogli k blaženju posledic podnebnih sprememb tudi na urbane gozdove.

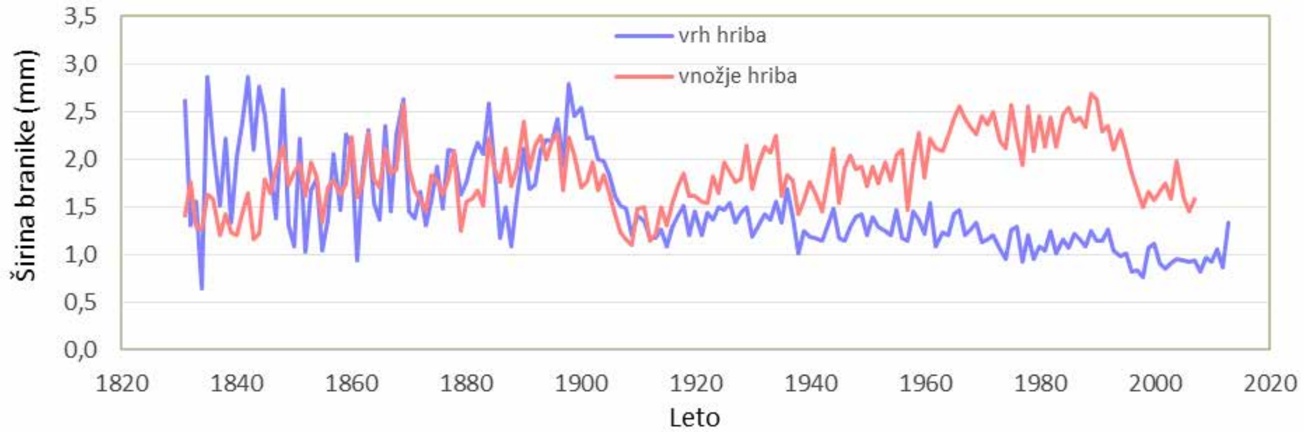
## RESPONSE OF THE TREES GROWTH IN URBAN FOREST TO THE ENVIRONMENTAL FACTORS

We also measured radial increment of the trees within the EMoNFUr project in two ways – with electronic dendrometres and with increment cores taken from the tree trunk. With electronic dendrometres we measure minute changes in tree's increment (< 0.1 mm) on a time scale between 15 and pride. Changes in radial increment measured with electronic dendrometres can be later on connected with the environmental factors. This information is crucial for understanding intra-annual dynamics of tree growth and correct interpretation of seasonal variation in cambium dynamics. Cores, on the other hand, provide information on tree growth at the inter-annual level.




**Slika 7: Detajl ročnega tračnega dendrometra, ki z nonijsko skalo omogoča neposredno odčitanje premera drevesa. (Foto: Tom Levanič)**
**// Figure 7: Detail of the manual girth band displaying scale for direct reading of the tree's diameter. (Photo: Tom Levanič)**

**Slika 8: Elektronski dendrometer, nameščen na smreki. Pod njim je nameščen ročni tračni dendrometer (rjavi trak). (Foto: Tom Levanič)**
**//Figure 8: Electronic dendrometer installed on a spruce tree. Below is installed manual girth band (brown tape) (Photo: Tom Levanič)**



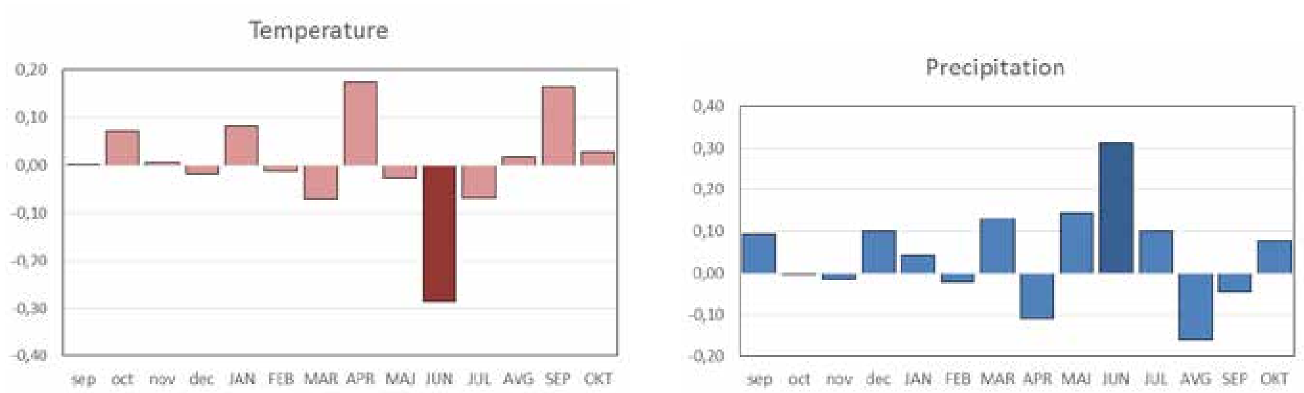

**Slika 9: Kronologija širin branik za hraste, ki rastejo na vznožju hriba (urbani gozd na obrobju parka Tivoli) in na vrhu hriba, na Rožniku, ki je ravno tako del urbanega gozda**
**// Figure 9: Tree-ring width chronology from the bottom of the slope (forest within Tivoli Park) and on the top of the slope (forest on Rožnik Hill – also part of urban area)**

Raziskovalci s primerjavo med povprečno mesečno temperaturo ali mesečno količino padavin in širino branike ugotovimo, kateri meseci so ključni za nastanek branike. Ljubljana ima enega najdaljših klimatskih nizov v Sloveniji. Dolg je prek 100 let in zato smo ga tudi uporabili v naši analizi.

Prva ugotovitev je, da drevesa v urbanem gozdu v primerjavi z naravnim gozdom nimajo bistveno drugačnega odziva na klimo. Na širino branike hrastov v urbanem gozdu najpomembneje vplivajo klimatske razmere v juniju. Najširša branika nastane takrat, ko ni prevroče in ko je količina padavin nekoliko nad dolgoletnim povprečjem za junij – slika 10.

Tree-ring width sequences can be used to study growth of trees in the past and their response to different (mostly meteorological) parameters. By knowing the response of trees to climate in the past we can develop silvicultural measures that will help forest ecosystems mitigate the impacts of climate change. By comparing average monthly temperature or monthly sum of precipitation, researchers can identify which months within a particular year are playing a crucial role in tree growth. Ljubljana has a quite long and reliable temperature and precipitation record (from 1900 to the present day).

First important observation is that climate response of trees in an urban area is not different comparing to response of trees in a managed or old-growth forest. The most important month for a wide ring in trees in urban area is June and the best combination for a wide ring in a particular year is a combination of not so warm June with a good supply of precipitation in the same month – Figure 10.




**Slika 10: Odziv debelinske rasti hrasta na povprečne mesečne temperature (levo) in mesečno vsoto padavin (desno). S temnejšo barvo smo obarvali tiste mesece, ki ključno vplivajo na rast, z velikimi tiskanimi črkami so prikazani meseci tekočega leta, z majhnimi tiskanimi pa meseci predhodnega leta.**
**// Figure 10. Response of the oak's radial growth to average monthly temperatures (left) and monthly sum of precipitation (right). Darker colour indicates the months with crucial impact on the growth, while capital letters denote the months of the current year and small letters of the previous year.**

## EKONOMSKO VREDNOTENJE URBANEGA GOZDA

Ekosistemske storitve urbanih gozdov, npr. zmanjševanje vsebnosti onesnaževal v zraku, uravnavanje mikroklime, rekreacija v naravnem okolju idr., in njihovo ekonomsko vrednotenje omogoča preskok vrzeli med ekonomisti in okoljevarstveniki. S tehnikami ekonomskega vrednotenja netržnih storitev gozda je mogoče v urbanistično planiranje enakovredno vključevati tako tržne dobrine, ki jim vrednost pripišemo na podlagi njihove cene na trgu (les, vezava $CO_2$), kot tudi netržne storitve, ki so po naravi bodisi javne dobrine bodisi skupno dobro (možnost rekreacije, koristi za javno zdravje, blaženje vremenskih ekstremov). Presoja različnih politik upravljanja z urbanimi gozdovi je tako bolj celostno, saj bolj gotovo upošteva raznolika pričakovanja družbe do gozda.

## KLIMATSKE RAZMERE V MESTNEM GOZDU

Spremljanje podnebnih razmer v mestnem okolju je z vidika obveščanja, posebej ob vročinskih valovih, za meščane izrednega pomena. Vrednosti vremenskih spremenljivk, kot so denimo temperatura in relativna vlažnost zraka ter veter, se lahko v mestu krajevno in časovno občutno razlikujejo. Tovrstno izmenjevanje okoljskih vplivov meščani še posebej občutijo prav zaradi součinkovanja zgradb, prometa in vmesnih zelenih površin.

Podatke, pridobljene iz meteoroloških postaj, ki so bile med projektom nameščene v urbane gozdove, smo primerjali s podatki z mestnih meteoroloških postaj in potrdili pomen urbanih gozdov na zmanjševanje učinkov toplotnih otokov v Ljubljani. Slika 11 prikazuje razlike v temperaturi zraka med mestnim središčem in urbanim gozdom v času vročinskega vala v Ljubljani leta 2013.

## ECONOMIC EVALUATION OF URBAN FOREST

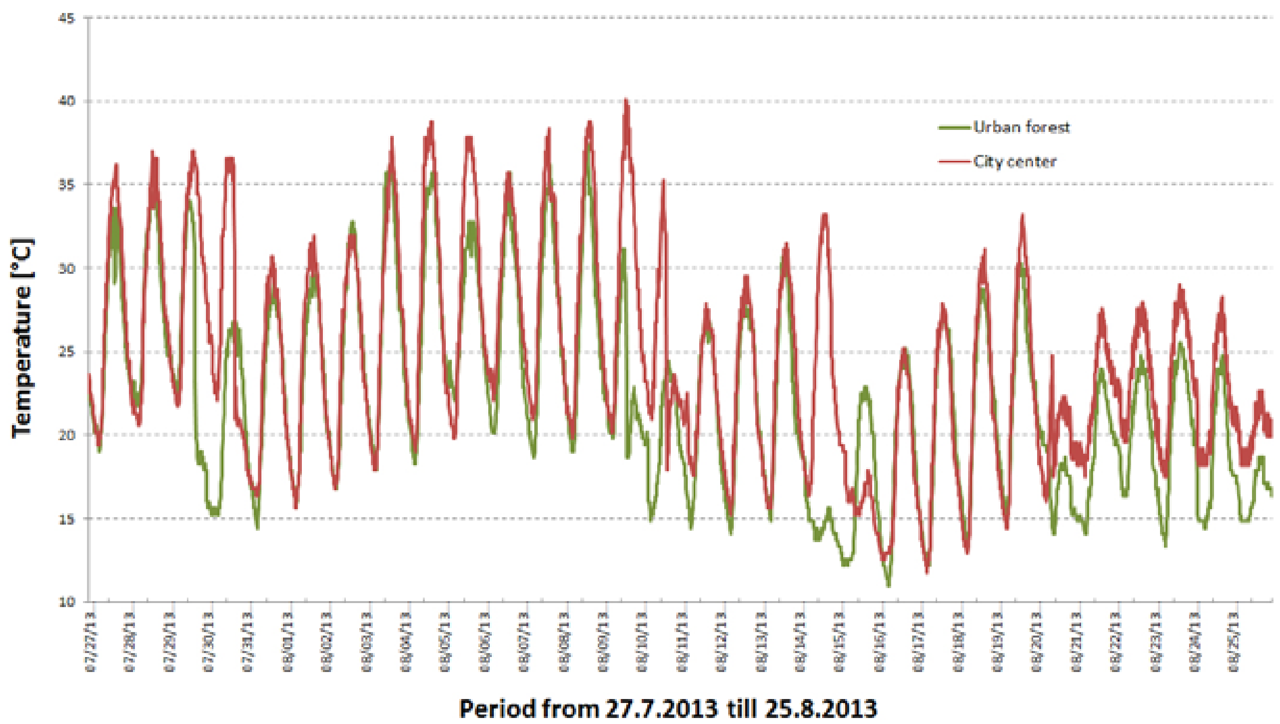
Ecosystem services of urban forests, such as mitigating air pollution, regulation of microclimate, recreation in the natural environment etc. and their economic valuation, bridge the gap between economy and nature protection. By employing techniques of economic valuation of non-market goods and services of forests, urban planning can be extended to cover both, market goods, which can be valued upon their market price (wood, $CO_2$ sequestration), and non-market goods, which can be either public goods or common property (recreation opportunities, benefits for public health, mitigation of weather extremes). In this way, procedures of policy appraisal would be more comprehensive, as it can consider public expectations to a much greater extent.

