NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro; doi.org/10.59665/rar43132
ROMANIAN AGRICULTURAL RESEARCH, NO. 43, 2026
First Online: November, 2026. DII 2067-5720 RAR 2026-246

Field Shelterbelts as Functional Biodiversity Infrastructure in the Lowland Agroecosystems of Romania. A Critical Synthesis of Aero-Ecological Permeability, Functional Distance and Toxicological Refuge

Laurențiu Ciornei[1], Victor Petcu[1,2*], Elena Toma[3], Bogdan Petre[4]

[1]Center of Study and Research for Agroforestry Biodiversity "Acad. David Davidescu", Romanian Academy, Bucharest, Romania

[2]National Agricultural Research and Development Institute Fundulea, Călăraşi County, Romania

[3]Faculty of Social Sciences, Humanities and Natural Sciences, Hyperion University, Bucharest, Romania

[4]Bucharest University of Economic Studies, Bucharest, Romania

[*]Corresponding author. E-mail: petcuvictor86@gmail.com

ABSTRACT

Field shelterbelts were conceived, throughout the history of European agriculture, as instruments of defense against wind, wind erosion and drifting snow. This paper offers a rereading of these linear structures from the standpoint of functional biodiversity, that is, of the organisms that return measurable services to the field, from natural pest control and pollination to microclimate regulation and soil conservation. Drawing on a critical synthesis of the international and Romanian literature published between 1988 and 2026, the article formulates three operational concepts. Aero-ecological permeability describes the structural density at which the aerodynamic optimum of a shelterbelt coincides with its ecological optimum. Functional distance links the zone of microclimatic shelter to the decay curve of ecosystem services within the field and suggests a spacing rule for shelterbelt networks. Toxicological refuge denotes the capacity of a shelterbelt to support the recovery of beneficial arthropods after insecticide applications, a capacity recently observed in wheat agroecosystems in Transylvania. The limits of the approach are discussed, in particular the conflict with steppe and wetland birds, and the findings are set within the framework of aridification in the Romanian Plain and of Regulation (EU) 2024/1991 on nature restoration.

Keywords: field shelterbelts, functional biodiversity, biological control, pollination, agroforestry, nature restoration, Romanian Plain.

INTRODUCTION

For the twentieth-century agronomist, the shelterbelt was an aerodynamic machine built of trees. Its efficiency was measured in percentages of wind speed reduction, in metric tons of soil retained per hectare and in yield gains obtained in its lee, and the classical literature patiently confirmed these effects (Kort, 1988; Cleugh, 1998; Brandle et al., 2004). The image remains accurate, yet it leaves in the shade a fact that landscape ecology has brought to the foreground only in the last two decades. A shelterbelt functions at once as habitat, corridor and reservoir of organisms that work for the farmer without ever appearing in any account book.

The global synthesis coordinated by Dainese et al. (2019) showed that the simplification of agricultural landscapes reduces the richness of service-providing organisms, and that this loss is transmitted, through declining pollination and natural pest control, all the way to crop production. European analyses have refined the mechanism. Landscape composition and configuration act jointly on predators, pollinators and pests (Martin et al., 2019), while the subdivision of large fields into smaller units with permanent margins increases diversity across several trophic levels (Sirami et al., 2019). Kremen and Merenlender (2018) described this type of territory as a landscape that works for biodiversity and for people at the same time. In the great cereal plains, the shelterbelt holds a distinctive place in this architecture, being

Received 31 July 2026; accepted 17 November 2026.

often the only permanent woody element across tens of square kilometers.

For Romania, the question carries particular weight. Southern Oltenia and Dobrogea have recorded, over the last half century, a rising trend in climatic aridity, accentuated after 1980 (Prăvălie, 2013; Prăvălie and Bandoc, 2015), precisely in the regions where the historical shelterbelt network was most severely dismantled. The aim of this paper is to move the discussion from the exclusive ground of physical protection to that of functional biodiversity and to propose three concepts, aero-ecological permeability, functional distance and toxicological refuge, which can be used in the design and assessment of future networks.

