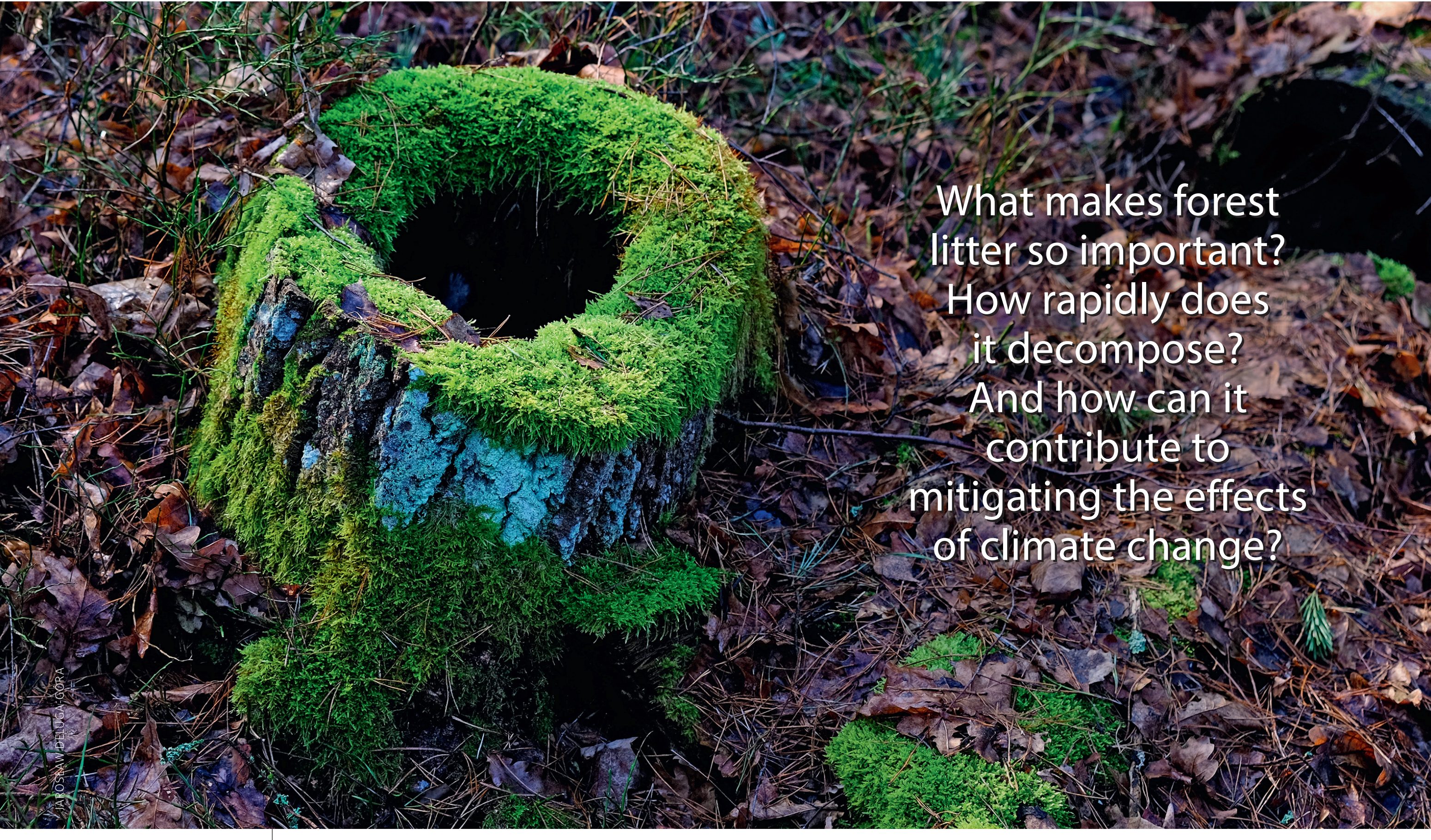
Forest Litter – a Life-Sustaining Component



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Forest litter is the name for plant material such as leaves, bark, needles and twigs which have fallen to the forest floor. However, the term "litter" of course more colloquially carries connotations of trash, waste, something which is redundant or even undesirable – and many people perceive forest litter as such.