## CLIMATE CONDITIONS IN URBAN FOREST

Monitoring of climate conditions in an urban environment is of great importance for the citizens, especially during heat waves. Values of the meteorological variables, e.g. air temperature, relative air humidity and wind speed, can significantly differ in the city in space and time. Such exchange of environmental impacts is felt extremely strongly by the citizens because of the buildings, traffic and intermediate green spaces interactions.

Data, acquired from the meteorological stations set up in the urban forests, were compared with the data of the urban meteorological stations. We confirmed that the urban forests reduce the impact of heat islands in Ljubljana. Fig. 11 shows the differences in air temperature comparing the city centre and urban forest at the time of heat wave in Ljubljana in 2013. The highest air temperature in the city centre and urban forest reached 40.2 °C and 37.4 °C, respectively. A better insight into heat stress






**Slika 11: Razlika v temperaturi zraka v središču Ljubljane in v urbanem gozdu med vročinskim valom leta 2013**
**// Figure 11. The difference in air temperature between the city centre and the urban forest during the 2013 heat wave in Ljubljana.**

Najvišja temperatura zraka je v središču mesta dosegla +40,2 °C, v urbanem gozdu pa +37,4 °C. Podrobnejši vpogled na toplotno obremenitev predstavlja tudi povprečna dnevna temperatura zraka – razlike slednjih lahko med središčem mesta in urbanim gozdom dosegajo tudi 10 °C.

was also enabled by the average daily temperature - in some cases the difference between the city centre and urban forest reached up to 10 °C.

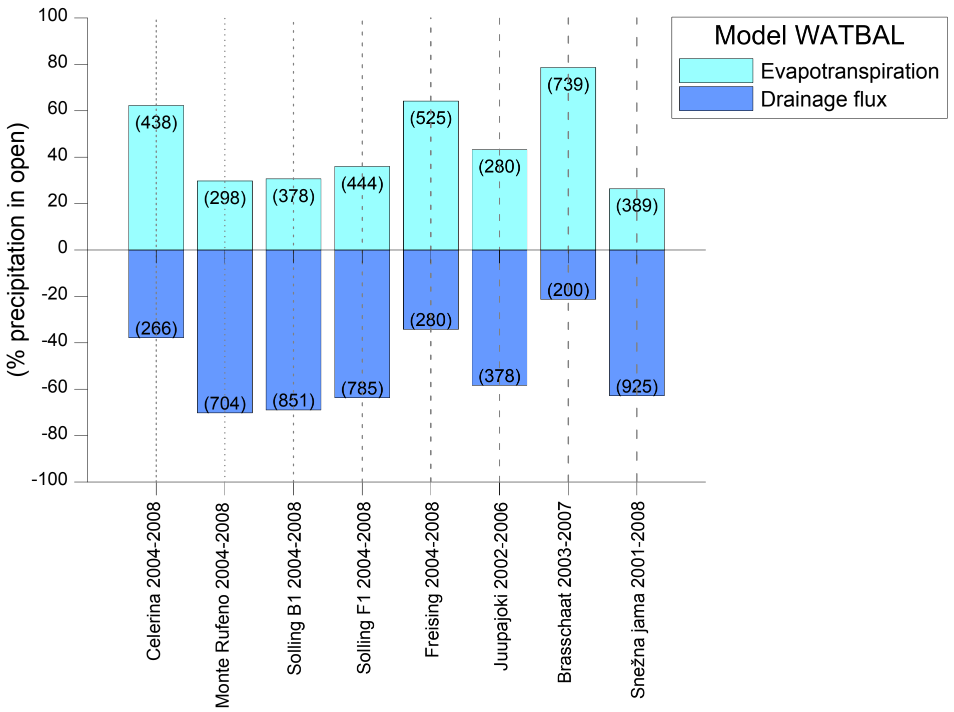
# MODELIRANJE VODNE BILANCE GOZDA

## // FOREST WATER BALANCE MODELLING

**Urša Vilhar**

**Ocena elementov vodne bilance in toka hranil skozi gozdni ekosistem je nepogrešljiva za razumevanje kroženja elementov in napovedovanje odziva gozdnega ekosistema na spremembe v okolju. Na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov, kjer eksperimentalni pristopi za ugotavljanje elementov vodne balance tal niso na voljo, je mogoče odtok v podtalje oceniti z uporabo hidroloških modelov za tla, pri čemer lahko uporabimo preproste modele zalog ali celostne mehanistične modele.**

**// Assessment of water and nutrient fluxes through forest ecosystem is indispensable for understanding the element cycles and to predict forest ecosystem response to environmental changes. On forest monitoring plots, where experimental approaches to determine soil water fluxes are not available, drainage can be assessed by using soil hydrological models, ranging from simple budget models to comprehensive mechanistic models.**




**Slika 1. Dejanska evapotranspiracija in odtok v podtalje (v % padavin na prostem) na ploskvah intenzivnega spremljanja stanja gozdnih ekosistemov širom Evrope, simulirane z modelom Watbal v okviru projekta Life FutMon. Številke v oklepajih so vrednosti v mm.** **// Figure 1. Actual evapotranspiration and drainage flux (% of precipitation in open) at several forest monitoring plots across Europe, simulated by the WATBAL model within the framework of Life project FutMon. Figures in brackets are values in mm.**

# MAHOVI KOT BIOMONITORJI ONESNAŽENOSTI OKOLJA Z DUŠIKOVIMI SPOJINAMI

## // MOSSES AS BIOMONITORS OF ATMOSPHERIC NITROGEN POLLUTION

**Mitja Skudnik**

Povečane koncentracije N spojin so bile nedavno opredeljene kot kritične glede obremenitve okolja na globalni ravni. Z namenom, da bi za Slovenijo dobili boljše informacije o atmosferskem usedu N spojin, smo na 103 lokacijah v gozdovih po državi vzorčili mahove in določili koncentracije N v njihovem tkivu. Najvišje vrednosti N v mahovih so bile izmerjene v zahodnem alpskem delu Slovenije, v okolici velikih mest, kot so Ljubljana, Celje in Maribor, ter na območjih z intenzivnim kmetijstvom v vzhodnem delu države.

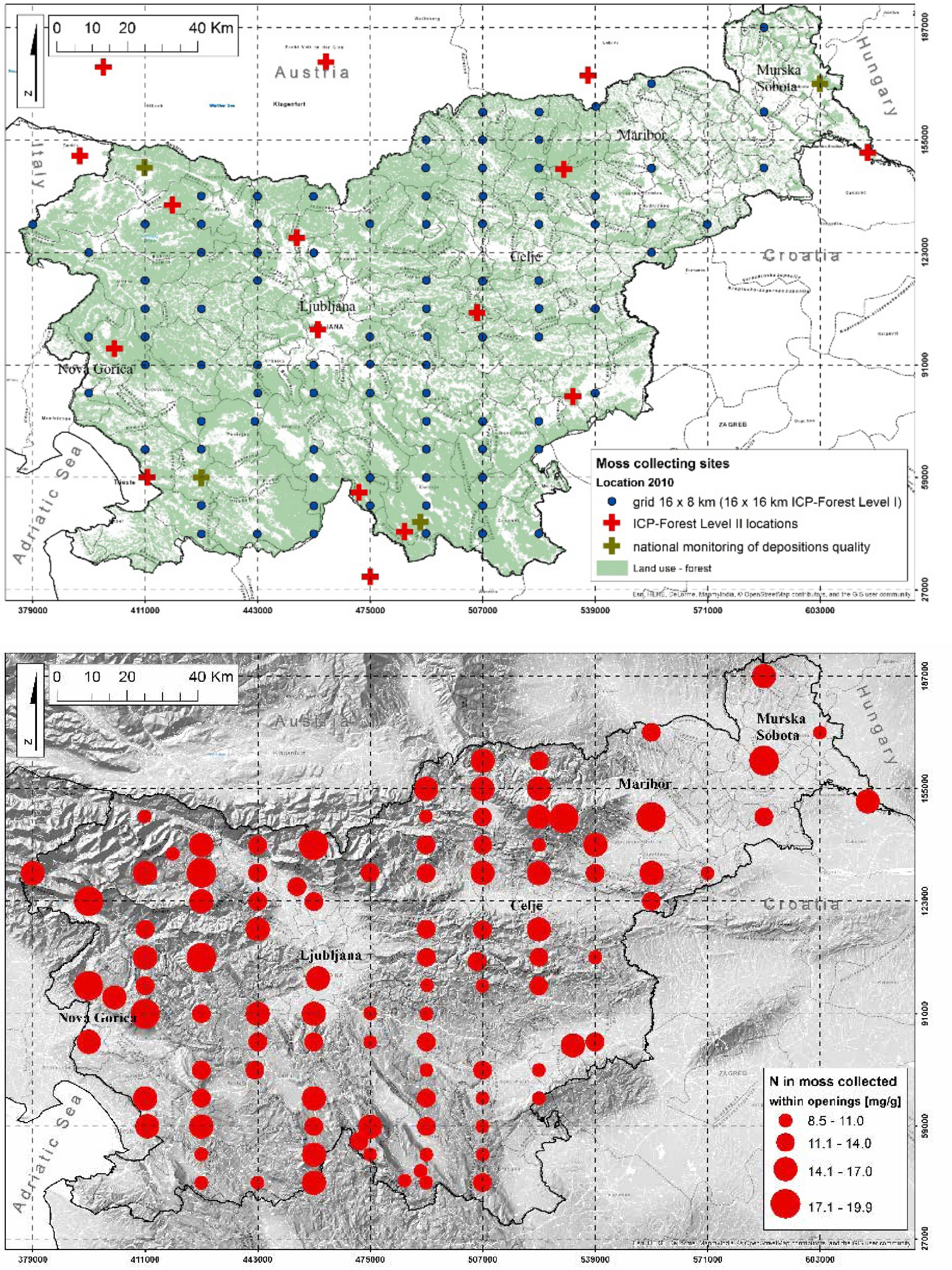
Po letu 1980 so v številnih evropskih državah nekatere zakonodajne obveze glede varstva okolja (kot npr. konvencija LRTAP) pomembno vplivale na zmanjševanje onesnaževanja zraka z žveplovimi spojinami (S) in prašnimi delci, vendar pa ne za različne spojine dušika (N). Na količine vnesenega N v ekosisteme vpliva vse večja uporaba fosilnih goriv in kmetijske dejavnosti. Zaradi zapletenih relacij med onesnaževali in ekosistemom je pogosto poudarjena potreba po zbiranju kakovostnih informacij o količini in prostorski porazdelitvi teh onesnaževal. Posledično so bili vzpostavljeni številni sistemi za spremljanje onesnaženosti okolja; nekateri temeljijo na fizikalnih in kemijskih meritvah usedlin in kakovosti zraka (zrak, padavine itd.), medtem ko drugi uporabljajo različne metode bio-indikacije z uporabo mahov, lišajev itd. Sistemi, ki temeljijo na meritvah usedlin in kakovosti zraka, so bolj natančni, vendar je običajno število takšnih opazovalnih postaj majhno. Razlog je pogosto povezan z visokimi stroški pri vzpostavitvi in vzdrževanju tovrstnih sistemov. Takšni načini lahko postanejo problematični, če želimo natančne prostorske informacije o nekaterih onesnaževalih, predvsem glede na to, da so nekatera onesnaževala močno izpostavljena hitrim prostorskim in časovnim spremembam.