MATERIAL AND METHODS

The paper is a critical narrative synthesis and contains no original experimental data. Three categories of sources were selected: meta-analyses and quantitative syntheses on the relationship between the semi-natural elements of agricultural landscapes and ecosystem services (Ricketts et al., 2008; Torralba et al., 2016; Dainese et al., 2019; Albrecht et al., 2020), field studies explicitly devoted to shelterbelts and tree rows (Lavrov et al., 2021; Einav et al., 2024; Vălean et al., 2025; Hisano et al., 2026), and the Romanian specialist literature, together with the technical documents of the forest administration and the national and European regulatory framework.

The analytical criterion focused on the points at which independent lines of evidence, drawn from aerodynamics, entomology, ornithology and agricultural economics, converge on the same design parameter. Wherever such convergence was identified, it was formulated as a working hypothesis testable under the conditions of the plains of southern and eastern Romania.

WHAT A SHELTERBELT HARBORS

Predators at the edge of the field

The bibliometric analysis by Enescu et al. (2025) of the literature on the agricultural benefits of shelterbelts shows that predatory arthropods, carabid beetles in particular, reach higher abundances near shelterbelts and hedgerows, and that mixed shrub plantings support more diverse beetle communities than woody monocultures. The most recent evidence comes from Romania itself. Between 2022 and 2024, Vălean et al. (2025) compared winter wheat crops on the Transylvanian Plateau, located about 14 km apart, some bordered by agroforestry shelterbelts (Bolduț) and others in open field (Turda). In the insecticide-free variants, the mean annual abundance of beneficial arthropods was 1,632 individuals at the shelterbelt site, against 969 in the open field, a surplus of approximately 68%. Spiders dominated the community and were found at higher densities in the vicinity of the woody structures.

Ukrainian data complete the picture along the vertical axis. Lavrov et al. (2021) found that dense, three-layered shelterbelts with a well-developed understory host between 10 and 27 breeding bird species, among which insectivores account for 70.4% to 90% of the trophic structure. Of the 29 nesting species identified, 27 are protected under international agreements. The shelterbelt thus becomes a source from which invertebrate and vertebrate predators periodically spill over into the crop, and the intensity of this spillover depends on the structural quality of the source.

Pollinators and the geometry of distance

For pollinators, the relationship with semi-natural habitat follows a relatively stable mathematical form. The synthesis by Ricketts et al. (2008) showed that the visitation rate of wild pollinators declines with distance from natural habitat, falling to half of its maximum value at about 0.6 km. Albrecht et al. (2020), analyzing 17 pollination studies, confirmed an exponential decline of the service with increasing distance from floral plantings and showed that perennial, older plantings with greater floral diversity are the most effective. Hedgerow restoration in the intensive farming systems of California increased the abundance and richness of wild bees and hoverflies relative to unmanaged field edges

(Morandin and Kremen, 2013), although the benefit depends on hedge quality and on landscape context (Garratt et al., 2017).

The practical consequence for the Romanian plain lies in the choice of species. A shelterbelt composed exclusively of wind-pollinated species offers shelter but little food. Including lime, Tatarian maple, wild cherry, Cornelian cherry, hawthorn, blackthorn and dog rose, all native to the forest-steppe, extends the flowering period from early spring into summer and turns the tree line into a food reserve for solitary bees, bumblebees and hoverflies, whose larvae in turn feed on aphids.

Hunters of the air

Insectivorous bats use tree rows as navigation landmarks and foraging corridors. An experiment conducted in the Arava desert brought an unexpected nuance (Einav et al., 2024). Small gaps in windbreaks recorded on average 477 bat passes per night, against 374 along continuous tree lines, and the feeding buzz ratio was 0.07 at the gaps, compared with 0.02 along the unbroken windbreak. Hunting activity was therefore three and a half times more intense where the tree line opened. Continuity, long regarded as an absolute virtue of the shelterbelt, turns out to be a parameter that calls for careful measure.

