



FOREST HEALTH IN A CHANGING CLIMATE: COMPARATIVE ASSESSMENT OF DEFOLIATION TRENDS IN ROMANIAN AND SERBIAN FORESTS

Andela Vasić¹; Cristian Mihai Enescu²

¹University of Belgrade, Faculty of Forestry, 1 Kneza Višeslava, 11000 Belgrade, Serbia

²University of Agronomic Sciences and Veterinary Medicine, 59 Mărăști Boulevard, București, 011464, Romania



Introduction



Forest policy and governance

1. National Forest Programmes or equivalent
2. Institutional frameworks
3. Legal/regulatory framework: National (and/or Sub-National) and International commitments
4. Financial and economic instruments
5. Information and communication

Criterion 1: Forest Resources & Carbon Cycles

- C.1 Related policies, institutions & instruments
- 1.1 Forest area
 - 1.2 Growing stock
 - 1.3 Age structure &/or diameter distribution
 - 1.4 Forest carbon

Criterion 2: Forest Health and Vitality

- C.2 Related policies, institutions & instruments
- 2.1 Deposition & concentration of air pollutants
 - 2.2 Soil condition
 - 2.3 **Defoliation**
 - 2.4 Forest damage
 - 2.5 Forest land degradation

Criterion 3: Productive Functions

- C.3 Related policies, institutions & instruments
- 3.1 Increment and fellings
 - 3.2 Roundwood
 - 3.3 Non-wood goods
 - 3.4 Services

Criterion 4: Biological Diversity

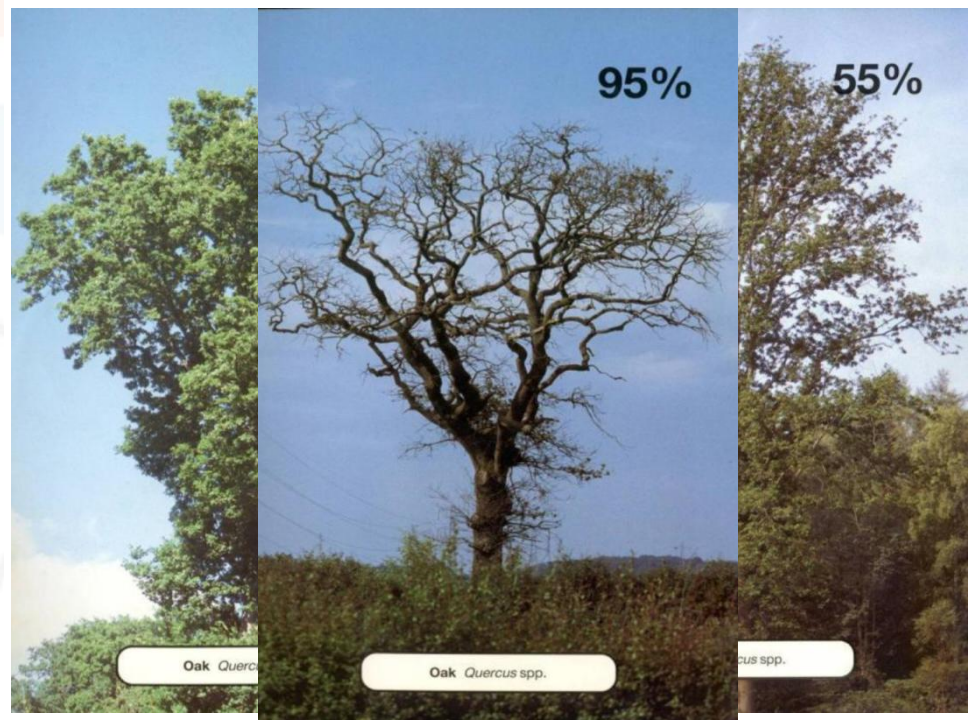
- C.4 Related policies, institutions & instruments
- 4.1 Diversity of tree species
 - 4.2 Regeneration
 - 4.3 Naturalness
 - 4.4 Introduced tree species
 - 4.5 Deadwood
 - 4.6 Genetic resources
 - 4.7 Forest fragmentation
 - 4.8 Threatened forest species
 - 4.9 Protected forests
 - 4.10 Common forest bird species