Z namenom dobiti dodatne prostorske informacije o onesnaževalih, so bile razvite številne metode bioindikacije, kot je npr. evropska mreža biomonitoringa z mahovi, ki jo v zadnjih letih razvijajo v okviru programa ICP

// Increased concentrations of N compounds have recently been identified as a critical load for the environment on a global scale. To get better information on N depositions of Slovenia, mosses were collected at 103 locations within forests at the national level. The highest values of N in moss occurred in the western mountainous part of Slovenia, around large cities, such as Ljubljana, Celje and Maribor, and in areas with intensive agriculture in the eastern part of the country.

After 1980, the environmental protection legislative (like CLRTAP) convention) had a significant impact on achieved reduced air pollution of sulphur (S) compounds and dust particles in many European countries, but not for nitrogen (N) compounds. The amount of N entering the ecosystems is affected mainly by increasing consumption of fossil fuels and use of fertilizers. Complex relationships between pollutants and ecosystems often exposed the need to collect quality information on amount and spatial distributions of pollutants. Consequently, numerous different monitoring systems were established; some are based on physical and chemical measurements of depositions and air quality (air, precipitation etc.), while others are using different bio-indicators (e.g. mosses, lichens etc.). Monitoring systems, which are based on the measurements of deposition and air quality, are more accurate, but usually the number of such monitoring stations is low. The reason is often linked with high costs to establish and to maintain this kind of monitoring systems. But this could be problematic to gain accurate spatial information on some pollutants, while some could have high spatial and temporal variability.

To gain additional spatial information on deposited pollutants, numerous biomonitoring methods were established, such as European moss biomonitoring survey, which has lately been developed within the framework of ICP Vegetation (International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and




**Slika 1. Pomembno je povezati različne sisteme monitoringov onesnaženosti zraka, ki zbirajo podatke na različnih prostorskih ravneh.**
**// Figure1. It is important to correlate different monitoring systems gathering information on different scales.**



Vegetation (Mednarodni program sodelovanja o vplivu onesnaženega zraka na naravno vegetacijo in poljščine, ki poteka v okviru konvencije LRTAP). Prednost tovrstnega spremljanja je, da je metodologija zbiranja podatkov enostavnejša in tudi kemične analize so cenejše; posledično je mogoče doseči večjo gostoto vzorčenja.

Da bi dobili boljše informacije o atmosferskem vnosu N v Sloveniji, smo v letu 2010 na 103 gozdnih lokacijah vzorčili mahove vrste *Hypnum cupressiforme* Hedw. Med izbrane lokacije so bile vključene tudi vse ploskve ICP Forests Ravni I in Ravni II, dodatno pa tudi nekatere lokacije državne meteorološke mreže, kjer spremljajo kvaliteto padavin, vključno tudi z eno postajo EMEP.

Poleg koncentracije N smo v mahovih določili tudi koncentracije težkih kovin in izotopsko sestavo dušika (δ $^{15}$N). V okolju poznamo številne različne vire emisij N, ki jih delimo glede na to, ali sproščajo v atmosfero reducirane (amonijske) ali oksidirane (nitratne) oblike dušika. Frakcionacija dušikovih izotopov ($^{15}$N, $^{14}$N) v teh spojinah pa je različna in s tem tudi vrednost δ $^{15}$N. Literaturni podatki kažejo, da bi lahko iz izotopske sestave dušika v biomonitorjih sklepali na izvore dušika v atmosfero. Analiza je namreč pokazala, da so vrednosti δ $^{15}$N v mahovih bolj negativne, če N izvira iz kmetijskih virov, in nasprotno, manj negativne, če N izvira iz procesov zgorevanja fosilnih goriv in transporta.

Naši rezultati kažejo na pomen povezave med različnimi sistemi spremljanja onesnaženosti zraka, ki delujejo na različnih prostorskih ravneh.

Crops) as a part of LRTAP convention. Advantage of this kind of monitoring is that the methodology of data collection is simpler and also that the chemical analyses are cheaper; consequently, much higher sampling density can be achieved.

To get better information on N depositions of Slovenia, mosses (*Hypnum cupressiforme* Hedw.) were collected in 2010 at 103 locations within forests including all sites from ICP Forest Level I and Level II and additionally also the locations where depositions are measured for national reports including one EMEP station.

Additionally to N concentrations, heavy metals and stable N isotopes ($^{15}$N/$^{14}$N ratio expressed relative to an international standard as (δ $^{15}$N value) were also determined in the mosses. Usually within the area of survey, there could be numerous different N emission sources. They can be divided into emitting mainly reduced N or oxidized N. Analysis showed that the $^{15}$N/$^{14}$N ratios differ between oxidized and reduced forms of N and that they are more negative if the N originates from agricultural sources and, contrary, less negative if the N originates from combustion processes and transport. Researchers suggested that information on stable isotopes of N could be used to explore the source of N in moss tissue and with this identify the main N emitters around the sampling location.

Our results indicate importance of correlating different monitoring systems gathering information on different scales.

# MIKO-BIOINDIKACIJA ONESNAŽENOSTI GOZDNIH RASTIŠČ

## // MYCOBIOINDICATION OF FOREST SITE POLLUTION

**Hojka Kraigher**

**Bioindikatorji so organizmi ali združbe organizmov, ki se odzovejo na vplive iz okolja s spremembo njihovih vitalnih funkcij in / ali njihove kemijske sestave ter tako omogočajo oceno stanja okolja (Arndt et al., 1987). Bioindikatorje delimo na odzivne ali akumulativne indikatorje, ki so nato razvrščeni v tri skupine: (1) kazalniki oziroma ekološki indikatorji, ki podajajo oceno stanja celotnega ekosistema; (2) testni organizmi, ki se uporabljajo v standardiziranih laboratorijskih postopkih in (3) organizmi za spremljanje kakovosti in količine škodljivih snovi v okolju ter zaznavanja njihovih vplivov. Ti organizmi so lahko že prisotni v okolju (pasivni monitorji) ali pa se jih po standardizirani obliki vnese v ekosistem (aktivni monitorji).**

Upadanje vrstne pestrosti makromicet ter številčnosti njihovih trosnjakov v Evropi je bila opažena že v drugi polovici 20. stoletja (Arnolds, 1988, 1991; Jaenike, 1991). Posledično sta Fellner (1989) ter Fellner in Peškova (1995) predlagala metodo mikobioindikacije za ugotavljanje onesnaženosti gozdov, ki temelji na osiromašenosti ektomikoriznih (ECM) mikobiocenoz. Vendar pa je pojavljanje trosnjakov povezano z vrsto vremenskih dejavnikov med letom (in v letu prej), med tem ko so tipi ECM v tleh prisotni celo leto. Poleg tega pri celi vrsti ektomikoriznih gliv, kot na primer skupini, v preteklosti imenovani »Fungi imperfecti«, trosnjaki sploh niso poznani. Posledično so se v 90. letih prejšnjega stoletja pričele podrobnejše raziskave ECM potenciala gozdov, z vizijo uporabe rezultatov za potrebe bioindikacije (Fellner & Peškova, 1995; Kraigher, Batič, & Agerer, 1996; Al Sayegh Petkovšek, 1997, 2004, 2005; Taylor, Martin, & Read, 2000; Al Sayegh Petkovšek & Kraigher, 2003; Erland & Taylor, 2002; Taylor & Alexander, 2005).

V Sloveniji je bila izvedena vrsta raziskav z analizo rasti drobnih korenin ter tipov ECM kot orodja za bioindikacijo stresnih razmer na gozdnih rastiščih (Kraigher et al 2007; Kraigher & Al Sayegh Petkovšek 2013). Uporabljene in testirane so bile različne skupine bioindikatorjev za namene slovenske miko-bioindikacije:

1a. Pestrost tipov ECM na navadni smreki (*Picea abies* (L) Karst) ali bukvi (*Fagus sylvatica* L.) v gozdovih (*in situ* ekološki indikatorji); indikatorji biotske pestrosti so bili zelo nazorni v smrekovih monokulturah, manj pa v mešanih gozdovih z bukvijo (Kraigher 1999; Al Sayegh Petkovšek 2004, Cudlin et al 2007);

1b. Določanje tipov ter kvantifikacija izbranih, na onesnaženje občutljivih ali neobčutljivih tipov ECM (*in situ* pasivni monitorji); tip, ki ga tvori gliva *Paxillus involutus* in tip *Piceirrhiza terrafila*, ki se pojavlja na smreki, vrsta ECM glive pa ni znana, sta neobčutljiva na onesnaževala, med tem ko je *Hydnum rufescens* občutljiv tip ECM na navadni smreki (Kraigher 1995, 1996; Kraigher et al 2007).

2. Razvoj ECM na sadikah smreke, posajenih na razi-skovalnih ploskvah (aktivni monitorji) (Vukovič 2003);

3. Razvoj ektomikorize ali analize različnih parametrov rasti korenin na sadikah dreves, testiranih v eksperimentalnih pogojih (*ex situ* indikatorji onesnaženosti tal) (Al Sayegh Petkovšek 1997);

4. Trosnjaki gliv so bili testirani kot akumulativni pasivni monitorji strupenih snovi v okolju (AlSayegh Petkovšek & Pokorny 2011).

**//Bioindicators are organisms or communities of organisms which react to environmental effects by changing their vital functions and/or their chemical composition, thus making it possible to draw conclusions on the state of their environment (Arndt et al., 1987). Bioindicators can be differentiated into sensitive (response) and accumulative indicators, and are subdivided into three different groups: (1) pointer organisms or ecological indicators give evidence on the state of entire ecosystems; (2) tester organisms are used in standardised laboratory procedures; and (3) monitoring organisms are used to monitor quality and quantity of harmful substances in the environment and to detect their effects. These monitoring organisms can either already exist in the ecosystem (passive monitoring) or are introduced into the ecosystem in a standardised form (active monitoring).**

Decreases in species diversity and in the abundance of sporocarps of macromycetes in Europe have been reported in the second half of the 20th century (Arnolds, 1988, 1991; Jaenike, 1991). As a result the method of mycobioindication of forest site pollution was suggested by Fellner (1989) and Fellner and Peškova (1995), based on the impoverishment of ectomycorrhizal (ECM) mycobiocenosis. However, the occurrence of fruitbodies depends on a range of climatic factors in different years, while ECM types are supposed to be present in the soils at any time of the year. Furthermore, a range of ectomycorrhizal fungi, such as the group commonly named Fungi Imperfecti, do not produce any sporocarps. As a result, more detailed studies of ECM potential of forest sites by ECM types determination were initiated in the 1990s, with a view to applying the results to bio indication (Fellner & Peškova, 1995; Kraigher, Batič, & Agerer, 1996; Al Sayegh Petkovšek, 1997, 2004, 2005; Taylor, Martin, & Read, 2000; Al Sayegh Petkovšek & Kraigher, 2003; Erland & Taylor, 2002; Taylor & Alexander, 2005).

In Slovenia, a series of studies was carried out by applying growth of roots and types of ECM as tools for bioindication of stress in forest sites (Kraigher et al 2007; Kraigher & Al Sayegh Petkovšek 2013). All different groups of bioindicators were applied and tested in the Slovenian mycobioindication approach:

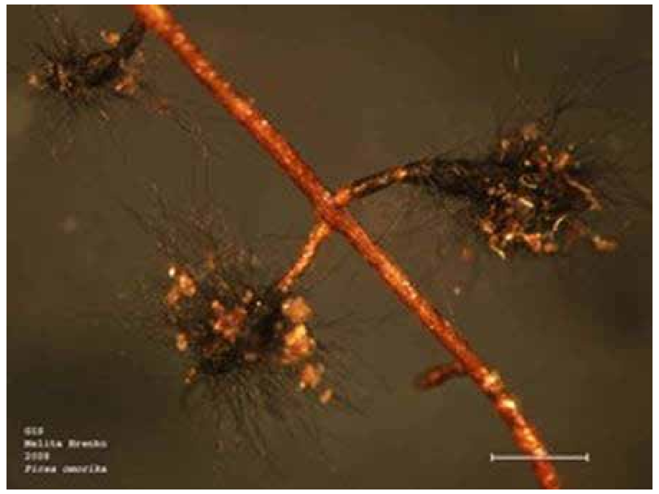
1a. Diversity of ECM types on Norway spruce (*Picea abies* (L) Karst) or beech (*Fagus sylvatica* L.) in forest stands (*in situ* ecological indicators); biodiversity indices were highly indicative in Norway spruce monocultures, less so in mixed beech forests (Kraigher 1999; Al Sayegh Petkovšek 2004, Cudlin et al 2007).