AERO-ECOLOGICAL PERMEABILITY: AERODYNAMICS AND ECOLOGY ARRIVE AT THE SAME MEASURE

The aerodynamics of shelterbelts established long ago that an overly dense barrier behaves like a wall. The wind passes over it, generates turbulence in its lee, and the protected zone becomes shorter. Shelterbelts of medium optical density, between 40% and 60%, produce the longest and most uniform sheltered zone for field crops (Cleugh, 1998; Brandle et al., 2004). Ecological research reached a related conclusion along an entirely separate path. Multi-layered shelterbelts with an understory and occasional gaps support more bird species (Lavrov et al., 2021) and more bat foraging activity (Einav et al., 2024) than compact, uniform structures. The same Ukrainian shelterbelts also reveal the reverse, since the degradation of the main canopy layer, with losses of up to 43.5% of the trees, was accompanied by a herb layer dominated by ruderal (36.5%) and alien (24.5%) species.

We define aero-ecological permeability as the degree of openness of a shelterbelt at which optimal protection against wind coincides with optimal habitat heterogeneity. The term describes a single physical property, the extent to which the shelterbelt lets air and light pass through, assessed simultaneously against two independent criteria, the aerodynamic and the ecological. Our hypothesis holds that a shelterbelt designed for an optical density of 40-60%, achieved through the alternation of layers and species, without the mechanical thinning of a uniform plantation, reaches at the same time the optimum of crop protection and the optimum of habitat for beneficial fauna. In the Nicomachean Ethics, Aristotle (1988) described virtue as a mean between excess and deficiency, and a well-built shelterbelt offers a vegetal illustration of this idea, being neither wall nor sieve. The hypothesis can be tested through simultaneous measurements of optical density, wind speed profile and surveys of invertebrates and birds along the same shelterbelt sections.

FUNCTIONAL DISTANCE, A SPACING RULE FOR THE NETWORK

The microclimatic effect of a shelterbelt is expressed in multiples of its height (H). The most consistent yield gains occur approximately between 3 and 10 H in the lee of the shelterbelt, with weaker effects that may extend further (Cleugh, 1998; Enescu et al., 2025). Long-term economic studies from the American Great Plains, summarized by Enescu et al. (2025), indicate that a spacing of about 13 H between shelterbelts generated, after 40 years, net returns 7.61% higher for maize and 9.23% higher for soybean. In parallel, the biological services provided by the shelterbelt decline exponentially toward

the interior of the field (Albrecht et al., 2020).

Overlaying the two curves leads to what we propose to call functional distance, namely the maximum interval between two parallel shelterbelts within which no point of the crop lies simultaneously outside the range of microclimatic shelter and outside the range of action of beneficial fauna. For a mature shelterbelt 15 m tall, the 13 H rule corresponds to a spacing of approximately 200 m, a distance that carabid beetles, spiders and wild pollinators can cover without difficulty, starting from both edges of the field. The result has a planning consequence. The shelterbelt network and the habitat network for functional biodiversity can be one and the same, provided that spacing is determined on the basis of both criteria. The proposed values require validation under the conditions of the Bărăgan Plain and Dobrogea, where wind regimes and soil structure differ from those described in the North American literature.

TOXICOLOGICAL REFUGE, A FUNCTION STILL WITHOUT A NAME

The study by Vălean et al. (2025) contains an observation that goes beyond strictly entomological interest. In 2022, the first application of acetamiprid reduced beneficial arthropods by 100% in the open field, compared with 54.5% at the shelterbelt site. The result was not uniform, since with tau-fluvalinate the reduction was greater at the shelterbelt site (73.1%, compared with 41.8%), yet the authors found that populations in the vicinity of the shelterbelts recovered more rapidly after treatments. The most parsimonious explanation lies in recolonization dynamics. The shelterbelt harbors populations that are not directly reached by the treatment and from which the crop is repopulated once the concentration of the active substance declines.