Criterion 5: Protective Functions

- C.5 Related policies, institutions and instruments
- 5.1 Protective forests – soil, water and other ecosystem functions - infrastructure and managed natural resources

Criterion 6: Socio-economic

- C.6 Related policies, institutions & instruments
- 6.1 Forest holdings
 - 6.2 Contribution of forest sector to GDP
 - 6.3 Net revenue
 - 6.4 Investments in forests and forestry
 - 6.5 Forest sector workforce
 - 6.6 Occupational safety and health
 - 6.7 Wood consumption
 - 6.8 Trade in wood
 - 6.9 Wood energy
 - 6.10 Recreation in forests





Materials and Methods

$$I_{aDM} = \frac{P_a}{T_a + C}$$

De Martonne Aridity Index



$I_{aDM} < 26$	DRY
$26 \leq I_{aDM} \leq 45$	MODERATE
$I_{aDM} > 45$	WET



Spearman's correlation coefficient (r_s)

0 none (%)
1 slight (%)
2 moderate (%)
3 severe (%)
4 dead (%)
2-4 moderate-dead (%)

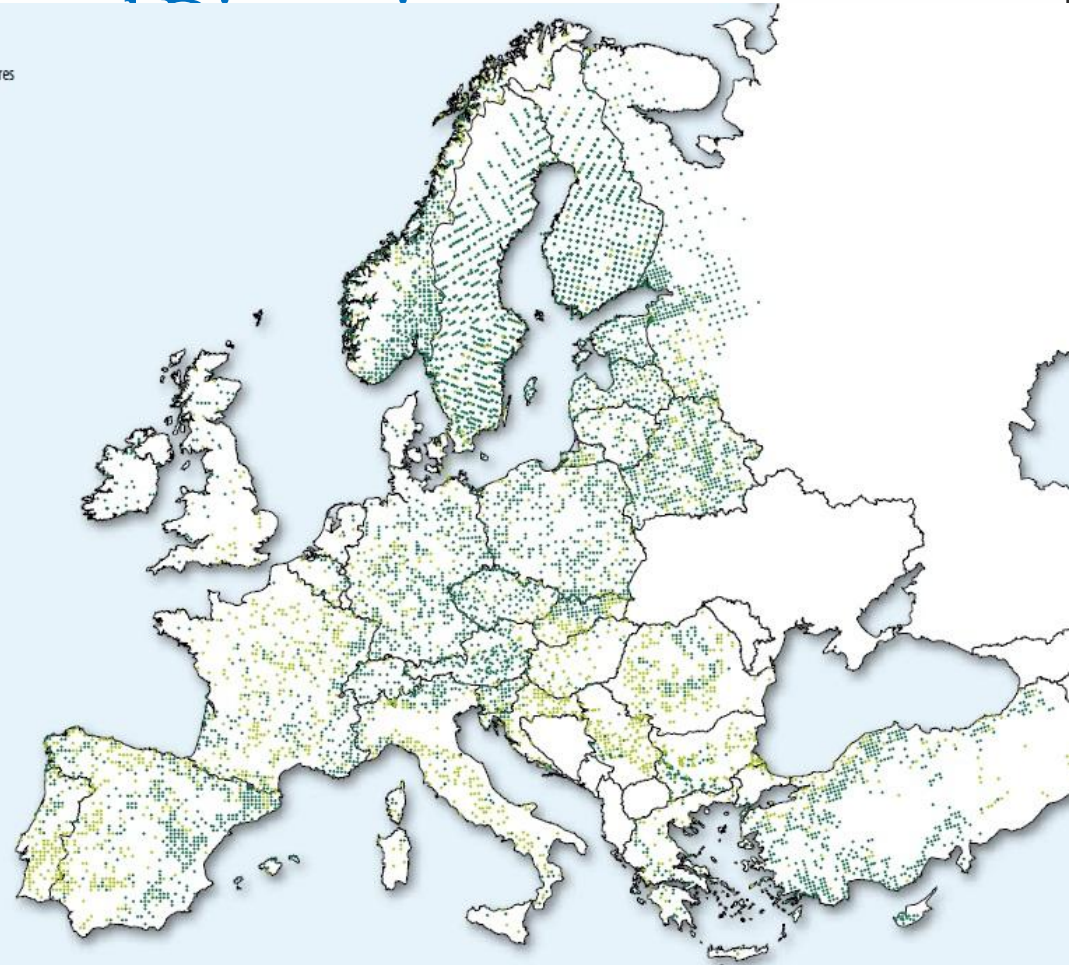




Level I plots with dominating shares
of conifers or broadleaves

- Broadleaves
- Conifers

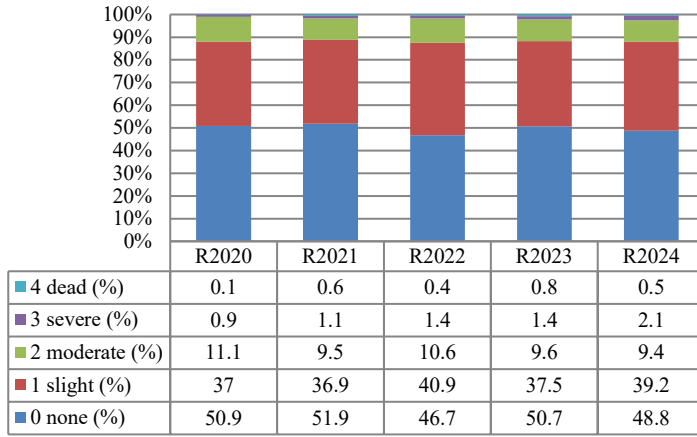
	Total area (1000 ha)	Forest area (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
2020					
Romania	23,839	6,592	16x16	226	5,425
Serbia	8,836	2,360	4x4/16x16	130	2,956
2021					
Romania	23,840	7,046	16x16	234	5,616
Serbia	8,836	2,360	4x4/16x16	130	2,928
2022					
Romania	23,840	7,046	16x16	238	5,712
Serbia	8,836	2,252	4x4/16x16	130	2,886
2023					
Romania	23,840	7,046	16x16	239	5,623
Serbia	8,836	2,360	16x16	130	2,879
2024					
Romania	23,840	7,046	16x16	227	5,453
Serbia	8,836	2,360	4x4/16x16	130	2,879



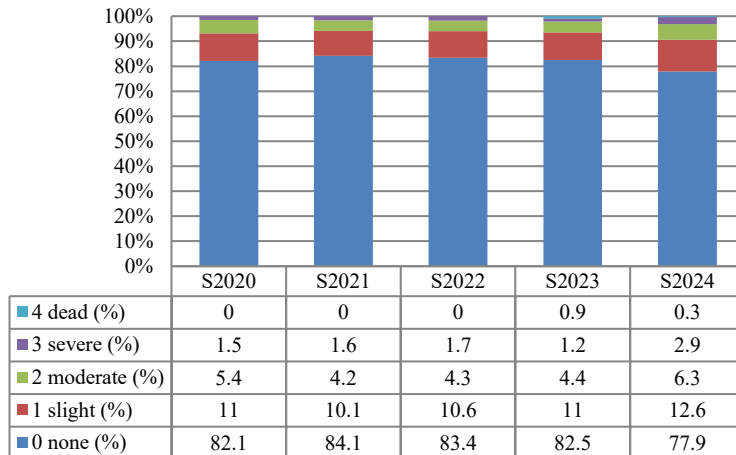
Azores (Portugal)