1b. Determination and quantification of selected pollution-sensitive or -insensitive ECM types (*in situ* passive monitors); *Paxillus involutus* and the ECM type *Piceirrhiza terrafila* (formed on *Picea abies* and an unidentified ECM fungus) were shown to be polluton tolerant, while *Hydnum rufescens* was a sensitive ECM type on Norway spruce (Kraigher 1995, 1996; Kraigher et al 2007).

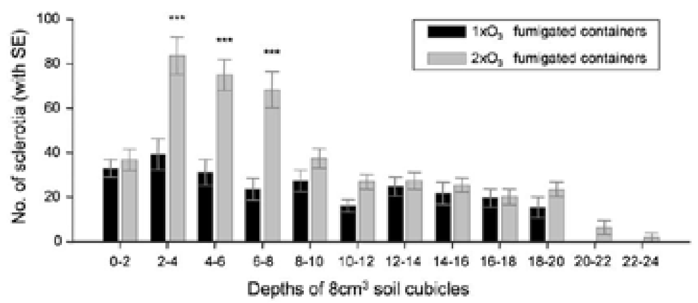
2. Development of ECM of spruce seedlings, planted into the studied sites (active monitors) (Vukovič 2003).

3. ECM or root growth parameters in tree seedlings, tested in an experimental set-up (*ex situ* testers of substrate pollution) (Al Sayegh Petkovšek 1997).

4. Fungal fruitbodies were tested as acumulative passive monitors of toxic elements in the environment (Al-Sayegh petkovšek & Pokorny 2011).



**Slika 1. Tip ektomikorize *Cenococcum geophilum* (tu na omoriki) je odporen na sušo in onesnaževala Posebnost je tvorba sklerocijev, ki tej ektomikorizi omogočajo preživetje v neugodnih pogojih v okolju in so tudi kazalec stresnih razmer na gozdnem rastišču.**
**// Figure 1. Type of ectomicorrhizae *Cenococcum geophilum* (here with *Picea omorika*) is drought and pollution resistant. Its special charactersitics is formation of sclerotia, which allow surviving of this ectomicorrhiaze in unfavorable environmental conditions and are also indicator of stress conditions at forest site.**




**Slika 2. Pojavljanje sklerocijev *Cenococcum geophilum* v kontejnerjih, zaplinjenih z ozonom (sivi stolpci) v primerjavi s kontrolo (črni stolpci) v Free Air Ozone Fumigation System v gozdu Kranzberg (podrobnejši opis je na www.casiroz.de)**
**// Figure 2. Occurrence of sclerotia of *Cenoccocum geophillum* in ozone fumigated containers (grey bars) compared to the control (black bars) in the Free Air Ozone Fumigation System in Kranzberg Forest (for description see www.casiroz.de)**

# KRATEK PREGLED GOZDNEGA GENETSKEGA MONITORINGA

## // INTRODUCTION TO FOREST GENETIC MONITORING

**Domen Finžgar, Marjana Westergren, Gregor Božič, Barbara Fussi, Phil Aravanopoulos, Fotis Kiourtsis, Živan Veselič, Monika Konnert, Hojka Kraigher**

**Čeprav so prvi koncepti gozdnega genetskega monitoringa (GGM) stari že več kot dve desetletji, je bila njihova implementacija težavna. Z razvojem modernih laboratorijskih metod je GGM postal finančno in časovno izvedljiv, kar raziskovalcem omogoča preizkus novih konceptov, razvoj obstoječih konceptov in upoštevanje genetskih podatkov pri preučevanju trajnosti našega gospodarjenja z gozdom. GGM je orodje, s katerim bomo gozdarji na osnovi stanja in sprememb v sestavi gozdnih genskih virov (GGV) bolje razumeli spremembe v sestojih in laže ter učinkoviteje gospodarili z gozdom. Z letom 2014 je Gozdarski inštitut Slovenije postal vodilni partner v izvedbenem projektu GGM z naslovom LIFEGENMON.**

**// The concepts of forest genetic monitoring (FGM), although present for more than two decades, are still being discussed and developed due to the lack of their implementations. Progress in laboratory methods made FGM financially feasible and less time consuming, allowing researchers to take into account the genetic data when assessing sustainability of forest management. In 2014, the Slovenian Forestry Institute became the leading partner in the FGM implementation project - LIFEGENMON. Destined to recognize the state and changes in the composition of forest genetic resources (FGR), FGM is a tool designed for foresters to better understand changes in forest stands and to help them in forest management.**

KADAR GOVORIMO O BIOTSKI PESTROSTI, NE SMEMO POZABITI NA NJEN TEMELJNI DEL – GENETSKO PESTROST.

WHEN WE TRY TO UNDERSTAND BIODIVERSITY, ITS FUNDAMENTAL ELEMENT, SPECIFICALLY GENETIC DIVERSITY, CANNOT BE OVERSEEN.

Genetsko pestre (GD) populacije imajo večji potencial, da se lahko bolje prilagodijo kakršnimkoli spremembam v okolju, kar zvišuje njihovo preživetveno sposobnost. Absolutno merjenje GP določenega organizma je nemogoče. Zato znanstveniki predlagajo različne sisteme kriterijev, kazalnikov in meril GP. S takšnimi sistemi lahko sklepamo o celotni GP na osnovi majhnega dela genetskih in demografskih podatkov ter s tem testiramo naše hipoteze. Kadar takšen sistem uporabimo večkrat, v kontinuiranih časovnih intervalih, govorimo o GGM.

GGM obravnavamo kot integralni del upravljanja z GGV. Prvi koncepti so nastali v sodelovanju strokovnjakov iz FAO, bili kasneje poenostavljeni s strani strokovnjakov EUFORGEN in na koncu še Ekspertne skupine »Genetski monitoring« znotraj Delovne skupine za GGV in Zakona o semenskem materialu zveznih dežel in države Nemčije (BLAG-FGR). Če izvzamemo pilotno študijo 'nemškega koncepta GGM', ki je bila opravljena na Bavarskem, do pisanja tega prispevka še noben koncept ni bil realiziran v praksi. Trenutno je GGM zastavljen kot

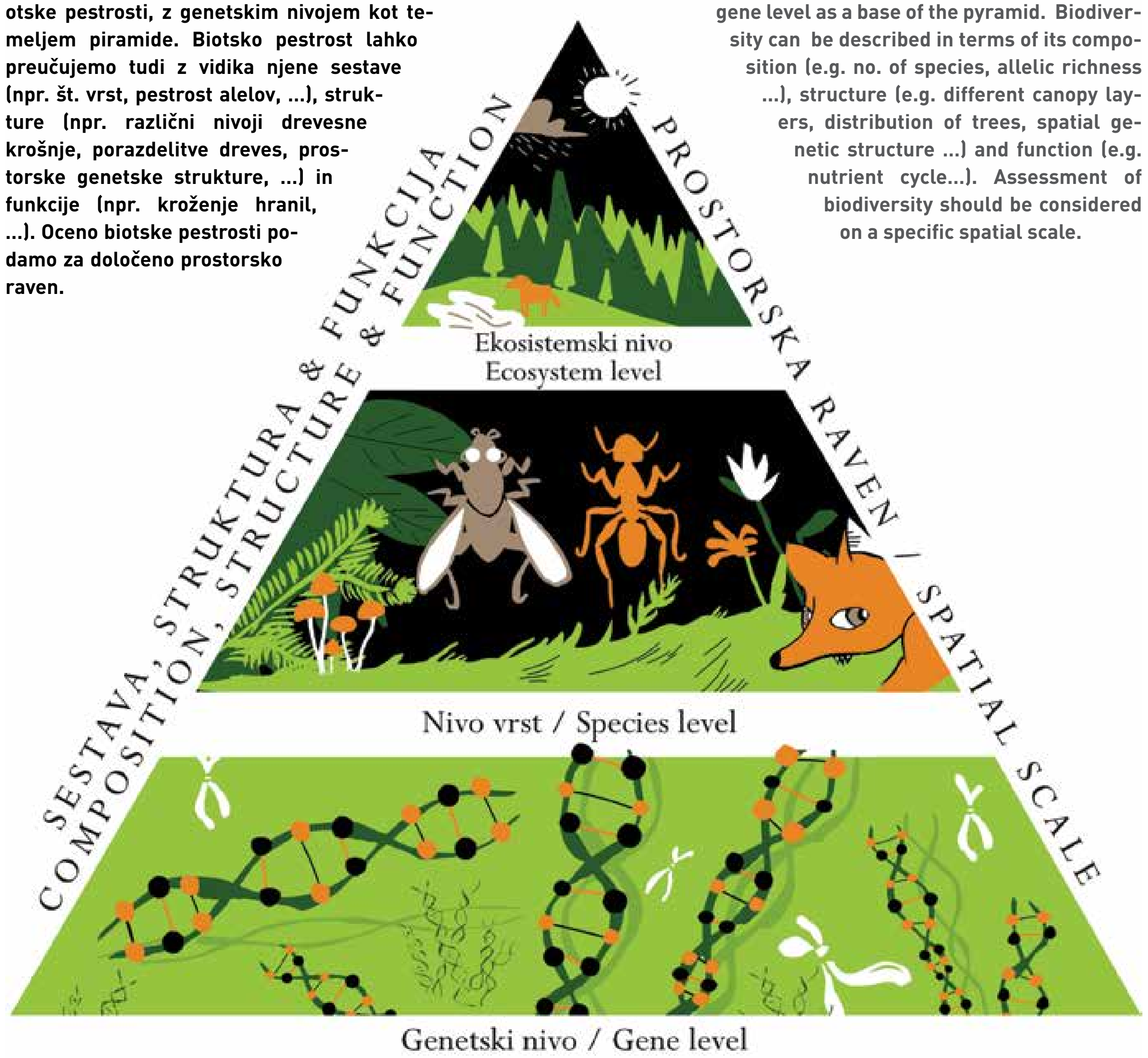
Genetically diverse (GD) forest populations can adapt more efficiently to the environmental changes, therefore increasing the survival rate of populations in the changing environment. To obtain the absolute value of GD of a given organism is an impossible task. Scientists therefore propose different criteria, indicators and verifiers to sample a portion of genetic data or its proxies to allow formation and testing of hypothesis regarding GD. When such research is done in time lapsed intervals, we are talking about FGM.

FGM is an integral part in the management of FGR and was first proposed by experts from FAO. It was later simplified by experts from EUFORGEN, and by the FGM expert group of the Federal and State Working-Group on FGR and Forest Seed Law (BLAG-FGR). With the exception of a pilot study of the Concept for the FGM in the Federal Republic of Germany, FGM has not been implemented in practice to date. Currently, FGM is conceptualized as a system of criteria, indicators and verifiers that can serve as an early warning sys-



**Slika 1: Piramidalna predstavitev nivojev biotske pestrosti, z genetskim nivojem kot temeljem piramide. Biotsko pestrost lahko preučujemo tudi z vidika njene sestave (npr. št. vrst, pestrost alelov, ...), strukture (npr. različni nivoji drevesne krošnje, porazdelitve dreves, prostorske genetske strukture, ...) in funkcije (npr. kroženje hranil, ...). Oceno biotske pestrosti podamo za določeno prostorsko raven.**

**// Fig 1: Organisation of biodiversity with the gene level as a base of the pyramid. Biodiversity can be described in terms of its composition (e.g. no. of species, allelic richness ...), structure (e.g. different canopy layers, distribution of trees, spatial genetic structure ...) and function (e.g. nutrient cycle...). Assessment of biodiversity should be considered on a specific spatial scale.**




zgodnji opozorilni sistem, ki bo pripomogel k ocenjevanju in napovedovanju dolgoročnega odziva drevesnih vrst na gospodarjenje z gozdom in na podnebne spremembe.