We propose the term toxicological refuge for this function, understood as the capacity of the community to recover after the shock rather than as direct protection against it. The technical consequence is immediate. The value of the refuge is lost if treatments reach the shelterbelt through spray drift, so that an untreated buffer strip at the base of the shelterbelt and a ban on applications within it become part of the design, as important as the choice of species.

LIMITS: WHEN THE TREE STANDS IN THE WRONG PLACE

An honest synthesis has a duty to record the results that temper enthusiasm as well. Albrecht et al. (2020) showed that flower strips increased pest control in adjacent crops by 16% on average, whereas hedgerows had no significant effect on this service. Tscharntke et al. (2016) documented numerous situations in which semi-natural habitat failed to improve biological control, owing to the pest species, to generalist predators or to a lack of synchrony between resources and needs. The lesson is constructive. A line of trees alone is rarely sufficient, and the shelterbelt attains full effectiveness when it is accompanied at its base by a perennial herbaceous strip rich in flowering species, which may be called a composite shelterbelt.

The second limit concerns the birds of open landscapes. In the farmland around Lake Kahokugata, Hisano et al. (2026) recorded a grassland bird abundance more than 70% lower next to shelterbelts than at open sites located about one kilometer away, and the diversity of wetland birds declined near the tree rows. The authors identified two mechanisms, the loss of open space and exposure to raptors that use the trees as perches. For Romania, the warning has a precise address. The steppe fragments of Dobrogea and the Bărăgan, the grasslands of the western part of the country and the floodplain wetlands host species for which an open horizon is a condition of survival. The shelterbelt network belongs on intensively farmed arable land, away from steppe relicts and from protected areas designated for open-habitat birds.

The third limit is botanical. Black locust, used extensively to stabilize sands and in historical shelterbelts, remains an alien

species with invasive behavior in many habitats, and the degraded Ukrainian shelterbelts analyzed by Lavrov et al. (2021) showed how quickly alien flora becomes established once the original structure breaks down. A shelterbelt that serves biodiversity is built from species native to the forest-steppe and is maintained throughout its entire lifespan.

ROMANIA, THE HISTORY OF AN INTERRUPTED NETWORK

The idea of the field shelterbelt as an instrument of the state was born in the Russian steppe after the drought of 1891, when Vasily Dokuchaev (1892) laid the foundations of the Stone Steppe experiment and set out, in Our Steppes Past and Present (1892), the program of an agriculture protected by linear forests. In Romania, the first shelterbelts appeared around 1880 in Ialomița County. Between 1947 and 1960 approximately 5,000 ha were planted, but most of them were cleared after 1961 under Council of Ministers Decisions No. 257 and No. 385 of 1962, and after 1989 many of those that remained disappeared through illegal logging (Iacob et al., 2014).

The relaunch that followed the adoption of Law No. 289/2002 was spectacular and short-lived. Between 2001 and 2003, Romsilva established 2,036 ha of shelterbelts, peaking at 614 ha in 2003, after which the annual rate fell to single-digit figures, with 0 ha in 2009 and 3 ha in 2012. The technical designs prepared in 2005-2006, by contrast, totaled 19,965 ha (Iacob et al., 2014). The gap between plan and implementation has been attributed to the lack of a specialized cadastre, of funding and of a mechanism to compensate landowners who would give up agricultural land (Vijulie et al., 2013). The current institutional framework maintains the objective, and Government Decision No. 123/2026 on the organization of Romsilva includes among the duties of the National Forest Administration the expropriation, on behalf of the state, of the land required for the national system of protective forest shelterbelts, alongside support for landowners who wish to establish shelterbelts.