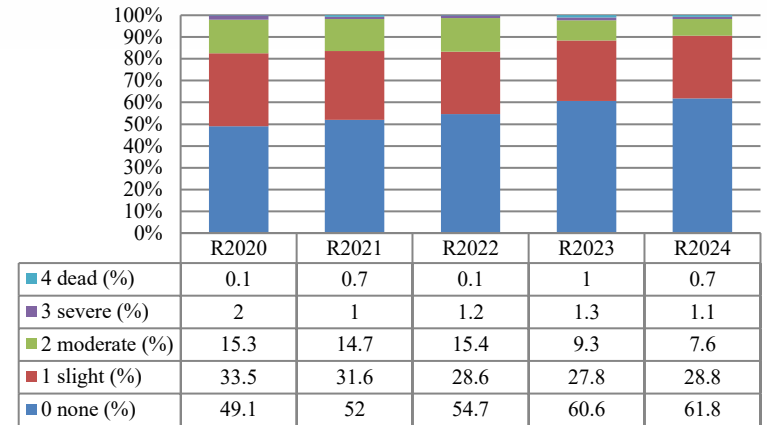
Canary Islands (Spain)



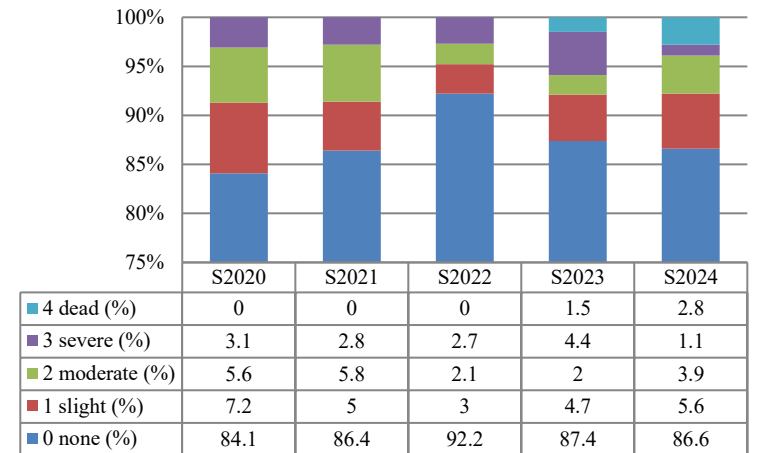
Defoliation classes (%), broadleaves, Romania