Pri tem je pomembno poudariti, da so vsi dosedanji koncepti obravnavali GGM kot orodje, pomagalo gozdnim načrtovalcem, gojiteljem in drugim gozdnim strokovnjakom pri njihovem delu. Ohranjanje GGV ni nikakršna ovira pri gospodarjenju z gozdom. Pomeni zgolj to, da morajo biti gozdnogospodarski ukrepi premišljeni iz vidika evolucijskih učinkov na GP izbrane drevesne vrste ali skupine več drevesnih vrst.

tem to aid the assessment of a species response to an environmental change at a long-term temporal scale.

It is particularly important to note that all of the FGM concepts so far, proposed FGM as a tool designed with forest managers in mind. Conservation of FGR does not mean exclusion of forest management. However, each management action must be thought through in terms of its evolutionary effect on genetic diversity of the selected tree species or groups of species.

Gozdarski inštitut Slovenije sodeluje v šestletnem projektu LIFE+ LIFEGENMON (LIFE for EUROPEAN FOREST GENETIC MONITORING SYSTEM) z namenom implementacije sistema GGM na transektu od Nemčije do Grčije. V projektu sodeluje šest partnerjev iz treh držav (Nemčije, Slovenije, Grčije). V projekt so vključeni tudi nacionalni koordinatorji (NFP – National Focal Point) držav med Nemčijo in Grčijo (Avstrija, Hrvaška, Srbija, Bosna in Hercegovina, Makedonija). Cilj projekta je prispevati k znanju o problemu dolgoročnega ohranjanja prilagoditvenega potenciala gozdov, v okviru cilja pa bodo naslednje naloge:

- Definirati optimalne kazalnike in merila za GGM za dve drevesni vrsti (*Fagus sylvatica* in kompleks *Abies alba*/*A. borisii regis*). V vsaki partnerski državi sta bili izbrani dve vzorčni GGM-ploskvi, z vizijo, da po koncu projekta postaneta 'dislociran razvojni center' GGM.
- Pripraviti smernice za GGM, izdati priročnik za GGM, modelni sistem za pomoč gozdarjem pri odločanju glede vzpostavitve GGM; organizirati delavnice in treninge za gozdarske strokovnjake. Pripraviti podlage smernic za odločanje na državni, regionalni in evropski ravni za podporo potencialnim prihodnjim spremembam v zakonodaji na državni ravni, v procesu FOREST EUROPE ter v prihajajočih evropskih politikah in strategijah na področju gozdarstva in ohranjanja biotske pestrosti.
- Razširjati informacije o GGM in trajnostnem gospodarjenju z gozdom.
- Vzpostaviti funkcionalne, mednarodno povezane ekipe gozdarskih strokovnjakov, ki bodo delovale na področju GGM.

Slovensko gozdarstvo s projektom LIFEGENMON ponovno pomembno sodeluje pri oblikovanju moderne, trajnostne in holistične vizije gozdarske stroke o kompleksnosti gozdnih ekosistemov.

A six-year LIFE+ LIFEGENMON project (LIFE for EUROPEAN FOREST GENETIC MONITORING SYSTEM) is intended to design, test and implement FGM on a transect from Germany to Greece, forming a regional implementation baseline for any future Pan-European forest genetic monitoring programme. The project involves six partners from three countries (Germany, Slovenia, Greece), while representatives of countries within the transect (Austria, Croatia, Serbia, Bosnia and Herzegovina, FYROM Macedonia) are included as expert National Focal Points. The overall objective is to contribute to the knowledge on the problem of long-term conservation of adaptability of forests to environmental change by:

- Defining optimal indicators and verifiers for monitoring of genetic diversity changes in time, based on two species (*Fagus sylvatica* and *Abies alba*/*A. borisii regis* complex). One plot per species was selected in each of the partner countries. These plots are also envisioned to become 'Dislocated Developmental Centres' for genetic monitoring, and kept active long after the end of the project.
- Preparing and publishing guidelines, a manual for FGM and a decision support system as well as practical training for foresters.Preparing background professional documents for policy makers for supporting the development of possible new regulations at the national level, the FOREST Europe process and future European Forestry and Biodiversity Conservation policies and strategies.
- Disseminating the information about FGM and sustainable forest management.
- Establishing a well-functioning internationally linked team of forestry professionals working in and for FGM.

With the LIFEGENMON project, Slovenian forestry is once again taking an important role in the way forest science envisions the complexity of forest ecosystems and their management. The FGM will contribute to the vision of holistic, sustainable approach to forestry.



# PRIHODNJI IZZIVI ZA SPREMLJANJE STANJA GOZDOV V SLOVENIJI

## // THE FUTURE CHALLENGES FOR FOREST MONITORING IN SLOVENIA

**Urša Vilhar, Dušan Jurc, Lado Kutnar, Hojka Kraigher, Daniel Žlindra, Primož Simončič**

**Potreba po primerljivih, dolgoletnih, visoko kakovostnih podatkih o stanju gozdnih ekosistemov, njihovih funkcijah oziroma ekosistemskih storitvah ter z njimi povezanih spremembah se povečuje na nacionalni in globalni ravni. Pretekla vlaganja v spremljanje stanja gozdov in zbrani podatki so dobra osnova za prihodnje potrebe, pod pogojem, da je vzpostavljena učinkovita komunikacija s končnimi uporabniki.**

**// The demand for comparable, long-term, high quality data on the status of forest ecosystems, their ecosystem services and the changes is increasing at the national and global levels. Previous investment in forest monitoring and data gathering is a strong basis for future needs, provided that effective communication with the end-users is established.**

V zadnjem desetletju smo s programom spremljanja stanja gozdov dobili učinkovito metodologijo za ekološko spremljanje in modeliranje procesov v gozdu ter za ugotavljanje učinkovitost različnih ukrepov gozdarske in okoljske politike.

Najbolj izjemen dosežek spremljanja stanja gozdov v Evropi je transnacionalni pristop, ki je bil dosežen s sprejetjem Konvencije o daljinskem transportu onesnaženega zraka prek meja (UN-ECE CLRTAP) v letu 1999. Že sredi 1980-ih, ko je bila Evropa še razdeljena na dva politična bloka, se je začelo usklajevanje metodologij. Rezultat je nastanek navodil ICP Forests (http://icp-forests.net/page/icp-forests-manual), ki vsebujejo najboljše v praksi preizkušene postopke, temelječe na znanstvenem razumevanju in usklajenem pristopu, dokumentiranju kakovosti podatkov in nenazadnje vse zbrane podatke in informacije. Transnacionalna mreža ploskev je vključno z njihovo namestitvijo in opremo izjemna pridobitev za evropske znanstvenike na področju gozdarstva, meteorologije, modeliranja, medicine in odločevalce. Zbrani podatki so na voljo tudi tretjim osebam in shranjeni v podatkovnih bazah ICP Forests, Evropskih koordinacijskih centrov za gozdna tla in foliarne vzorce ter Evropskega podatkovnega centra za gozdove (EFDAC). Hkrati so zbrani podatki pomembni za druga spremljanja, modeliranja in raziskave, na primer ICP IM, ICP M & M, EMEP, LTER-Europe, CarboEUROPE in ICOS.

Danes se spremljanje stanja gozdov v Sloveniji in v Evropi spopada s številnimi izzivi. Medtem ko zanj obstajata jasen interes in podpora raziskovalne skupnosti, so sočasno obsežno zmanjšanje finančnih sredstev, pomanj-

Over the past ten years, the forest monitoring programme has provided an effective methodology for ecological evaluation and modelling of forest processes as well as for investigating the effectiveness of a range of forestry and environmental policy measures.

The most outstanding achievement of the forest monitoring in Europe is transnational approach, which was achieved with adoption of the Long Rage Transboundary Air Pollution Convention (UN-ECE CLRTAP) in 1999. As early as in the mid-1980s, when Europe was still divided into two political blocks, the harmonization of methodologies was initiated, resulting in ICP Forests Manual (http://icp-forests.net/page/icp-forests-manual) with adopting best practice procedures based on scientific understanding and agreed approach, data quality documentation and, finally, data and information collected. The transnational network of monitoring plots, including their installation and equipment, is an outstanding asset for European scientists in forestry, meteorology, modelling, medicine and decision makers. Data collected are available also to third parties and stored in the ICP Forests database and the databases of the European Forest Soil and Foliar Coordinating Centres and the European Forest Data Centre (EFDAC) and are important for supporting other monitoring, modelling and research initiatives, for example ICP IM, ICP M&M, EMEP, LTER-Europe, CarboEUROPE and ICOS.

Today, forest monitoring in Slovenia and Europe is confronted with several challenges. While there is a clear interest and support by researchers, at the same time a severe reduction of financial resources, lack of appreciation and communication problems have led to kanje spoštovanja in komunikacijske težave privedli do nizkega pomena spremljanje stanja okolja na splošno s strani javnih agencij.

V prihodnosti se spremljanje stanja gozdov mora nadaljevati kot podpora nacionalnemu in mednarodnemu poročanju ter vrednotenju in uresničevanju načel trajnostnega upravljanja z gozdovi. Vendar pa se morajo ob vseskozi spreminjajočih se političnih tendencah spremembe kazati tudi v razvoju prilagodljivega spremljanja stanja gozdov z novimi prednostnimi nalogami. Spremljanje stanja gozdov mora okrepiti spremljanje vplivov: i. onesnaževanja zraka, ii. podnebne spremenljivosti in velikopovršinskih motenj, iii. genetske pestrosti, iv. funkcij oziroma ekosistemskih storitev gozdov, npr. biotska pestrost, ponori ogljika in zagotavljanje čistega zraka in vode.

**ONESNAŽEVANJE ZRAKA**

Vse od implementacije UN-ECE CLRTAP so se emisije žvepla po vsej Evropi, vključno s Slovenijo, bistveno zmanjšale. Vendar pa so se zaradi povečanega prometa z vozili dušikove emisije v reduciranih in oksidiranih oblikah le malo zmanjšale. Poleg tega so te snovi predhodniki tvorbe ozona, zelo oksidacijskega plina, ki je škodljiv za rastline, živali in ljudi. Zato učinki onesnaževanja zraka na gozdove ostajajo pereča problematika prihodnjih let v Sloveniji, še posebej v gozdovih blizu urbaniziranih območjih. Poleg tega obstaja v okviru spremljanja stanja gozdnih ekosistemov velik potencial za širitev seznama spremljanih parametrov, kot so novi kemični onesnaževalci (npr. obstojna organska onesnaževala (angl. POP's), težke kovine itd.).

**PODNEBNA SPREMENLJIVOST IN VELIKOPOVRŠINSKE MOTNJE V GOZDOVIH**

Spremljanje stanja gozdov lahko zagotovi koristne informacije o procesnih spremembah in vplivih podnebne spremenljivosti na gozdove, kar je pomembno pri razvoju prilagoditvenih strategij za trajnostno gospodarjenje z gozdovi. V zadnjih desetletjih se je v srednji in južni Evropi močno povečala pogostost ekstremnih vremenskih dogodkov, kot so viharji, žledolomi, vročinski vali in suše, na kar zavarovalniška industrija že dolgo opozarja.

Slovenija leži v prehodnem podnebnem območju med Sredozemskim morjem, Alpami, Dinarskim gorstvom in Panonsko kotlino. Posledično je njeno podnebje zelo lokalno raznoliko v dokaj velikem razponu. Po predvidevanjih bodo poletja v Sloveniji postala toplejša in sušnejša s pogostejšimi hudimi sušami. Požarna ogroženost, dolžina obdobja s povišano požarno ogroženostjo ter obseg požarov naj bi se povečali predvsem v submediteranski ekoregiji. Zime naj bi postale bolj mile, nevarnost poplav večja. Pogostnost in intenziteta nalivov s točo ter žledu v Sloveniji sta med najvišjimi v Evropi, pri čemer

low priorisation for environmental monitoring in general by the funding agencies.