The European dimension now offers a new lever. Article 11 of Regulation (EU) 2024/1991 on nature restoration requires Member States to achieve an increasing trend in at least two of three indicators for agricultural ecosystems, among them the share of agricultural land with high-diversity landscape features. The European Commission guidance on monitoring these features (C/2025/980) explicitly includes tree rows and hedgerows and requires that they not be subject to fertilization or pesticide treatment. A shelterbelt designed according to the principles set out above falls naturally within this category. The shelterbelt thus becomes an instrument through which Romania can fulfill its nature restoration obligations in the very regions with the lowest forest cover.

THE SHELTERBELT AS NATURAL CAPITAL

The farmer first perceives a shelterbelt as land taken out of production. Farm accounting records the loss of land and the costs of planting and maintenance, but it does not record the predators, pollinators and soil moisture that the shelterbelt supplies free of charge to the neighboring field. The meta-analysis by Torralba et al. (2016), based on 53 publications and 365 comparisons, indicated an overall positive and significant effect of European agroforestry systems on biodiversity and ecosystem services, with an effect size of 0.454 relative to conventional agriculture and forestry.

In an earlier paper I argued that artificial afforestation generates benefits for air quality and sustainable development that can be valued economically and integrated into public decision-making (Ciornei, 2021). The same logic applies to field shelterbelts, with a difference of scale. The benefits of a shelterbelt materialize primarily in the agricultural output of its immediate surroundings, which makes possible a direct, farm-level assessment of the flows of services. The shelterbelt thus finds its place

in the category of productive natural capital, alongside soil and water, and agricultural policy can treat its establishment as an investment in farm infrastructure, amortized over several decades.

CONCLUSIONS

Field shelterbelts were designed to stop the wind, and they can be redesigned to welcome life. Recent literature converges on the idea that their value for crops derives equally from their physical effect and from the biological community they harbor, and that the two dimensions can be optimized through the same design decisions. Aero-ecological permeability links the structure of the shelterbelt to its ecological functions, functional distance links the spacing of the network to the range of action of beneficial fauna, and toxicological refuge assigns to the shelterbelt the role of a biological reserve in an agriculture that still relies on insecticides.

In Becoming within Being, Constantin Noica (1981) described the idea of a limitation that does not limit, a determination which, instead of closing, opens up possibilities. The shelterbelt appears to be the agronomic expression of this idea. It divides the field and reduces its cultivated area, but gives it in return microclimate, soil, predators and pollinators, that is, precisely the capacity to remain productive in a plain undergoing aridification. For the Bărăgan, Dobrogea and southern Oltenia, restoring the shelterbelt network is one of the few investments that serve agricultural production, biodiversity and European nature restoration obligations at the same time.

Box: Solutions for a shelterbelt network with a biodiversity function

Composite shelterbelt. Every new shelterbelt should be accompanied at its base by a perennial herbaceous strip rich in flowering species, untreated with pesticides and unfertilized.

Aero-ecological permeability. Optical density of 40-60%, achieved through three layers (trees, shrubs, herb layer) and occasional short gaps, which benefit bats.

Native forest-steppe species. *Quercus pedunculiflora*, *Quercus pubescens*, *Tilia* spp., *Acer tataricum*, *Prunus avium*, *Cornus mas*, *Crataegus monogyna*, *Prunus spinosa* and *Rosa canina*, avoiding invasive alien species.

Functional distance. Indicative spacing of about 13 H between parallel shelterbelts, that is, approximately 200 m for mature shelterbelts 15 m tall, to be validated experimentally in the Bărăgan and Dobrogea.

Toxicological refuge. No treatments within the shelterbelt and an untreated buffer strip, in order to preserve the reserve of predators and parasitoids that repopulate the crop.

The right place. Planting on intensively farmed arable land, excluding steppe relicts, grasslands and protected areas designated for open-habitat birds.

