Why Won't Trees Save the Climate?

Every year Poland emits more CO_2 into the atmosphere than can be absorbed by all the forests in the country.

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Recently, the Polish media have been widely reporting on the idea of consciously using trees to counteract the effects of climate change. The proposal would likely have gone largely unnoticed had it not been voiced by Prime Minister Mateusz Morawiecki at the ruling Law and Justice (PiS) party's election convention in Katowice in July 2019, at which he vowed that 500 million trees would be planted by the end of 2019. This is not a completely new idea, as the previous Prime Minister, Beata Szydło, had mentioned it at the Paris Climate Summit (COP21) in 2015, and Minister of the Environment Jan Szyszko also spoke about it in an interview with Dziennik Gazeta Prawna on 3 August 2017. So this is a recurring concept, and moreover the plan is actually doable. The Polish State Forests, the institution which manages one-third of Poland's land, has been conducting sustainable forest management for decades. It is difficult to find a similar example, elsewhere in Europe or anywhere in the world, of such effective forest management on such a large scale, combining economic, ecological, educational and social aspects, so the idea of this institution striving to tackle a major existential challenge facing Poland should not surprise anyone.

What is more, the problem is a serious one: it is our country's strong dependence on the combustion of hard coal and other fossil fuels, resulting in the release of significant amounts of CO_2 into the atmosphere, one of the main factors responsible for managing our climate. CO_2 concentrations in the atmosphere are constantly increasing and this is undoubtedly related to the burning of fossil fuels. As to whether this is a correlation or a cause-effect relationship is up for discussion, but the fact is that the level of CO_2 in the

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Pine cultivation, Łochów Forest District

atmosphere is about one and a half times higher than at the beginning of the twentieth century. Because in the process of burning coal releases CO_2 that was absorbed by vegetation back in the Carboniferous era (over millions of years), the cause-and-effect relationship seems obvious. In the hot and humid Carboniferous climate, many plants were deposited in swamps, in anaerobic conditions. With increasing pressure, they became petrified and gasified over many years. So the notion of using plants (trees) to reverse this process would seem quite a simple one: since CO_2 was once absorbed by plants, maybe it will work again. Although things are not as simple as they seem, it's a good thing that trees and forests are returning in public debate as an important element of the country's climate policy.

But can planting these 500 million tree seedlings stop or delay climate change in Poland? Probably not stop it, but if it is done correctly and with a good understanding of how the climate in Central Europe will change over the next 50–60 years, we can locally mitigate some processes and delay others. Unfortunately, on the global scale, this will not be very significant. Poland covers only 3% of the continent, while the whole of Europe covers only 7.5% of the entire Earth. An independent initiative on the part of a medium-sized country, such as Poland, will have only a minimal impact on the overall global situation.

Replenishment is not enough

But let's get back to the notion of planting 500 million trees. In fact, this is not an unusual endeavor: for sustainable forestry, which we have had in Poland for many decades, this scale is actually routine. That's how many trees are planted every year in the Polish State Forests. Currently, these are almost exclusively planted to replenish trees already cut down. In addition, approx. 300 million more trees are planted every year in other (private) Polish forests and on other wooded lands, such as in fields, by the roadside, green areas in cities and on poorer quality soils. Tree nurseries provide the needed number of seedlings.

On a per-hectare basis, depending on the type of species and habitat, anywhere from 1,500 (larch) to 16,000 (pine) trees are planted. To calculate the area covered by Polish State Forests plantings, then, let us assume we are talking about planting various species of trees, both coniferous and deciduous, and the average number per hectare is 8,000 trees. From this it follows that to plant 500 million trees we need an area of approximately 62,500 ha. In addition, approximately 37,500 ha. are afforested outside the areas belonging to State Forests. In total, this gives approximately 800 million trees and 100,000 ha. per year. This is only one ninetieth of the forest area in Poland so it will not significantly increase that area, nor will it have any significant effect on CO_2 accumulation in the wood of planted trees. On the contrary, when we cut trees and remove them from the forest and replace them with young trees, the amount of CO_2-storing wood decreases in the area where felling occurred.

So if we want to really do something for the climate, we should enlarge the forested area in Poland to accommodate 500 million new adult trees.