Defoliation classes (%), broadleaves, Serbia



Defoliation classes (%), coniferous, Romania

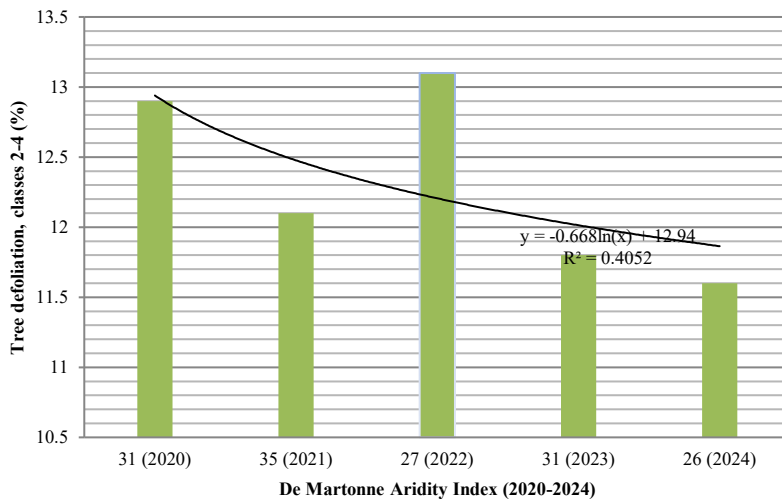


Defoliation classes (%), coniferous, Serbia

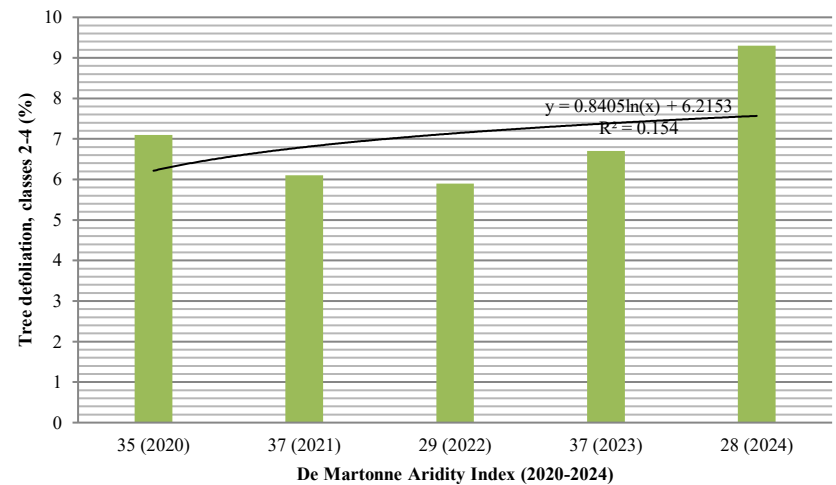


Romania					
Year	2020	2021	2022	2023	2024
I_{aDM}	31	35	27	31	26
Serbia					
Year	2020	2021	2022	2023	2024
I_{aDM}	35	37	29	37	28

$I_{aDM} < 26$	DRY
$26 \leq I_{aDM} \leq 45$	MODERATE
$I_{aDM} > 45$	WET



Defoliation classes 2-4 distribution (%) depending on De Martonne Aridity Index in Romania (2020-2024)



Defoliation classes 2-4 distribution (%) depending on De Martonne Aridity Index in Serbia (2020-2024)



		r_s	p
Romania	Broadleaves	-0.616	0.269
	Conifers	0.359	0.553
	all trees	0.205	0.741
Serbia	Broadleaves	-0.616	0.269
	Conifers	0.564	0.322
	all trees	-0.359	0.553

The findings underscore the importance of coordinated, long-term monitoring for informing adaptive forest management and strengthening resilience under projected climate change scenarios.



Conclusions

- Consistently higher levels of defoliation in Romania for both broadleaved and coniferous species, with **Romanian conifers representing the most affected group**.
- Years with lower aridity values (**2022 - Romania, 2024 - Serbia**) coincided with slight increases in the proportion of trees from moderate to severe defoliation classes - suggests a sensitivity of forest vitality to short-term moisture deficits, particularly in already drought-prone areas.
- **Biotic agents**: defoliators, xylophagous insects, and fungal pathogens, emerged as dominant contributors to crown deterioration, aligning with broader European trends of increasing pest and disease impacts under warming conditions.
- Despite the absence of statistically significant **drought index–defoliation correlations**, the combined evidence highlights the **importance of long-term, standardized monitoring** for detecting emerging stress patterns and understanding how climatic anomalies interact with biotic disturbances.