Cadastre and compensation. A national shelterbelt register, linked to the high-diversity landscape features indicator of Regulation (EU) 2024/1991, and compensation payments for landowners.

REFERENCES

Albrecht, M., Kleijn, D., Williams, N.M., Tschumi, M., Blaauw, B.R., Bommarco, R., Campbell, A.J., Dainese, M., Drummond, F.A., Entling, M.H., Ganser, D., de Groot, G.A., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., Jonsson, M., Knop, E., Kremen, C., Landis, D.A., Loeb, G.M., Marini, L., McKerchar, M., Morandin, L., Pfister, S.C., Potts, S.G., Rundlöf, M., Sardiñas, H., Sciligo, A., Thies, C., Tscharntke, T., Venturini, E., Veromann, E., Vollhardt, I.M.G., Wäckers, F., Ward, K., Westbury, D.B., Wilby, A., Woltz, M., Wratten, S., Sutter, L., 2020. *The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: a quantitative synthesis*. Ecology Letters, 23(10): 1488-1498.

Aristotle, 1988. *Etica Nicomahică [Nicomachean Ethics]*. Translated by Stella Petecel. Editura Științifică și Enciclopedică, Bucharest.

Brandle, J.R., Hodges, L., Zhou, X.H., 2004. *Windbreaks in North American agricultural systems*. Agroforestry Systems, 61: 65-78.

Ciornei, L., 2021. *Impactul împăduririlor artificiale asupra calității aerului. Principii de dezvoltare*

durabilă. Revista OEconomica, Romanian Society for Economic Science.

Cleugh, H.A., 1998. *Effects of windbreaks on airflow, microclimates and crop yields*. Agroforestry Systems, 41: 55-84.

Dainese, M., Martin, E.A., Aizen, M.A., Albrecht, M., Bartomeus, I., Bommarco, R., Carvalheiro, L.G., Chaplin-Kramer, R., Gagic, V., Garibaldi, L.A., Ghazoul, J., Grab, H., Jonsson, M., Karp, D.S., Kennedy, C.M., Kleijn, D., Kremen, C., Landis, D.A., Letourneau, D.K., Marini, L., Poveda, K., Rader, R., Smith, H.G., Tscharntke, T., Andersson, G.K.S., Badenhausser, I., Baensch, S., Bezerra, A.D.M., Bianchi, F.J.J.A., Boreux, V., Bretagnolle, V., Caballero-Lopez, B., Cavigliasso, P., Ćetković, A., Chacoff, N.P., Classen, A., Cusser, S., da Silva e Silva, F.D., de Groot, G.A., Dudenhöffer, J.H., Ekroos, J., Fijen, T., Franck, P., Freitas, B.M., Garratt, M.P.D., Gratton, C., Hipólito, J., Holzschuh, A., Hunt, L., Iverson, A.L., Jha, S., Keasar, T., Kim, T.N., Kishinevsky, M., Klatt, B.K., Klein, A.-M., Krewenka, K.M., Krishnan, S., Larsen, A.E., Lavigne, C., Liere, H., Maas, B., Mallinger, R.E., Martinez Pachon, E., Martínez-Salinas, A., Meehan, T.D., Mitchell, M.G.E., Molina, G.A.R., Nesper, M., Nilsson, L., O'Rourke, M.E., Peters, M.K., Plećaš, M., Potts, S.G., Ramos, D.L., Rosenheim, J.A., Rundlöf, M., Rusch, A., Sáez, A., Scheper, J., Schleuning, M., Schmack, J.M., Sciligo, A.R., Seymour, C., Stanley, D.A., Stewart, R., Stout, J.C., Sutter, L., Takada, M.B., Taki, H., Tamburini, G., Tschumi, M., Viana, B.F., Westphal, C., Willcox, B.K., Wratten, S.D., Yoshioka, A., Zaragoza-Trello, C., Zhang, W., Zou, Y., Steffan-Dewenter, I., 2019. *A global synthesis reveals biodiversity-mediated benefits for crop production*. Science Advances, 5(10), eaax0121.