Afforestation is key

According to the Polish Central Statistical Office (GUS), in 2018 the area of forests in Poland was about 9.2 million ha., meaning forests covered nearly 30 percent of our country. First, let's try to visualize some facts that might be shocking and hard for many people to imagine. Even if talking about planting 500 million trees is impressive, we must remember that only a small number of trees planted ever reach adulthood. For example, if we plant 8,000 trees on 1 ha., 120 years later only about 250 to 500 of them will remain! This, of course, is due to numerous operations necessary to maintain the proper condition of the stand, such as clearing and thinning (removing trees that are growing too densely), as well as natural processes such as the death of young trees, damage caused by animals, etc. Let's assume that 250 large trees remain on 1 ha. So, to ultimately end up with 500 million new mature trees, we would need an additional 2 million ha, on which we would have to plant 8–16 billion trees. We can see that there is a fundamental difference between the idea of increasing the number of adult trees in Poland by 500 million and that of planting 500 million new sapling trees from forest nurseries. Hence the question: do we have enough space for the former in Poland? Certainly, we could additionally afforest about 2 million ha of the agriculturally poorest land (V and VI valuation class) and mountainous areas, especially in the catchment areas of major Polish rivers, such as in areas of significant retention (increas-

ing flood safety at the same time). By so doing, we could afforest approximately 11 million ha. and increase the CO_2 storage potential of our forests by more than 10 percent. But will even this solve the problem of CO_2 emissions?

Will trees absorb all of the CO_2?

We can assume that one of the key causes of global warming is the increasing amount of CO_2 in the atmosphere. If so, planting additional trees will definitely help absorb some of this gas. If we assume that a 120-year-old tree has 1 t of dry matter (its trunk, branches, and roots), then this tree can store approx. 1.5 t of CO_2 (adopting a simplified conversion factor: approx. 1.5 t of CO_2 produces approx. 1 ton of cellulose, hemicellulose and lignin, the main components of wood). Thus, around 750 million tons of CO_2 can be stored away in 500 million 120-year-old trees. If we divide this number by the age of the stand, we get the amount of CO_2 stored annually. In this case, these additional 2 million ha. of forest will be able to lock away over 6 million tons of CO_2 per year. Will that be enough for trees to absorb the total amount of annual CO_2 emissions in Poland? No, because in a single year a little over 325 million tons of CO_2 are emitted in Poland (data from 2017). Indeed, that means that only two years of CO_2 emissions in Poland can be stored away in 500 million 120-year-old trees. It is easy to calculate that, at current rates, our total emissions over a period of one hundred years will significantly exceed 30 billion tons of CO_2! And this is still an optimistic number, because Poland's CO_2 emissions are actually increasing by 1–2 percent every year. So, unfortunately, simply increasing afforestation in Poland will not solve the problem.

Poland ranks seventh in Europe in terms of total forest area, behind Sweden, Finland, Spain, France, Norway and Germany. It is approaching 10 million ha., which means over 30 percent of its land covered by forests. However, if we take into account the country's entire area, the percentage that is made up of forests is not very impressive. In this case we rank nineteenth among EU and associated countries. Additional afforestation of the area needed for 500 million mature 120-year-old trees would bring Poland's forest cover to around 35 percent (this would put us in tenth place). This would be great news, of course, if it concerned new plantings, not artificial forest replenishment.

To compensate for 100 years of CO_2 emissions by our industry, energy and transport, it would not be enough to cover the entire area of Poland with forests (since there are about 500 trees per 1 ha. of a 120-year-old forest and Poland's total area is about 32 million ha., meaning that a forest covering the entire area of Poland could store about 24 billion tons of CO_2). But that would only be the case if we also stopped industrial logging, avoided forest fires, windfalls, and other natural disasters that would reduce the amount of CO_2 stored in forests. In a dynamic situation, when the forest life cycle would take 120 years, the average age of the stands would be about 60 years (as we have now). Thus, even with the whole country afforested, the amount of CO_2 stored would actually be about 12 billion tons, or about one-third of the projected hundred years' of CO_2 emissions.

Young spruce, Botanical Garden in Powsin

Forests alone are not enough

Whether we like it or not, forests in Poland cover about 30 percent of the country, not 100 percent. So how much CO_2 can they store annually? Let's also look at the upcoming threats to existing stands, which are directly and indirectly related to climate change and may threaten the current sequestration potential (CO_2 capture and storage) of our forests.