References

- Badea, O., Bytnerowicz, A., Silaghi, D., Neagu, S., Barbu, I., Iacoban, C., Iacob, C., Guiman, G., Preda, E., Seceleanu, I., Oneata, M., Dumitru, I., Huber, V., Iuncu, H., Dinca, L., Leca, S., Taut, I. (2012): Status of the Southern Carpathian forests in the long-term ecological research network. *Environmental Monitoring and Assessment*, 184, 7491-7515.
- Badea, O., Silaghi, D., Tăut, I., Neagu, S., Leca, S. (2013): Forest Monitoring – Assessments, Analysis and Warning System for Forest Ecosystem Status. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 41(2), 613–625. <https://doi.org/10.15835/nbha4129304>.
- Bălăcenoiu, F., Japelj, A., Bernardinelli, I., Castagnyrol, B., Csóka, G., et al. (2021). *Corythucha arcuata* (Say, 1832) (Hemiptera, Tingidae) in its invasive range in Europe: perception, knowledge and willingness to act in foresters and citizens. *NeoBiota*, 69, 133-153. doi: [ff10.3897/neobiota.69.71851ff.f5hal-03432000f](https://doi.org/10.3897/neobiota.69.71851ff.f5hal-03432000f).
- Češljarić, G., Đorđević, I., Brašanac-Bosanac, Lj., Eremija, S., Mitrović, S., Čirković-Mitrović, T., Lučić, A. (2021): Determination of forest decline due to the action of dominant stress factor through monitoring of defoliation – case study of Maljen, Serbia. *Agriculture & Forestry*, 67, 2:211-226.
- Drekić, M., Orlović, S., Galić, Z., Stojnić, S., Pekeć, S., Vasić, V., Pilipović, A. (2016): Rezultati procene uticaja aerozagađenja na stanje šuma u Vojvodini. *Topola*, 197-198, 81-90.
- Forzieri, G., Dutrieux, L. P., Elia, A., Eckhardt, B., Caudullo, Álvarez Taboada, G. F., Andriolo, A., Bălăcenoiu, F., Bastos, A., Buzatu, A., Dorado, F. C., Dobrovolný, L., Duduman, M. L., Fernandez-Carrillo, A., Hernández-Clemente, R., Hornero, A., Ionuț, S., Lombardero, M. J., Junntila, S., Lukeš, P., Marianelli, L., Mas, H., Mlčoušek, M., Mugnai, F., Nețoiu, C., Nikolov, C., Olenici, N., Olsson, P. O., Paoli, F., Paraschiv, M., Patočka, Z., Pérez-Laoga, E., Quero, J. L., Rüttschi, M., Stroheker, S., Nardi, D., Ferenčík, J., Battisti, A., Hartmann, H., Nistor, C., Cescatti, A., Beck, P. S. A. (2023): The Database of European Forest Insect and Disease Disturbances: DEFID2. *Global Change Biology*, 29/21. 6040-6065. <https://doi.org/10.1111/gcb.16912>.
- Gavrilo, M. B., An, W., Xu, C., Radaković, M. G., Hao, Q., Yang, F., Guo, Z., Perić, Z., Gavrilo, G., Marković, S. B. (2019): Independent Aridity and Drought Pieces of Evidence Based on Meteorological Data and Tree Ring Data in Southeast Banat, Vojvodina, Serbia. *Atmosphere*, 10, 586, doi: [10.3390/atmos10100586](https://doi.org/10.3390/atmos10100586).
- Karadžić, D., Milanović, S., Golubović-Čurguz, V. (2017): Uzroci sušenja smrčce (*Picea abies* Karst.) na području parka prirode „Golija“. *Univerzitet u Beogradu, Šumarski fakultet*, 13-22.
- Marković, M., Rajković, S., Nevenić, R. (2014): The most frequent agents of damages of trees at the sample plots in Serbia. *Sustainable Forestry*, 69-70, 85-94.
- Michel, A., Kirchner, T., Prescher, A.-K., Schwärzel, K., editors (2021) *Forest Condition in Europe: The 2021 Assessment*. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Eberswalde: Thünen Institute. <https://doi.org/10.3220/ICPTR1624952851000> ,
- Michel, A., Kirchner, T., Prescher, A.-K., Schwärzel, K., editors (2022) *Forest Condition in Europe: The 2022 Assessment*. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Online supplementary material, 48 p. Eberswalde: Thünen Institute. Retrieved from: <http://icp-forests.net/page/icp-foreststechnical-report> ,