Indeed, we rarely think of it at all, unless perhaps while out foraging in the autumn. Mushroom-hunters in Poland suddenly become experts on different types of forest litter – and, when they also have a good knowledge of trees, they have high expectations when out foraging. Silver birches and their litter are indicative of chanterelles and girolles, while open pine litter and its aromatic fragrance draws those in search of bay boletes. When litter is low on moisture during droughts, foresters frequently limit people's access to woodlands. And that tends to be it as far as the general public's understanding of forest litter goes; not many people are aware of the crucial role it plays in forest ecosystems.

Why is litter important?

As the uppermost level of soil, litter is an extremely important element of the natural environment. Nutrients in the decaying organic matter it contains are gradually mineralized, improving soil fertility. The quality of organic matter which falls to the forest floor, in combination with climate factors and the degree of development of soil life (edaphon – all organisms that spend a significant portion of their life cycles within a soil profile, or at the soil-litter interface), determine the rate of release and binding of macro- and microelements and make them available again to plants, fungi and animals. Extensive research has been conducted in recent years on the rates of decomposition of different kinds of litter under a range of conditions. As a result we can name the plant species whose litter accelerates chemical and energy cycling in ecological systems and those which slow down those processes, thus contributing to an accumulation of humified organic matter (amorphous organic fragments at various stages of decomposition). Leaves of trees such as alder, sycamore, elm, linden and ash decompose relatively quickly, making soil more fertile, while leaves and needles of trees such as beech, oak, pine and spruce decompose relatively slowly.

Decay processes

Litter does not always improve soil fertility. Everything depends on the condition of the soil at the outset. At the PAS Institute of Dendrology, we have been studying the rate of decomposition processes of litters originating from different species growing in postindustrial areas – those that have been heavily changed by human activity. Such soils tend to be at early stages of development: their organic matter content is lower than that of fully developed soils, they have lower microbial activity, and poorer general porosity and capacity to absorb and store water. In this instance, we can confidently state that decomposition of dead organic matter originating from any plants growing in such areas has a positive impact on the fertility of "reforming" soils.

In our research we analyzed the breakdown of leaves and needles of 14 tree species, revealing that some species were more beneficial in the process of replenishing top soil layers and improving the fertility of soil in degraded regions. For example, in mixed woodlands growing on spoil tips created by opencast lignite mining, the native tree species whose leaves decompose at the fastest rates are black alder, ash, elm, sycamore and aspen, while the slowest rates are shown by English oak, beech and Scots pine. We can also recommend planting several different tree species to provide the most beneficial ratio between the mineralized part of the litter (which returns biogenic elements into the cycle) and its humified part (which improves the physical properties of soil) during the decomposition process, as well as reducing the time required to return soil damaged by human activity (such as opencast mining) to an optimal condition. When recreating forest ecosystems at damaged sites, we should take care to improve the diversity of tree species. This is because decay processes occur at a faster rate in mixed forests than in monocultures of species such as beech or pine, which are commonly planted on terrain being reclaimed for forest stands.

Soil improvement

We can draw very different conclusions about how well the fertility of forest soil is improved by decomposing litter when we look at stands of specific species growing on sites with greater productive potential. The several tons of pine needles that fall every year on a hectare of a mature pine forest, growing on rich forest habitats, contribute to the degeneration of plant communities and excessive soil acidity. Fertile habitats that are inhabited by existing vegetation that is in line with their "potential vegetation" (a hypothetical state of affairs that would be reached if the growth tendencies of existing vegetation could be fulfilled immediately, without limitations resulting from human activity or natural destructive factors) maintain a relatively steady level of fertility and the breakdown of necromass is relatively fast. In turn, mineralization processes of dead organic matter release relatively lower levels of nutrients in woodlands growing on fertile soil, but with low numbers of species or even tending towards monocultures (for example pine or spruce), than in woodlands where actual and potential vegetation are in agreement.

In typical forest habitats, analysis of breakdown processes of specific types of litter allows us to determine whether we are likely to see processes of enrichment or degradation of the soil. This depends on factors such as species composition of the forest stand in the given area, and the quality of organic matter falling to the forest floor every year. With sufficient information at our disposal on the potential of development of upper layers of soil under given forest conditions, we can influence the process at other, similar sites. This enables us to prevent or curtail the effects of soil degradation, for example by changing the species distribution in a woodland. The rate of decay (and the associated ratio of mineralization to humification) is highly sensitive to habitat conditions, and more broadly to environmental conditions on the micro and macro scale; as such, any disturbance may affect the volume

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of elements available to plants, and, as a consequence, the rate of plant growth, increased biomass, net primary production and local carbon balance.

