



# Policy brief

## Landscape Diversity Enhances Human Health

Diverse agricultural and forest landscapes enhance human physical and mental health. Even small land use changes can introduce health risks into the environment



### Key results

- Dramatic land use changes have reduced landscape diversity, threatening the benefits that biodiversity provides to human health and well-being.
- Diverse agricultural landscapes enhance ecosystem services, improve food quality, and support social well-being and mental health.
- Forests provide multiple human health benefits, strongly influenced by canopy density and species diversity. However, trade-offs between forest health outcomes must be considered.
- Forests with high species diversity and a variety of canopy structures effectively absorb air pollution.
- Diversity of tree species creates closed and dense canopies that help reduce health risks associated with high temperatures and heatwaves.
- Forests improve mental health and cognitive performance. Biodiversity enhances these psychological benefits.
- European rivers and watersheds reveal that even small land use changes, not only large-scale ones such as wastewater downstream of cities, can introduce antimicrobial resistance into the environment.



### Policy recommendations

- Adopt practices that enhance landscape heterogeneity, including maintaining semi-natural patches, using diverse crop rotations, and implementing agroforestry systems.
- Support and restore forest structural diversity by including diverse tree species, ages, and sizes to enhance forest resilience and increase human health benefits.
- Incorporate forests and other green infrastructures into urban planning to address local health needs, such as reducing air pollution, alleviating heat stress, and improving communities' mental health.
- Raise awareness among the general public, public health practitioners, and doctors about the mental health benefits of spending time in nature.
- Protect water sources by regulating livestock grazing near rivers and riparian areas, even small-sized, and implement additional steps in wastewater treatment downstream of cities.







## Context

Biodiversity provides multiple ecosystem services crucial for human health and well-being. An essential aspect of biodiversity, in addition to the diversity of genes and species, is the diversity of ecosystems and landscapes. **Landscape diversity** includes the variety of land cover patches and their sizes, shapes, spatial arrangement, and connectivity, and it underpins the diversity of habitats, ecological communities, and ecosystem functions. However, human-driven land use change has transformed 75% of the Earth's surface, mostly at the expense of forests, wetlands,

and grasslands, and has been the leading threat to biodiversity and natural ecosystems<sup>1\*</sup>. In parallel, the intensification of land management, including agricultural intensification and intensive use of forests and pastures, has led to landscape homogenization (Figure 1).

This brief presents findings on the relationship between landscape diversity in agricultural systems, forests, and riparian areas and species and functional biodiversity and the consequences for human health.



Figure 1: Intensification of land use leads to landscape homogenisation and decline in biodiversity (with farmlands as an example). (© European Union, source: European Court of Auditors, [special report 13/2020](#), figure 1)



\* Full citations are provided in the attached information sheet for this policy brief.



## Key results

In 2018, Biodiversa+ launched the BiodivHealth call to support research at the nexus of biodiversity and health. This policy brief highlights findings from three funded research projects: [FUNPROD](#), [Dr.FOREST](#), and [ANTIVERSA](#).

### Diverse agricultural landscapes provide multiple ecosystem services that benefit human health

Diverse agricultural landscapes support diverse ecological communities that provide ecosystem services that contribute to human health (Figure 2)<sup>2</sup>. While agricultural intensification contributes to higher crop yields in the short term, it leads to landscape homogenization, which diminishes the health and resilience of agroecosystems and undermines the provision of essential ecosystem services critical to human well-being<sup>2</sup>.

[Birkhofer et al.](#) showed that landscape complexity in cereal fields is correlated with species biodiversity. Landscape complexity was also associated with an

increase in ecosystem services such as soil organic content and pest control, but was linked to reduced crop yield<sup>3</sup>.

Eco-friendly agricultural practices that enhance landscape complexity can improve human health by providing a larger variety of ecosystem services, supplying higher food quality in terms of a lower chemical load of pesticides and fertilizers, and a higher nutritional value. Diverse agroecosystems also provide cultural services such as recreation, cultural heritage, and community gathering that are crucial for physical and mental health<sup>2,4</sup>.