- Michel, A., Kirchner, T., Prescher, A.-K., Schwärzel, K., editors (2023) *Forest Condition in Europe: The 2023 Assessment*. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Eberswalde: Thünen Institute. <https://doi.org/10.3220/ICPTR1697801881000> ,
- Michel, A., Haggmüller, K., Kirchner, T., Prescher, A.-K., Schwärzel, K., Wohlgemuth, L., editors (2024) *Forest Condition in Europe: The 2024 Assessment*. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Eberswalde: Thünen Institute. 96 p. <https://doi.org/10.3220/ICPTR1732702585000> ,
- Michel, A., Haggmüller, K., Kirchner, T., Prescher, A.-K., Schwärzel, K., editors (2025) *Forest Condition in Europe: The 2025 Assessment*. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Eberswalde: Thünen Institute. 100 p. <https://doi.org/10.3220/253-2025-62> ,
- Nețoiu, C., Tomescu, R., Olenici, N., Buzatu, A., Bălăcenoiu, F., Iliescu, O. (2018): The Invasive Insect Species in the Oltenia Region (Romania). *Muzeul Olteniei Craiova. Oltenia. Studii și comunicări. Științele Naturii*, 34, 1/2018 ISSN 1454-6914.
- Popa, I., Badea, O., Silaghi, D. (2017): Influence of climate on tree health evaluated by defoliation in the ICP level I network (Romania). *iForest - Biogeosciences and Forestry*, 10, 3, 554-560, doi: <https://doi.org/10.3832/ifor2202-009>,
- Stojanović, D. B., Orlović, S., Zlatković, M., Kostić, S., Verica, V., Miletić, B., Kesić, L., Matović, B., Božanić, D., Pavlović, L., Milović, M., Pekeć, S., Đurđević, V. (2021): Climate change within Serbian forests: current state and future perspectives. *Topola*, 208, 39-56.
- Tăut, I.; Bora, F.D., Rebrea, F.A., Moldovan, C.M., Varga, M.I., Simonca, V., Colișar, A., Bartha, S., Timofte, C.S., Sestras, P. (2025): Climate-Driven Decline of Oak Forests: Integrating Ecological Indicators and Sustainable Management Strategies. *Sustainability*, 17, 9197. <https://doi.org/10.3390/su17209197>.
- Tomescu, R., Olenici, N., Nețoiu, C., Bălăcenoiu, F., Buzatu, A. (2018): Invasion of the oak lace bug (*Corythucha acruata* (Say.) in Romania: a first extended reporting. *Annals of Forest Research*, 61(2): 161-170, 2018, DOI: [10.15287/aft.2018.1187](https://doi.org/10.15287/aft.2018.1187),
- ***Administrația Națională de Meteorologie, Raport Anual, (ANM 2020, 2021, 2022, 2023, 2024). Retrieved from: <https://www.meteoromania.ro/>
- ***Food and Agriculture Organization (FAO), (2025). *Global Forest Resources Assessment (GFRA) for Serbia and Romania*. Retrieved from <https://www.fao.org/forest-resources-assessment/fra-2025-country-reports/en>,
- ***Forest Europe (SEF). (2020): *State of Europe's Forests 2020*,
- ***Monitoring and Assessment of Air Pollution Impacts and its Effects on Forest Ecosystems in Republic of Serbia – Forest Condition Monitoring, Level I and Level II, NFC National Focal Centre for monitoring the condition – vitality of the forests of the Republic of Serbia (LIS, 2021, 2022, 2023, 2024, 2025). Retrieved from: <https://www.forest.org.rs/?%D0%91%D0%98%D0%A2-%D0%B8%D0%B7%D0%B2%D0%B5%D1%88%D1%82%D0%B0%D1%98%D0%B8> ,
- ***Republic Hydrometeorological Service of Serbia (RHSS, 2021, 2022, 2023, 2024, 2025). Retrieved from: https://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php

Thank you for your attention!



Corresponding author: Anđela VASIĆ

E-mail: a.vasic.www@gmail.com

Address: University of Belgrade, Faculty of Forestry, Kneza Višeslava 1,
11000 Belgrade



December 3-5, 2025, București



One Health
Student Conference
USAMV București