Forest litter vs. carbon

In the face of ongoing climate change, the extensively confirmed average temperature increases across the globe and the consequences of these facts, the stability and endurance of complex forest ecosystems are nowadays under great human-caused threat. The increasing concentration of greenhouse gases in the atmosphere is gradually warming our planet. Carbon dioxide, the best known of these gases and the one used as a gauge of global warming, reached a concentration of almost 409 ppm in the atmosphere in September 2019. In 1912, the year the Titanic sank, CO_2 concentration exceeded 300 ppm for the first time, while during the preindustrial era (before 1750), it had been just 280 ppm – a level which had remained steady over previous centuries. Average global temperatures have risen by approx. 1°C since then. The most pessimistic current predictions stipulate an increase of CO_2 concentration in the atmosphere to 1350 ppm by 2100, which is likely to increase average global temperatures by as much as 4.8°C in comparison to the preindustrial era. The global scale feels distant, seeming as though it does not concern us personally, yet the dramatic changes can be experienced close to home. According to direct measurements taken at the meteorological station at the PAS Institute of Dendrology, the average annual temperature in Kórnik has increased by approx. 1.6°C over the last sixty years. This should certainly give us food for thought.

According to many scientists, soil – or, more precisely, any habitat of which soil is just one component – serves as an important buffer against more rapid change. This is because soil stores the great majority of organic carbon bound in forest ecosystems, globally estimated to be around 2,500 metric gigatons; soil is defined as having a thickness of one meter, because organic carbon is rarely detected below this level. The estimates should also include the volume of carbon (approx. 1,100 metric gigatons) bound up in the world's peatlands, comprising only organic layers and with a considerably greater thickness than one meter. By comparison, the total carbon bound in plant biomass around the globe is approx. 500 metric gigatons. Furthermore, the total carbon accumulated in Earth's soil is two or even three times greater than that found in the atmosphere as CO_2. The most significant source of this element in soil is vegetation falling to the ground, decaying roots, fungi and bacteria, and products of metabolic activities of soil-dwelling organisms. All this means that as a component of forest ecosystems, litter is highly significant in counteracting climate change. Maintaining stable carbon reservoirs is essential for the CO_2 concentration in the atmosphere.

Condition of forest soils vs. climate change

Although soils are relatively stable in the context of ongoing global climate change, they are not entirely resistant to it. The condition of the uppermost layers of soil – they organic layer (of which litter is the visible part) and humus layer – and the amount of carbon bound within them – largely depends on the local climate and vegetation. In the tropics, chemical cycling in forest ecosystems occurs at a significantly faster rate than in other zones, therefore relatively more carbon is bound in plant biomass. The farther we are from the equator, the more the balance shifts towards litter. Additionally, soil condition (the amount of dead organic matter and carbon contained within it) is strongly affected by all kinds of disturbances to vegetation in all climate zones. And it has been shown in recent decades that such disturbances are increasingly common. Hurricane-force winds, vast wildfires and mass swarms of insects devastating crops can all