Dokuchaev, V.V., 1892. *Nashi stepi prezhde i teper*. Saint Petersburg.

Einav, A., Giladi, I., Schäckermann, J., Korine, C., 2024. *Enhancing insectivorous bat activity through sound manipulation and assessing the contribution of small gaps in windbreaks in the hyper-arid Arava desert*. Frontiers in Conservation Science, 5, 1491713.

Enescu, C.M., Mihalache, M., Ilie, L., Dinca, L., Constandache, C., Murariu, G., 2025. *Agricultural benefits of shelterbelts and windbreaks: a bibliometric analysis*. Agriculture, 15(11), 1204.

European Commission, 2025. *Guidance on a framework for developing methodologies to monitor high-diversity landscape features pursuant to Article 14(7) of the Nature Restoration Regulation [Regulation (EU) 2024/1991]*. Official Journal of the European Union, C/2025/980, 14 February 2025.

European Parliament and Council of the European Union, 2024. *Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869*. Official Journal of the European Union.

Garratt, M.P.D., Senapathi, D., Coston, D.J., Mortimer, S.R., Potts, S.G., 2017. *The benefits of hedgerows for pollinators and natural enemies depends on hedge quality and landscape context*. Agriculture, Ecosystems and Environment, 247: 363-370.

Government of Romania, 2026. *Government Decision No. 123 of 5 March 2026 on the organization, functioning and reorganization of the National Forest Administration Romsilva*. Official Gazette of Romania, No. 191 of 12 March 2026.

Hisano, M., Deguchi, S., Xu, W., Xiao, X., Sannoh, K., Chen, X., Motomura, K., 2026. *Shelterbelts support edge birds but limit grassland and wetland specialists in agricultural landscape*. Journal of Environmental Management, 2026, 128583.

Iacob, D., Achim, D., Daia, M., 2014. *Stadiul actual și perspectivele realizării sistemului național al perdelelor forestiere de protecție*. Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Șișești", Bucharest.

Kort, J., 1988. *Benefits of windbreaks to field and forage crops*. Agriculture, Ecosystems and Environment, 22-23: 165-190.

Kremen, C., and Merenlender, A.M., 2018. *Landscapes that work for biodiversity and people*. Science, 362(6412), eaau6020.

Lavrov, V., Miroshnyk, N., Grabovska, T., Shupova, T., 2021. *Forest shelter belts in organic agricultural landscape: structure of biodiversity and their ecological role*. Folia Forestalia Polonica, Series A, Forestry, 63(1): 48-64.

Law No. 289/2002 on protective forest shelterbelts, as subsequently amended and supplemented. Official Gazette of Romania.

Law No. 331/2024, the Forest Code. Official Gazette of Romania.

Martin, E.A., Dainese, M., Clough, Y., Báldi, A., Bommarco, R., Gagic, V., Garratt, M.P.D., Holzschuh, A., Kleijn, D., Kovács-Hostyánszki, A., Marini, L., Potts, S.G., Smith, H.G., Al Hassan, D., Albrecht, M., Andersson, G.K.S., Asís, J.D., Aviron, S., Balzan, M.V., Baños-Picón, L., Bartomeus, I., Batáry, P., Burel, F., Caballero-López, B., Concepción, E.D., Coudrain, V., Dänhardt, J., Diaz, M., Diekötter, T., Dormann, C.F., Duflot, R., Entling, M.H., Farwig, N., Fischer, C., Frank, T., Garibaldi, L.A., Hermann, J., Herzog, F., Inclán, D., Jacot, K., Jauker, F., Jeanneret, P., Kaiser, M., Krauss, J., Le Féon, V., Marshall, J., Moonen, A.-C., Moreno, G., Riedinger, V., Rundlöf, M., Rusch, A., Scheper, J., Schneider, G., Schüepp, C., Stutz, S., Sutter, L., Tamburini, G., Thies, C., Tormos, J., Tscharntke, T., Tschumi, M., Uzman, D., Wagner, C., Zubair-Anjum, M., Steffan-Dewenter, I., 2019. *The interplay of landscape composition and configuration: new pathways to manage functional*

biodiversity and agroecosystem services across Europe. Ecology Letters, 22(7): 1083-1094.