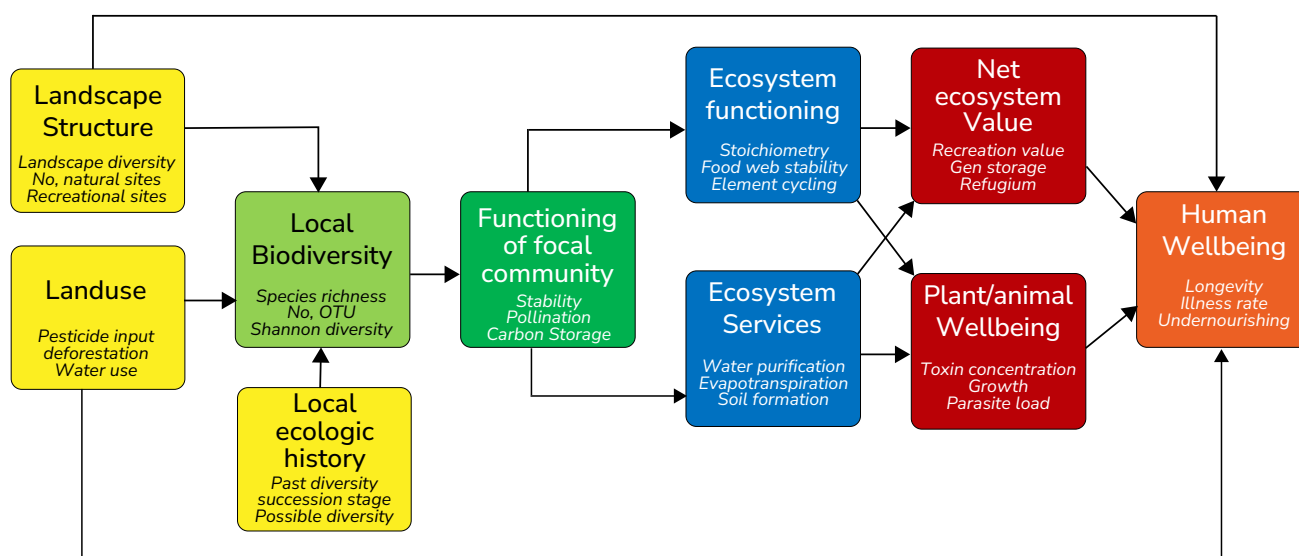


Figure 2: Pathways linking land use and landscape structure to functional diversity and human well-being with examples of possible ways of quantification in italic. (Source: adapted from [Ulrich et al. 2023](#).)

### Forest structural diversity is essential for ecosystem resilience and human health

Intensive management has led to simplification and homogenization of European forests and a reduction in forest diversity. One-third of European forests consist of only a single species, and 75% of forests are even-aged. Low diversity reduces forests' resilience, exposing them to risks like fires, pest outbreaks, and tree damage, which diminishes their capacity to provide wood, carbon sequestration, and human health benefits ([EC, 2023](#))<sup>5</sup>.

The [Dr. FOREST](#) research project developed a synthesis based on an interdisciplinary European forest network

that measured the relationship between different forest types and human physical and mental health. Results show that forests always generate overall health benefits for humans<sup>6</sup>. Canopy density and tree species diversity are the key drivers of human health outcomes. However, variation in **canopy densities** can generate trade-offs and disservices. For example, dense forests that are optimal for heat buffering and air pollution mitigation may reduce medicinal plant yield and increase Lyme disease prevalence<sup>7-9</sup>. The impact magnitude of **tree diversity** on human health is smaller than that of canopy density but is consistently positive



(Figure 2)<sup>6</sup>. Forest management should, therefore, consider these trade-offs to tailor forest biodiversity to

the local community's health needs.