As we look forward, the forest monitoring must continue to support national and international reporting and the evaluation and application of sustainable forest management principles. However, as the emphasis of policy drivers is continuously changing, the evolution into adaptive forest monitoring should well reflect these new priorities. Forest monitoring should enhance the study of the impacts of: i. air pollution, ii. climate change and large-scale disturbances, iii. genetic diversity, iv. ecosystem services of forests, e.g. biodiversity, carbon sequestration and clean air and water production.

**AIR POLLUTION**

Since the implementation of the UN-ECE CLRTAP in 1979, sulphur emissions across Europe including Slovenia have fallen significantly. However, with the increase in vehicle traffic nitrogen emissions in reduced and oxidised forms have been reduced only slightly. Furthermore, those substances are precursors for ozone, a very oxidizing gas, which is harmful for plants, animals and humans. Therefore, the effects of air pollution on forests will remain an issue of concern in the forthcoming years in Slovenia, especially in forests close to urbanized areas. In addition, forest monitoring has a big potential to expand the list of monitored parameters, such as emerging chemical contaminants (e.g. Persistent Organic Pollutants, heavy metals, etc.).

**CLIMATE CHANGE AND LARGE-SCALE DISTURBANCES IN FORESTS**

Forest monitoring can provide valuable information into processes and climate change impacts on forests in guiding the development of adaptation strategies for sustainable forest management. In the last decades, the frequency of extreme weather events such as rain- and ice storms, heatwaves and droughts have significantly increased in Central and Southern Europe, and the insurance industry has long been warning us about these trends.

Slovenia is a transitional climate area between the Mediterranean Sea, the Alps, the Dinaric Mountains and the Pannonian Basin. As a consequence, its climate displays wide local climatic variability and fairly large gradients. The climate in Slovenia is predicted to become warmer and drier in the summer, with more frequent and severe droughts. Fire danger, length of the fire season and fire frequency and severity are expected to increase in the sub-Mediterranean ecoregion. Winters are expected to become milder and wetter, increasing the risk of flooding. The frequency and intensity of windstorms, hailstorms and ice storms in Slovenia is one of



lahko v enem padavinskem dogodku pade več kot 100 mm padavin v eni uri.

the highest in Europe, during which more than 100 mm of precipitation may fall within one hour.

**Slika 1: Pozimi 2014 je bilo na Notranjskem (Slovenija) poškodovanih približno pol milijona hektarov gozdov, 3.000.000 $m^3$ lesa podrtega, ocenjena škoda pa je dosegla 430 milijone evrov. (Foto: Iztok Sinjur)**
**// Figure 1. In winter 2014, forest area of around half a million hectares in the Notranjska region was entirely damaged; 3,000,000 $m^3$ of wood mass were on the ground, with estimated total damage reaching 430 million € (Foto: Iztok Sinjur)**

**Slika 2: Požarna ogroženost ter pogostnost in obseg požarov se bosta v submediteranskem delu Slovenije povečevala. (Foto: Saša Vochl)**
**// Figure 2. Fire danger, length of the fire season and fire frequency and severity are expected to increase in the sub-Mediterranean ecoregion of Slovenia. (Photo: Saša Vochl)**

**Slika 3. V vetrolomu na prelazu Črnivec blizu Kamnika v letu 2008 je bilo poškodovanih 14.400 ha gozda, pri čemer je bilo zaradi poškodb odstranjenih 400.000 $m^3$ lesa. (Foto: Lado Kutnar)**
**// Figure 3. During the windthrow on Črnivec mountain pass near Kamnik in 2008, 14,400 ha of forest area were damaged and 400,000 $m^3$ of wood mass had to be removed. (Photo: Lado Kutnar)**

**GOZDNI GENETSKI MONITORING**

Genetska pestrost predstavlja temeljni del biotske pestrosti. Drevesnim vrstam omogoča prilagoditveni potencial v spreminjajočem se okolju in jim s tem pomaga preživeti. Stanje in spremembe v gozdnih genskih virih lahko spremljamo z gozdnim genetskim monitoringom. Z njim upoštevamo genetski vidik trajnostnega gospodarjenja z gozdom in tako zagotavljamo vse funkcije gozdov prihodnjim generacijam.

**FOREST GENETIC MONITORING**

Genetic diversity is the basic component of biodiversity. It ensures the adaptive potential of a species, helping it to survive in a changing environment. Forest genetic monitoring is a tool, destined to recognize the state and changes in forest genetic resources composition. It takes into account the genetic principles of sustainable forest management, in order to deliver all the benefits of forests to future generations.

**GOZDNI ŠKODLJIVCI, BOLEZNI IN INVAZIVNE TUJERODNE VRSTE**

Povečevanje globalne trgovine vpliva na povečan vnos invazivnih tujerodnih vrst, patogenov in škodljivcev, ter na povišanje stroškov, povezanih s preprečevanjem vnosa in upravljanjem z že vnesenimi organizmi v gozdove. Segrevanja podnebja že povzroča spremembe v življenjskem ciklu in razširjenosti sredozemskih škodljivcev in bolezni, ki se širijo proti severu. Posledice teh sprememb so zmanjševanje produktivnosti, povečana erozija tal, zmanjšanje kakovosti vode, zmanjšano nosilna sposobnost za divjad, znižana rekreacijska privlačnost ter izgube avtohtonih vrst v gozdnih ekosistemih. Zgodnje odkrivanje novih škodljivih organizmov in invazivnih tujerodnih vrst je izjemnega pomena, saj omogoča njihovo izkoreninjenje.

Nove vnose lahko odkrivamo le s stalnim spremljanjem celotnega gozdnatega območja, osredotočeno na škodljive dejavnike. Ocenjevanje vzrokov poškodb je sestavni del navodil ICP Forests, s čimer je podan pregled škodljivcev, bolezni in škodljivih abiotskih dejavnikov, zbranih na nacionalni in evropski ravni. V Sloveniji so bila navodila prilagojena, tako da vključujejo vse pomembne karantenske organizme, ki še niso bili vneseni v Slovenijo. Evropski fitosanitarni sistem ima veliko pomanjkljivosti in je v procesu izboljšave z novo zakonodajo. Spremljanje osutosti in poškodovanosti krošenj ter ugotavljanje vzrokov poškodb je lahko dragocen vir podatkov za fitosanitarno upravo, ki bi se lahko uporabili v postopkih odločanja glede eradikacije ali ublažitve vnosa invazivnih tujerodnih vrst.

**FOREST PESTS, DISEASES AND INVASIVE ALIEN SPECIES**

Expanding global trade increases both the introduction of invasive alien species, pathogens and pests, and the costs associated with preventing the introduction and managing new infestations in forests. Climate warming already causes shifts in life cycles and distribution of Mediterranean pests and diseases, which are expanding northwards. The consequences of these changes are diminished productivity, increased soil erosion, decreased water quality, decreased carrying capacity for wildlife, lowered recreational value, and loss of native species in forest ecosystems. Early detection of new pests and invasive alien species is of utmost importance since it makes their eradication possible.

Detection of new introductions can be achieved only with constant monitoring of a whole forested area, focused on damaging agents. In the ICP Forests Manual, assessment of damage causes is included and thus data on pests, diseases and harmful abiotic agents are collected on the national and European levels. In Slovenia, the Manual was adapted to include all important quarantine organisms, which have not yet been introduced to Slovenia. The European phytosanitary system has many deficiencies and is in the process of improvement with new legislature. Monitoring of crown damages and identification of their causes could be a valuable source of the data needed by phytosanitary administration and could be used in decision making processes concerning eradication or mitigation of invasive alien species.

**Slika 4: Pooglenitev hrastov (*Biscogniaxia mediterranea* (De Not.) Kuntze) se pojavlja v Mediteranu, hkrati pa je bila opažena na severu, daleč od svoje prvotne razširjenosti. (Foto: Dušan Jurc)**
**// Figure 4: Charcoal disease of oak (*Biscogniaxia mediterranea* (De Not.) Kuntze) occurs in Mediterranean area and was detected far to the north from its previous distribution. (Photo: Dušan Jurc)**

Dinamiko širjenja invazivnih tujerodnih vrst, ki negativno vplivajo na gozdne habitate (regije) in izpodrivajo avtohtone rastlinske vrste ter vplivajo na različne funkcije oziroma ekosistemske storitve gozdov, je treba spremljati ves čas. V bližnji prihodnosti bo potrebna tudi vzpostavitev ukrepov za njihovo omejevanje. Potrebna bi bila večja vpletenost na področju upravljanja z gozdovi in gozdnogojitvenih ukrepov za upravljanje z invazivnimi vrstami, ki že ovirajo razvoj gozdov (na primer naravno pomlajevanje), zlasti v nižinskih poplavnih in obrežnih gozdovih.

The dynamic of expansion of invasive alien species, which adversely affect the forest habitats (regions) and outcompete native plant species, and affect different forest ecosystem services, should be monitored, and appropriate measures for its limitation need to be established in the near future. More forest management and silvicultural activities should be engaged with regard to the invasive species that already disturb forest development (e.g. forest natural regeneration), especially alluvial and riparian forests in lowlands.



**Slika 5. Deljenolistna rudbekija (*Rudbeckia laciniata* L.) je domorodna vrsta vzhodnega dela Severne Amerike ter invazivna tujerodna vrsta v Evropi, ki uspeva predvsem v poplavnih ravnicah na vlažnih tleh. V sestojnih vrzelih in na gozdnem robu nižinskih gozdov tvori gosto pritalno plast. (Foto: Lado Kutnar)**
**// Figure 5: Cutleaf coneflower (*Rudbeckia laciniata* L.) is a species native to eastern North America and invasive alien species in Europe, most often found in flood plains and moist soils. It forms dense cover in forest gaps and forest edges of lowland forests. (Photo: Lado Kutnar)**

**Slika 6: *Fallopia japonica* (Hout.) R. Decr. se hitro širi ter zaradi goste pritalne plasti izriva domače rastlinske vrste. Najbolj ogroža obrečna rastišča, saj preživi obdobja poplav in hitro naseljuje opustošene rečne brežine in otoke. Potem ko se na določenem območju razširi, je izjemno obstojna rastlina. (Foto: Lado Kutnar)**
**// Figure 6: *Fallopia japonica* (Hout.) R. Decr. spreads quickly to form dense thickets and drives out native plant species. Knotweed poses a significant threat to riparian areas where it can survive flooding events and rapidly colonize scoured shores and islands. Once established, populations are extremely persistent. (Photo: Lado Kutnar)**

**EKOSISTEMSKE STORITVE**

Gozdovi pokrivajo več kot 60 % površine v Sloveniji in sestavljajo enega bistvenih gradnikov okolja te dežele, tako z varovalnega kot tudi socialnega vidika. Gospodarjenje z gozdovi v Sloveniji temelji na paradigmah trajnosti, sonaravnosti in večnamenskosti, ki so bili vpeljani v okviru hierarhično organiziranega sistema gozdnogospodarskih načrtov. Javnost na splošno priznava velik pomen funkcij oziroma ekosistemskih storitev, ki jih zagotavljajo gozdovi, čeprav nimajo vse ekosistemske storitve gozdov enakega pomena. Poleg proizvodnje lesa imajo velik pomen podporne ekosistemske storitve (npr. habitat za rastlinske in živalske vrste) in uravnavanje (npr. zagotavljanje čistega zraka in vode) gozdov.

Ploskve za spremljanje stanja gozdov ležijo v gospodarjenih gozdovih, ki so prevladujoči gozdni tipi v Sloveniji. Dolgoročno spremljanje njihovega stanja omogoča oceno sprememb biotske raznovrstnosti v povezavi z okoljskimi dejavniki in gospodarjenjem z gozdovi. Posebna prednost je razpoložljivost natančnih fizikalnih in kemijskih podatkov o procesih ozračje-vegetacija-tla, ki lahko pripomorejo k pojasnjevanju vzrokov morebitnih zabeleženih sprememb v stanju habitatov.

**ECOSYSTEM SERVICES**

By covering more than 60% of the land, forests are an essential feature and a constituent of Slovenia's environment, apart from having a high protective and social significance. Forest management in Slovenia is based on the paradigms of sustainability, close-to-nature management and multifunctionality, all of which have been implemented through the hierarchically organized system of forest management plans. Public in general acknowledges the high benefits of ecosystem services provided by forests, though not all forest ecosystem services hold the same importance. Apart from wood production, high importance is placed on supporting (e.g. habitat for animal and plant species) and regulating (e.g. clean air and water production) services in forests.