Morandin, L.A., and Kremen, C., 2013. *Hedgerow restoration promotes pollinator populations and exports native bees to adjacent fields*. Ecological Applications, 23(4): 829-839.

Noica, C., 1981. *Devenirea întru ființă*. Editura Științifică și Enciclopedică, Bucharest.

Prăvălie, R., 2013. *Climate issues on aridity trends of Southern Oltenia in the last five decades*. Geographia Technica, 1: 70-79.

Prăvălie, R., and Bandoc, G., 2015. *Aridity variability in the last five decades in the Dobrogea region, Romania*. Arid Land Research and Management, 29(3): 265-287.

Ricketts, T.H., Regetz, J., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Bogdanski, A., Gemmill-Herren, B., Greenleaf, S.S., Klein, A.M., Mayfield, M.M., Morandin, L.A., Ochieng, A., Potts, S.G., Viana, B.F., 2008. *Landscape effects on crop pollination services: are there general patterns?* Ecology Letters, 11(5): 499-515.

Sirami, C., Gross, N., Baillod, A.B., Bertrand, C., Carrié, R., Hass, A., Henckel, L., Miguet, P., Vuillot, C., Alignier, A., Girard, J., Batáry, P., Clough, Y., Violle, C., Giralt, D., Bota, G., Badenhausser, I., Lefebvre, G., Gauffre, B., Vialatte, A., Calatayud, F., Gil-Tena, A., Tischendorf, L., Mitchell, S., Lindsay, K., Georges, R., Hilaire, S., Recasens, J., Solé-Senan, X.O., Robleño, I., Bosch, J., Barrientos, J.A., Ricarte, A., Marcos-García, M.Á., Miñano, J., Mathevet, R., Gibon, A., Baudry, J., Balent, G., Poulin, B., Burel, F., Tscharntke, T., Bretagnolle, V., Siriwardena, G., Ouin, A., Brotons, L., Martin, J.-L., Fahrig, L., 2019. *Increasing crop heterogeneity enhances multitrophic diversity across agricultural regions*. Proceedings of the National Academy of Sciences, 116(33): 16442-16447.

Torralba, M., Fagerholm, N., Burgess, P.J., Moreno, G., Plieninger, T., 2016. *Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis*. Agriculture, Ecosystems and Environment, 230: 150-161.

Tscharntke, T., Karp, D.S., Chaplin-Kramer, R., Batáry, P., DeClerck, F., Gratton, C., Hunt, L., Ives, A., Jonsson, M., Larsen, A.E., Martin, E.A., Martínez-Salinas, A., Meehan, T.D., O'Rourke, M., Poveda, K., Rosenheim, J.A., Rusch, A., Schellhorn, N., Wanger, T.C., Wratten, S., Zhang, W., 2016. *When natural habitat fails to enhance biological pest control: Five hypotheses*. Biological Conservation, 204: 449-458.

Vălean, A.-M., Suciu, L., Tărău, A., Șopterean, L., Russu, F., Șimon, A., Chețan, F., Tritean, N., 2025. *Impact of shelterbelts on the diversity and dynamics of natural enemies in wheat agroecosystems*. Agronomy, 15(9), 2153.

Vijulie, I., Tîrlă, L., Manea, G., Achim, E., 2013. *Change of land-use patterns by planning field shelterbelts on farming lowlands vulnerable to water scarcity (Romania)*. Geographica Pannonica, 17(2): 37-45.