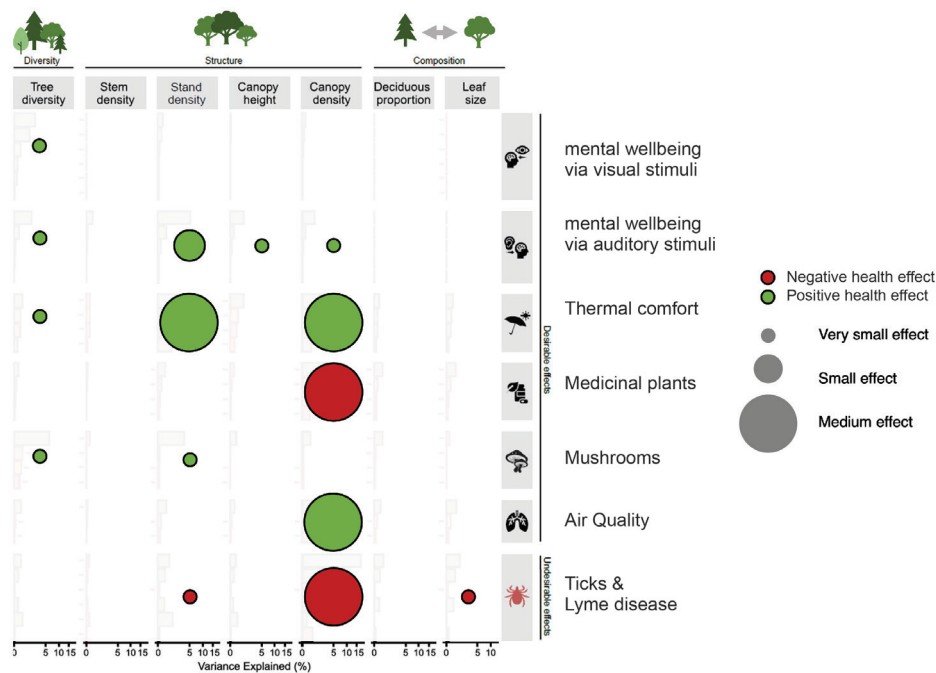


Figure 3: Effect of forest characteristics of tree diversity, structure, and composition on health outcomes (Source: adapted from Gillerot et al. 2024).

## Forest structure and composition improve the absorption of air pollution

Air pollution is one of the leading global drivers of premature death. Fine particulate matter (PM) under  $2.5\mu\text{m}$  ( $\text{PM}_{2.5}$ ) especially has adverse health effects and is most relevant to ambient air quality management<sup>10</sup>.

The Dr. FOREST project analyzed 190 tree species in Europe and found that evergreen conifers are the most effective tree type in attenuating air pollution because

they accumulate the most particulate matter of all sizes on leaves. Specific **leaf traits**, such as a leaf waxy coating and hairiness, played a significant role in trees' ability to retain air pollution<sup>8</sup>. Forest structure variables, including tree **species diversity**, total **leaf area**, and **canopy complexity**, significantly affect particulate matter retention<sup>10</sup>.

## Diverse forests mitigate thermal stress

Climate change and urbanization expose more people to heat stress, leading to excess morbidity and mortality. Gillerot et al. found that urban forests reduced perceived temperature by  $5.5^\circ\text{C}$  on average compared to paved urban spaces and by  $8.8^\circ\text{C}$  when ambient temperatures reached  $40^\circ\text{C}$ . Trees' cooling capacities are much stronger than shading by short vegetation or buildings<sup>11</sup>. Rural forests across European countries reduced the occurrence of days with extreme heat by 84%, reducing daily maxima by over  $10^\circ\text{C}$  in perceived temperature. The structure and composition of forests influence their cooling effect. **Dense trees** with closed and tall **canopies** and small-leaved **evergreen tree** species have the most substantial cooling effect<sup>7,12</sup>.



## Forest biodiversity improves mental health

In one of the largest experimental forest intervention studies, [Rozario et al.](#) demonstrated that spending time in a forest significantly enhances mental health. Forests reduce stress, increase positive emotions, and restore attention compared to built environments<sup>13</sup>.

The forest biodiversity *perceived* by people, probably related to high structural complexity, is strongly associated with positive mental outcomes<sup>13</sup> (Figure 4).

Acoustic diversity, reflecting the diversity of vocalizing animals, plays a crucial role in the mental benefits of spending time in forests. Higher acoustic animal richness was linked to improved spiritual well-being and positive emotions<sup>14</sup>. Intensive tree harvesting in forest management reduced stand age and structural diversity, thus reducing bird richness and acoustic diversity<sup>15</sup>.

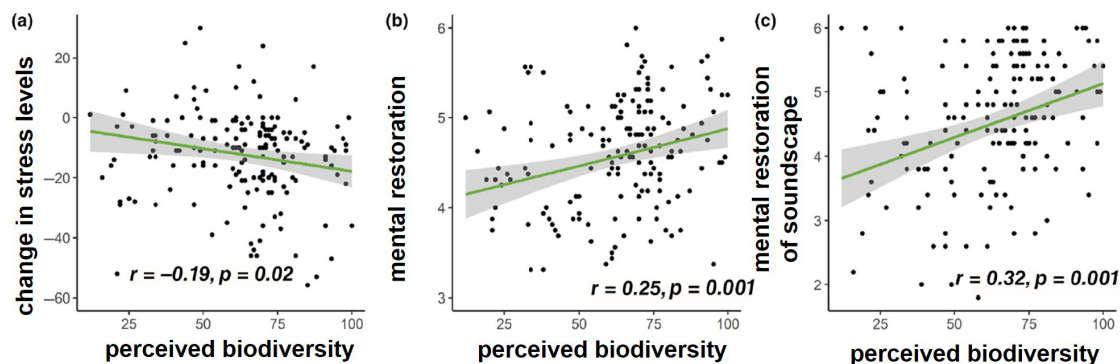


Figure 4: Relationships between perceived biodiversity and (a) change in subjective stress, (b) mental restoration, and (c) mental restoration of the soundscape (Source: adapted from [Rozario et al. 2023](#)).