Forest monitoring plots are located in managed forests, which are widely represented forest ecosystems in Slovenia. Long-term monitoring allows us to assess changes in biodiversity in relation to environmental factors and forest management. The particular advantage is the availability of detailed physical and chemical data on atmospheric-vegetation-soil processes that can help to explain the cause of any recorded changes in habitat condition.

Pomembno je, da lahko količinsko ovrednotimo zaloge ogljika in stopnjo izmenjave ogljika, s čimer ocenimo neto ponor in shranjevanje ogljika za katerikoli scenarij gospodarjenja z gozdovi. Ta proces »verifikacije« je pomembno načelo poročanja o ponoru ogljika v okviru Kjotskega protokola in v Sloveniji, pri čemer so ploskve intenzivnega spremljanja stanja gozdnih ekosistemov del tega procesa.

**PRIHODNJI IZZIVI**

Kot smo se naučili iz preteklih aktivnosti, lahko prilagodljivo spremljanje stanja gozdov opravljamo učinkovito le s transnacionalnim pristopom, ki omogoča prenos znanj. Zaradi globalne razsežnosti izzivov, s katerimi se spopada trajnostno gospodarjenje z gozdovi, sta potrebni koalicija deležnikov in boljša gozdarska politika na nacionalni, EU in mednarodni ravni.

Treba je spodbujati in izvajati integracijo spremljanja stanja gozdov z daljinskim zaznavanjem, inventurami, ekološkimi raziskavami, modeliranjem, *in-situ* raziskavami ter s posredovanjem podatkov na internetu. Treba je izboljšati kakovost podatkov ter poročanje, vključno s hitrejšo razpoložljivostjo in poročanjem nekaterih vrst podatkov o spremljanju stanja gozdov, da bi povečali njegovo pomembnost v hitro spreminjajočem se političnem okolju.

Dolgoročna opazovanja različnih delov gozdnih ekosistemov in možnost uresničevanja različnih mednarodno usklajenih tehnik in pristopov, ki morda niso visokotehnološke narave, temveč kratki projekti, so zelo koristna za ugotavljanje procesov v ekosistemu. Spremembe zalog ogljika po delih v skladu s Kjotskim protokolom, vzporedno s podnebnimi meritvami, so ena izmed najboljših in-situ virov informacij o procesih. S povezovanjem takih dolgoletnih ploskev za spremljanje stanja gozdnih ekosistemov in raziskovalne dejavnosti z dodatnimi specializiranimi meritvami lahko pridobimo bolj zanesljivo sliko o lokalnih procesih v gozdu, gozdnih tleh in interakcijami med deli gozdnega ekosistema. Ploskve za spremljanje stanja gozdnih ekosistemov bi morale biti na voljo vsem zainteresiranim interdisciplinarnim raziskovalnim skupnostim, z namenom doseganja sinergije med disciplinami za bolj poglobljene in celostne raziskovalne rezultate.

V okviru spremljanja vegetacije so korenine redko obravnavane, standardni postopki na evropski ravni pa še niso bili razviti. Vključiti bi bilo treba tudi raziskave o talnih organizmih, pticah in drugih živali, prav tako tudi sladkovodno in podzemno hidrologijo ter kemijo. Monitoring genetske pestrosti gozdnega drevja kot osnovne sestavine biotske pestrosti in temeljni pogoj za dolgoročno ohranjanje prilagodljivosti gozdnih ekosistemov na spreminjajoče se okolje se je pričel z namenom prihodnjega izvajanja na nacionalni, regionalni in vseevropski ravni. Vzpostaviti je treba hitro in zanesljivo spremljanje poškodb v gozdovih, ki bi lahko delovalo kot ukrep prilagajanja za spopadanje s posledicami podnebne spremenljivosti na gozdove, ki so pomembni za vse zainteresirane deležnike v gozdarskem sektorju, kot so javni organi na področju gozdarstva, lastniki gozdov, gozdarska podjetja in zavarovalnice, oblikovalci politik, organi EU itd., z namenom zagotavljanja pomembnega prispevka za prenos morebitnih ukrepov prilagajanja na raven uporabnika.

In nenazadnje, oblikovati je treba ustrezno komunikacijsko strategijo za pridobitev stalne podpore zainteresiranih deležnikov. Inovativni koncepti, katerih cilj je izboljšanje učinkovitosti in znižanje stroškov spremljanje stanja okolja, ki vključujejo lokalne skupnosti s podporo opazovalnic aktivnih državljanov (angleško »citizen observatories«), bi lahko prispevali k večji ozaveščenosti javnosti o okoljskih tveganjih za gozdove in za funkcije oziroma ekosistemske storitve, ki jih zagotavljajo družbi.

It is important to be able to quantify both carbon stocks and rates of carbon exchange in order to estimate net uptake and storage of carbon for any given forest management scenario. This process of »verification« is an important tenet of carbon stock and stock exchange reporting under the Kyoto Protocol and in Slovenia, and forest monitoring plots are part of the process.

**FUTURE CHALLENGES**

As we learned from past activities, adaptive forest monitoring can only be fulfilled efficiently by a transnational approach, where expertize is shared. Due to global dimensions of challenges, facing sustainable forest management, a coalition of stakeholders is needed and better forest policy making at the national, EU and international levels.

Integration of monitoring with remote sensing, inventories, ecological research, modelling, *in-situ* experiments and internet delivery needs to be promoted and implemented. Data quality and reporting should be improved, including speeding up the availability and reporting of some types of forest monitoring data in order to increase its relevance to the fast moving policy environment.

Long-term observations of different forest ecosystem compartments and the possibility of using different internationally harmonized technics and approaches which are not possible in high tech ranking but short terms projects are extremely useful to assess ecosystem processes. Changes in carbon stocks by the Kyoto Protocol pools in parallel with climate measurements are one of the best *in situ* sources of information about processes. By linking such long-lasting forest monitoring plots and research activities with additional specialised measurements, a more reliable picture about local processes within forests, forest soils and interactions between compartments can be achieved. Forest monitoring plots should be available to all interested interdisciplinary research communities to reach synergy between disciplines for better/in-depth research goals/results.

For vegetation monitoring, root compartment is rarely considered and no standard procedures at the European level have been developed yet. Surveys for forest genetic resources, soil biota, birds and other animals should be foreseen and freshwater and groundwater hydrology and chemistry considered. Monitoring of genetic diversity of forest trees, as the basic constituent of biodiversity and the fundamental requirement for long-term conservation of adaptability of forest ecosystems to the changing environments, has started with a view for future implementation at the national, regional and Pan-European scale. Fast and reliable forest damage monitoring should be established that could act as an adaptation measure to address climate change impacts on forests, relevant for all stakeholders in the forestry sector such as public forestry bodies, forest owners, forestry and insurance companies, policy-makers, EU bodies, etc., to provide a significant contribution to transfer potential adaptation measures to the user level.

And finally, a proper communication strategy is necessary to obtain continuous support from stakeholders. The innovative concepts aiming at improved efficiency and cost effectiveness of environmental monitoring involving local communities with the support of citizen observatories could contribute to increased public awareness of environmental risks to forests and ecosystem services they provide to the society.

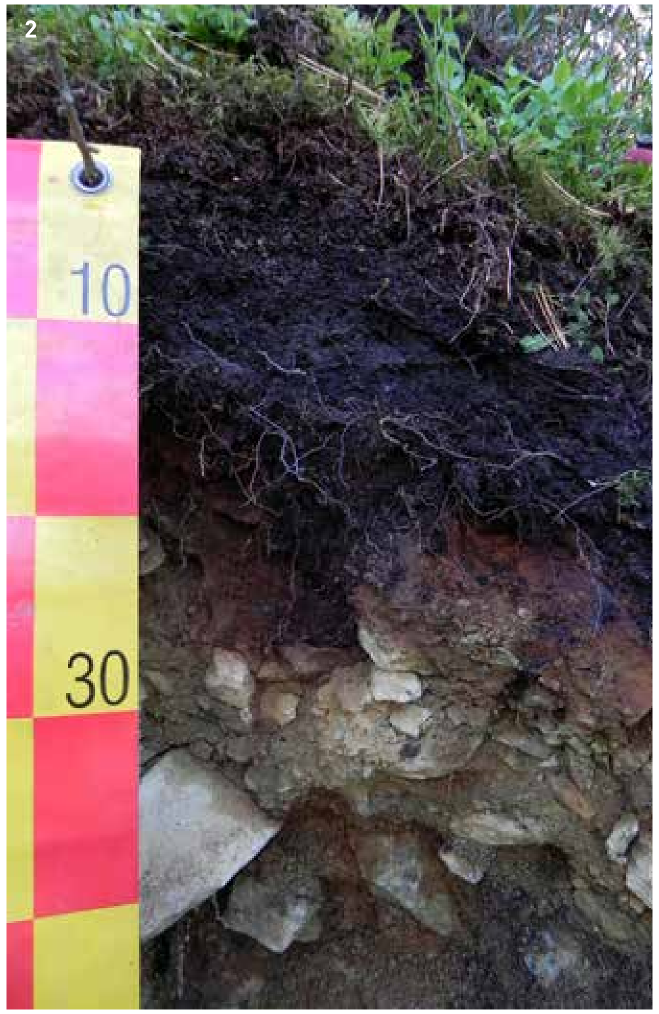




**Foto 1,2: Iztok Sinjur**
**// Photo 1,2: Iztok Sinjur**


**Foto 3: Iztok Sinjur**
**// Photo 3: Iztok Sinjur**

CIP - KatFložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

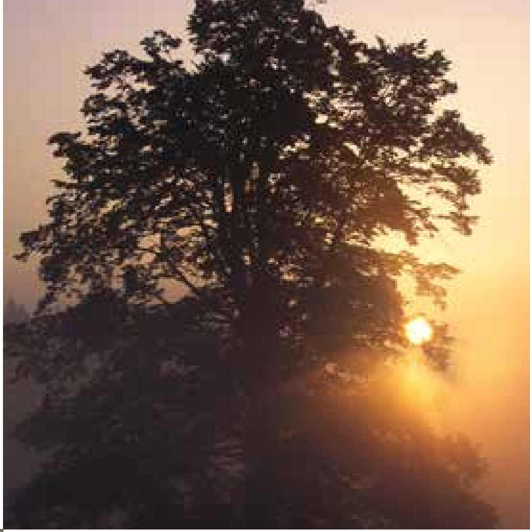
630*58(497.4)(082)

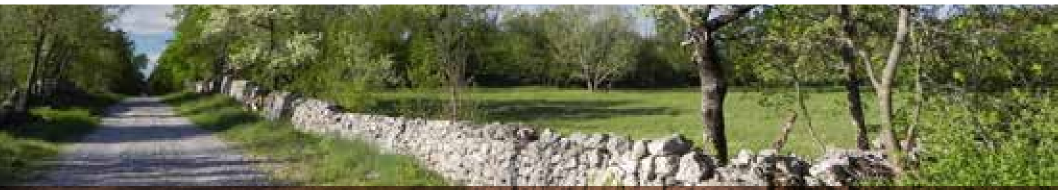
TRIDESET
30 let spremljanja stanja gozdov v Sloveniji = 30 years of forest monitoring in Slovenia / [glavna urednika Urša Vilhar, Daniel Žlindra]. - 2., dopolnjena izd. = 2nd revised ed. - Ljubljana : Gozdarski inštitut Slovenije, Založba Silva Slovenica = Slovenian Forestry Institute, The Silva Slovenica Publishing Centre, 2017. - (Studia forestalia Slovenica, ISSN 0353-6025 ; 156) ISBN 978-961-6993-24-1 1. Vilhar, Urša, 1977- 290284800