Litter in a sycamore forest


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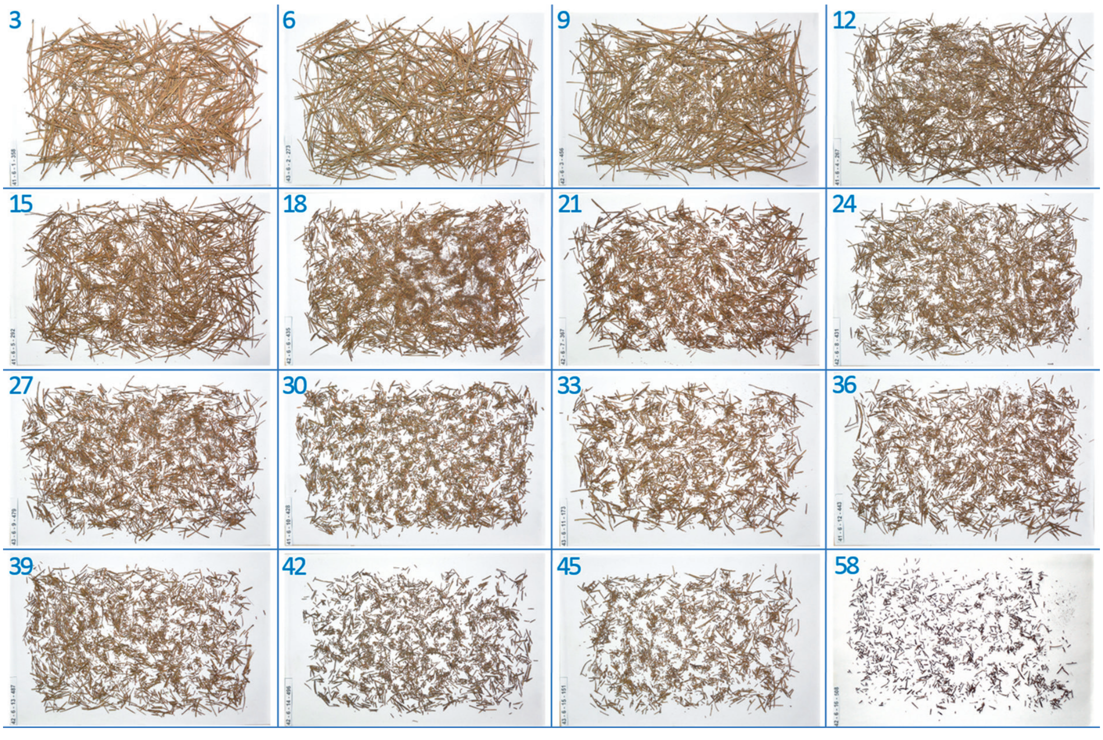

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Stages of decay of pine needles in mixed forests growing upon the spoil heap near the Bełchatów Opencast Lignite Mine. Numbers in the top-left corner of the images denote decomposition time (in months) from the start of the experiment

eliminate forest cover over huge areas. If soil lacks protection from vegetation, it is at risk of erosion, which in turn is followed by a release of huge volumes of CO_2 into the atmosphere. Locations where abiotic, biotic and anthropogenic (mainly resulting from forest management) disturbances do not occur are few and far between.

Swedish researchers, studying the condition of biomass of boreal forest floors, have found that on the smallest lake islands in Lapland, organic matter mass can reach 760 metric tons per hectare. This figure is significantly higher than for commercial forests in the region and other climate zones. The researchers found that the huge accumulation of organic matter is largely the result of rare disturbances to the local ecosystems. The islands are highly inaccessible, therefore they are excluded from commercial forestry. The most recent natural disasters – fires sparked by lightning – date back as far as three thousand years. When it comes to large landmasses, the probability of natural (and anthropogenic) disasters is considerably higher. The amount of biomass accumulated in such ecosystems is lower, both in terms of humified matter and biomass mainly composed of fast-growing tree species.

Commercial forestry, developed over the past centuries and conducted over vast swathes of land, has not only failed to improve (or at least maintain) the level of carbon in soil, but has had a negative impact on it. Although timber obtained from commercial forests serves as a long-term reservoir of carbon (apart from when it is used as fuel), large volumes of the element are released every time an area of soil is disturbed during logging. Additionally, in many countries land is prepared for forestry by deep ploughing of the soil. This can have catastrophic consequences, rapidly leading to mineralization of organic matter accumulated on the forest floor. However, forest managers are increasingly aware of the dramatic rate of climate change and understand the role played by forests in mitigating it, and as such they are trying to adapt activities currently in use in forest cultivation, such that any new plantations conducted as part of forest restoration, have the smallest possible negative impacts on topsoil. Today we are increasingly focusing on natural methods of forest regeneration. Additionally, before commercial forests reach the stage when they are ready for logging, they are increasingly being supplemented by young saplings which, with time, will become the main forest, thus ensuring the continuity of generations without extreme interference in the ecosystem. These activities bring together the main functions of forests: their commercial value of providing society with timber, and their environmental value of protecting soil from degradation. They also contribute to increasing the reservoir of carbon stored in forest ecosystems. According to estimates, changes in forest management strategies could increase this reservoir by an additional 50–100 metric gigatons globally in the coming fifty years. According to projections of the National Forest Carbon Management Programme, Poland's forests should capture an additional 37 metric tons of carbon per hectare over the coming thirty years.

Given the vast potential of forests in mitigating the effects of climate change, we should do everything within our power to protect forest soils and adapt current forest management strategies so that François-René de Chateaubriand's famous prediction, "forests precede civilizations and deserts follow them" does not come true. And let's not forget that carbon retention is hardly the only environmental function of forest ecosystems.