## Urbanization increases antimicrobial resistance in the environment

Antimicrobial resistance is a global threat to animal and human health, driven by the overuse of antibiotics in humans and animals and their release into the environment<sup>16</sup>.

[Cacace et al.](#) found that effluent from urban wastewater treatment plants in ten European countries contained significant amounts of antibiotic resistance genes (ARGs). Importantly, these genes were also found in rivers downstream, indicating that wastewater treatment plants contribute to the spread of antimicrobial resistance in the environment. The concentration of antibiotic resistance genes in

wastewater effluent was inversely related to the number of treatment steps implemented<sup>17</sup>.

A study of remote mountain rivers in watershed heads found that the invasion of antibiotic resistance genes in river microbial communities (biofilms) appeared with the first signs of human impact, even small ones like the first houses or farming activities. This demonstrates that land use changes affect the presence of antimicrobial resistance in the environment, not just from large wastewater plants but also from the cumulative effect of free-range cattle and small villages<sup>18,19</sup>.



## Policy recommendations

Landscapes intersect social and ecological systems, where diverse land uses and values meet. Effective integrated landscape management can promote multifunctional landscapes with diverse land uses that simultaneously support biodiversity conservation and enhance human health. This approach requires collaboration among stakeholders across multiple sectors, including urban planning, agriculture, forestry, water management, and public health<sup>1</sup>.

Although the [BiodivHealth](#) research projects did not conduct specific studies on the effectiveness and

cohesion of current policies, nor were they assessed during the production of this policy brief, the research results highlight the importance of preserving and enhancing diverse landscapes to support biodiversity and human health.

- **Protect diverse agricultural landscapes** by incentivizing farmers and providing them with technical support to maintain mixed land uses, smaller fields, semi-natural patches, diverse cropping systems, and agroforestry as part of implementing

the [Common Agricultural Policy \(CAP\) 2023-27](#). Higher landscape diversity increases functional and species diversity, supports regulatory ecosystem services, and contributes to human health.

- **Accelerate the implementation of EU commitments to plant an additional 3 billion trees** by 2030 as a nature-based solution within the [European Green Deal](#) for climate change mitigation and adaptation, using mixed stands of native trees. Dr. FOREST's findings have demonstrated the role of trees in providing myriad physical and mental health benefits, including the reduction of the devastating human health consequences of heat stress.
- **Restore diverse forests with a diversity of tree species, ages, and sizes.** Biodiversa+-supported research demonstrated that forest biodiversity enhances human health benefits and promotes healthier and more resilient forests. Forest diversity can be enhanced as part of the new [EU Nature Restoration Law](#). [State aid Guidelines](#) under the CAP can incentivise the implementation of the European Commission's voluntary "[Guidelines on closer to nature forest management](#)" that aim to improve forest diversity as part of the new [EU Forest Strategy](#).
- **Integrate mixed species stand of forests and other green infrastructures in urban and landscape planning**, to support the specific health needs of local communities. For example, include **native evergreen conifers** in urban forests to maximize the removal of particulate matter air pollution or enhance **dense canopies** to protect from heat stress. Intermingled stands with deciduous trees to enhance biodiversity and resilience. This can be integrated into the [EU Nature Restoration Law](#) that aims to steadily increase green urban space areas and tree cover by 2030. Enhancing biodiversity as a nature-based solution to safeguard human health

within urban areas can also be included in the [Urban Agenda for the EU](#) and the [Green City Accord](#).

- **Raise awareness of nature's significant mental health benefits.** Educate public health practitioners, doctors, and the general public on the mental health benefits of biodiversity. Programs like "[Dose of Nature](#)," which helps individuals with mental health challenges by encouraging spending time in nature, exemplify the practical application of the findings on the mental health benefits of forests.
- **Protect rivers and riparian areas from antimicrobial resistance.** Strictly regulate livestock grazing near water sources to prevent water pollution and avoid the spread of antimicrobial resistance. This can be implemented within the [Water Framework Directive](#). The revised [Urban Wastewater Treatment Directive](#) can obligate **additional water treatment steps in wastewater treatment plants to minimize antimicrobial resistance** in water discharges to the environment.



#### Link to sources

[ANTIVERSA](#)  
[Dr.FOREST](#)  
[FUNPROD](#)

The scientific publications used in this policy brief can be found in the Information Sheet of this briefing, downloadable from:

[www.biodiversa.eu/policy-briefs/](https://www.biodiversa.eu/policy-briefs/)

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#### About this Policy Brief

This Policy Brief is part of a series aiming to inform policymakers on the key results of the biodiversity research projects funded by Biodiversa+ and provide recommendations to policymakers based on research results.

The series of Biodiversa+ Policy Briefs can be found at <https://www.biodiversa.eu/policy-briefs/>.

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