## VIRI
## // REFERENCES


- Al Sayegh Petkovšek, S. (1997). Mycorrhizal potential of two differently polluted forest sites in the emission region of the Thermal Power Plant Šoštanj. Zbornik gozdarstva in lesarstva, 52, 323–350.
- Al Sayegh-Petkovšek, S., Pokorny, B. (2011). Obremenjenost trosnjakov užitnih vrst gliv iz Šaleške in Zgornje Mežiške doline z izbranimi kovinami (Cd, Hg, Pb, As), s poudarkom na oceni tveganja za prehranjevanje ljudi. Zbornik gozdarstva in lesarstva, 94, 21-38.
- Aravanopoulos FA, Tollefsrud MM, Kätzel R, Soto de Viana A, Graudal L, Nagy L, Koskela J, Bozzano M, Pilipovic A, Zhelev P, Bozic G. 2014. Development of genetic monitoring methods for genetic conservation units of forest trees. EUFORGEN Working Group on Genetic Monitoring, Draft Report November 2013 - Bioversity, Rome, Italy.
- Arndt, U., Nobel, W., & Schweizer, B. (1987). Bioindikatoren- Möglichkeiten, Grenzen und neue Erkentnisse. Stuttgart: Ulmer.
- Arnolds, E. (1988). The changing macromycete flora of the Netherlands. Transactions of the British Mycological Society, 90, 391–406.
- Arnolds, E. (1991). Decline of ectomycorrhizal fungi in Europe. Agriculture, Ecosystems and Environment, 35, 209–244.
- Barbante E, Calvo E, Sanesi G, Selleri B, Verlič A, Vilhar U EDS. (2014). Urban and periurban forests: management, monitoring and ecosystem services. Emonfur Life+ project experiences. pp. 279.
- Bouten W. and Jansson P.-E., 1995; De Vries W. et al., 2001; Federer C. A. et al., 2003; Van der Salm C. et al., 2004; Vilhar U. et al., 2010
- Bouten W., Jansson P.-E. 1995. Water balance of the Solling spruce stand as simulated with various forest-soil-atmosphere models. Ecological Modelling, 83, 1-2: 245-253
- Council Regulation (EEC) No 3528/86 of 17 November 1986 on the protection of the Community's forests against atmospheric pollution. Official Journal L 326 , 21/11/1986 P. 0002 - 0004 (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31986R3528)
- Council Regulation (EEC) No 2158/92 of 23 July 1992 on protection of the Community's forests against fire. Official Journal L 217 , 31/07/1992 P. 0003 - 0007. (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992R2158)
- Cudlin P., Grebenc, T., Kraigher, H. *et al* (2007) Fine roots and ectomycorrhizas as indicators of environmental change. *Plant Biosystems,* 141 (3) 406-425.
- Dakskobler, I., Kutnar, L., Šilc, U., 2013. Poplavni, močvirni in obrežni gozdovi v Sloveniji: Gozdovi vrb, jelš, dolgopecljatega bresta, velikega in ozkolistnega jesena, doba in rdečega bora ob rekah in potokih. (Floodplain woods, swamp woods and riverine forests in Slovenia: Forests of willows, alders, white elm, European and narrow-leaved ash, pedunculate oak and Scots pine along rivers and streams). Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije: Zveza gozdarskih društev Slovenije - Gozdarska založba, 127 s.
- Dakskobler, I., Kutnar, L., Šilc, U., 2013. Poplavni, močvirni in obrežni gozdovi v Sloveniji: Floodplain woods, swamp woods and riverine forests in Slovenia: Forests of willows, alders, white elm, European and narrow-leaved ash, pedunculate oak and Scots pine along rivers and streams. Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije: Zveza gozdarskih društev Slovenije - Gozdarska založba, 127 p. (in Slovenian with English abstract).
- Federer C. A., Vorosmarthy C., Fekete B. 2003. Sensitivity of Annual Evaporation to Soil and Root Properties in Two Models of Contrasting Complexity. Journal of Hydrometeorology, 4, 6: 1276-1290
- Fellner, R. (1989). Mycorrhiza-forming fungi as bioindicators of air pollution. Agriculture, Ecosystems and Environment, 28, 115–120.
- Fellner, R, & Peškova, V. (1995). Effects of industrial pollutants on ectomycorrhizal relationships in temperate forest. Canadian Journal of Botany, 73(Suppl. 1), 1310–1315.
- Ferretti M. and Fischer R. 2013. Forest Monitoring, Methods for terrestrial investigations in Europe with an overview of North America and Asia. 1st Edition. Elsevier, 536 pp.
- Hočevar, M., Mavsar R., Kovač M. 2002. Forest Condition in Slovenia in the Year 2000. Zbornik gozdarstva in lesarstva (67): 119-157.
- ICP Forests 2015: ICP Forest home page. (http://icp-forests.net/page/political-background)
- Jaenike, J. (1991). Mass extinction of European fungi. Tree, 6, 174–175.
- Jogan, N., Eler, K., Novak, Š., 2012. Priročnik za sistematično kartiranje invazivnih tujerodnih rastlinskih vrst. Zavod Symbiosis, Nova vas, 51 s.
- Jurc D., Ogris N. 2006. First reported outbreak of charcoal disease caused by *Biscogniauxia mediterranea* on Turky oak in Slovenia. Plant Pathology, vol. 55, no. 2, 299.
- Kalan J., Kalan P. 1997. Razvoj in pomen pedološkega laboratorija na Gozdarskem inštitutu Slovenije. V: Znanje za gozd. Zbornik ob 50. obletnici obstoja in delovanja Gozdarskega inštituta Slovenije. Ljubljana: 55-60.
- Konvencija 1979. 1979 Convention on Long-range Transboundary Air Pollution. UN/ECE. (http://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/1979.CLRTAP.e.pdf)
- Konnert M, Maurer W, Degen B, Kätzel R. 2011. Genetic monitoring in forests – early warning and controlling system for ecosystemic changes. iForest, 4: 77-81 doi: 10.3832/ifor0571-004
- Koskela J, Lefèvre F, Schueler S, Kraigher H, Olrik DC, Hubert J, Longauer R, Bozzano M, Yrjänä L, Alizoti P, Rotach P, Vietto L, Bordács S, Myking T, Eysteinsson T, Souvannavong O, Fady B, Cuyper B de, Heinze B, Wühlisch G von, Ducousso A, Ditlevsen B. 2013. Translating conservation genetics into management: Pan-European minimum requirements for dynamic conservation units of forest tree genetic diversity. Biological Conservation, 157: 39-49 doi: 10.1016/j.biocon.2012.07.023
- Kovač, M. 1997. The previous concepts as to forest decline and new ideas regarding integral ecological monitoring. Zbornik gozdarstva in lesarstva (52):23-52.
- Kovač M., Skudnik M., Japelj A., Planinšek Š., Vochl S., Batič F., Kastelec D., Jurc D., Jurc M., Simončič P., Kobal M. 2014. Monitoring gozdov in gozdnih ekosistemov: priročnik za terensko snemanje podatkov, Studia forestalia Slovenica, 140. Ljubljana: Gozdarski inštitut Slovenije, Založba Silva Slovenica, 228 str.
- Kraigher, H. (1999). Diversity of types of Ectomycorrhizae on Norway spruce in Slovenia. Phyton (Horn, Austria), 39, 199–202.
- Kraigher, H., Batič, F., & Agerer, R. (1996). Types of ectomycorrhizae and mycobioindication of forest site pollution. Phyton (Horn, Austria), 36, 115–120.
- Kraigher, H., Al Sayegh-Petkovšek, S., Grebenc, T., Simončič, P. (2007) Types of ectomycorrhiza as pollution stress indicators : case studies in Slovenia. *Environmental monitoring and assessment,* 128 (1) 31-45
- Kraigher, H., Al Sayegh-Petkovšek, S. (2011) Mycobioindication of stress in forest ecosystems. In: Rai, Mahendra, Varma, Ajit (Eds). *Diversity and biotechnology of ectomycorrhizae,* (Soil biology, ISSN 1613-3382, vol. 25). Heidelberg; New York: Springer, pp. 301-322.
- Kutnar, L., Pisek, R., 2013. Non-native and invasive tree species in the Slovenian forests. Gozdarski vestnik, 71 (9): 402-417. (in Slovenian with English summary).
- Kutnar L., Kobler A. 2011. Prediction of forest vegetation shift due to different climate-change scenarios in Slovenia. Šumarski list, 135, 3/4: 113-126
- Kutnar, L., Pisek, R., 2013. Tujerodne in invazivne drevesne vrste v gozdovih Slovenije (Non-native and invasive tree species in the Slovenian forests). Gozdarski vestnik, 71 (9): 402-417.
- Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. [http://www.icp--forests.org/Manual.htm]
- Mavsar R., Japelj A., Kovač M. 2012. Trade-offs between fire prevention and provision of ecosystem services in Slovenia. Forest Policy and Economics, 29, 62–69
- Pravilnik o varstvu gozdov 2009. Uradni list RS, št. 114/2009 z dne 31. 12. 2009.
- Regulation (EC) No 2152/2003 of the European Parliament and of the Council of 17 November 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus). Official Journal L 324 , 11/12/2003 P. 0001 - 0008. (http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32003R2152&from=EN)
- Rejmánek, M., Richardson, D. M., Pyšek, P., 2005. Plant invasions and invisibility of plant communities. In: van der Maarel, E. (ed.), Vegetation ecology. Blackwell Publishing, pp. 332-355.
- Rejmánek M, Richardson DM, Pyšek P, 2005. Plant invasions and invasibility of plant communities. In: van der Maarel E (ed.) Vegetation ecology. Blackwell, p. 332-355
- Simončič, P. Smolej I. 1997. Ekosistemske raziskave na gozdarskem inštitutu Slovenije. V: Znanje za gozd. Zbornik ob 50. obletnici obstoja in delovanja Gozdarskega inštituta Slovenije. Ljubljana: 81-92.
- Simončič, P., Rupel, M., Kovač, M. 2011. Spremljanje stanja gozdov v Sloveniji. Gozdarski vestnik, 69, 5/6: 259-262.
- Šolar, M. 1997. Raziskovanje poškodb gozdov zaradi onesnaženja zraka - mejniki. V: Znanje za gozd. Zbornik ob 50. obletnici obstoja in delovanja Gozdarskega inštituta Slovenije. Ljubljana: 61-80.
- Torkar G., Verlič A., Vilhar U. 2014. Importance of forest ecosystem services to secondary school students : a case from the North-West Slovenia. South-east European forestry, 5, 1: 1-9
- United Nations 1993 CBD. 1993. Convention on Biological Diversity. United Nations Treaty Series, 1760: 143-382.
- Van der Salm C., Reinds G., de Vries W. 2004. Assessment of the water balance in European forests: a model study. WASP FOCUS, 4, 2-3: 175-190
- Vilhar U., Skudnik M. and Simončič P. 2013. Phenological phases of trees on the intensive forest monitoring plots in Slovenia. Acta Silvae et Ligni 100: 5-17.
- Vilhar U., Žlindra D., Rupel M. and Simončič P. 2014. Spremljanje kakovosti zraka v gozdu. Vetrnica 7: 109-119.
- Vilhar U. 2014. Priročnik za fenološka opazovanja dreves v mestu in urbanih gozdovih. Manual on tree phenological observation in urban forests. (ur.) Ljubljana, Gozdarski inštitut Slovenije: 18 str.
- Vilhar U., Kraigher H., Kutnar L., Simončič P., Grecs Z. 2013. Načrtovanje obnove gozda po velikih poškodbah. Planning Forest Restoration after Large-Scale Disturbances. Gozdarski vestnik, 71, 1: 3-17
- Vilhar U., Starr M., Katzensteiner K., Simončič P., Kajfež-Bogataj L. et al. 2010. Modelling drainage fluxes in managed and natural forests in the Dinaric karst: a model comparison study. European Journal of Forest Research, 129, 4: 729-740
- Vuković, N. (2003). Bioindication of stress in different forest sites with exposure of one year old spruce seedlings. Graduation thesis, Biotechnical Faculty, University of Ljubljana.
- Westergren M, Kraigher H. 2011. Monitoring of forest genetic diversity. Gozdarski vestnik, 69 (5/6): 322-326.

This project is funded by the European Union





# KAZALO / TABLE OF CONTENTS