At present, in Poland, the average annual growth of timber (gross) per 1 ha. of forest is approx. 8 m^3 (approx. 5.3 m^3 of deadwood), i.e. approx. 4 t of dry matter, which means sequestration of approx. 6 t of CO_2/year/ha. We are interested in total wood biomass, not just deadwood (logs). Poland's forest areas that have the highest wood biomass include certain upland and mountain fir and spruce stands, with 1200–1400 m^3/ha. of deadwood (constituting about 60 percent of all biomass). Thus, the total wood biomass in such stands may reach about 2000 m^3. Let's

Young beech, Wolin National Park

assume that on average in a 120-year-old forest we can get half of this value, about 960 m^3 of wood per ha (taking into account the diverse classification of forest lands in Poland). The average age of trees in Poland is 60 years, which means that approximately 3.3 million tons of CO_2 should be stored on an area of approx. 9.2 million ha. This is equivalent to 10 years of CO_2 emissions in our country.

If we took into account gross wood production (without logging), our forests could neutralize about 55 million tons of CO_2 every year, about 17 percent of annual CO_2 emissions by Polish industry, energy, transport, and households. If logging took place at 50% of the gross annual growth, then this number would come to 27.5 million tons of CO_2 (which is about 8.5 percent of annual CO_2 emissions). As is plain to see, in any event, we will still need to drastically reduce CO_2 emissions.

Fires and CO_2

When it comes to CO_2 storage in forests, there is another interesting point worthy of discussion. Much has been said in recent years about the ecological function of forest fires. Research in Białowieża has shown that fires in this ancient forest were frequent, but with very limited reach. Traces of these fires have been found in still growing old trees and in the soil, in the form of barely decaying charcoal deposits. Charcoal is quite an interesting option for permanently introducing carbon into forest ecosystems. It is very valuable because it increases the water capacity of soils when a biologically active layer forms on its surface and, importantly, charcoal in forest soils can be deposited for thousands of years, so it affects subsequent generations of trees. This is noteworthy both in the context of the increased water deficit in soils, and the circulation of matter in nature. CO_2 is stored in a tree until its death, but when its wood decomposes or is combusted with oxygen, the CO_2 is released back to the atmosphere. However, if wood undergoes pyrolysis, a process of degassing at high temperatures in the absence of oxygen, it becomes charred and excluded from this circulation. This way, the equivalent (in artificial forest regeneration areas) of approx. 3 million tons of CO_2 per year can be stored in forest soils.

Certainly, an additional 500 million mature trees will have a positive impact on our local climate. However, looking at the tree-climate relationship, we should remember that it is trees that depend on the climate, not so much the other way around. Although at the same time they can contribute to the shaping of the (micro) climate locally, it is only once they reach maturity, because only then will they accumulate large amounts of CO_2 in their huge trunks, crowns and roots, and also contribute to reducing the albedo effect (diurnal temperature differences caused by sunlight reflecting from the Earth's surface), increase humidity locally, lower temperature and pressure, and also increase the likelihood of more regular rainfall in large areas of Poland. They also increase the soil's potential for water retention (especially if charcoal is also placed in the soil), and thus reduce the risk of flooding.

Believe the predictions

The gains would be great, insofar as climate change does not entail significant losses to our current stands, yet research shows that this process has already begun. This is despite the fact that trees have long lifespans and are highly adaptable to climate change. The present changes, however, are happening very rapidly, and the natural process of stand regeneration takes hun-

dreds or even thousands of years. Thus, if our region continues to experience steppe formation and desertification (aridization), as well as the mediterranization of its vegetation (vegetation becoming similar to that which is native to the Mediterranean), then our forest stands will become seriously threatened, and simply continuing to plant new trees as now will not bring expected results. What's more, it will generate considerable losses if the currently planted tree species are unable to adapt to climate change in the coming decades. This means that the cost of planting should take into account the expected changes in the ranges of individual tree species. What we can do is aid tree adaptation and accelerate stand regeneration, taking into account numerous variables affecting the species composition of forests over the next 50–60 years.

What then, according to predictions, should be and should not be planted in Poland over the next 50 years? To answer these questions, we must take into account a number of bioclimatic factors in climate change forecasts, such as temperature distribution, precipitation, sunlight, and wind force in 2080. Next, we must study the areas on Earth that currently have climates similar to that which is forecast for Poland in the future and examine what is growing in these areas. We will then know which species will survive the upcoming changes, what we should plant here, which alien species can stabilize the afforestation process, and how to replace the basic forest-forming species that have no chance of surviving the upcoming changes in our area.

Who stands to win?

Scientists from all over the world are trying to answer these questions, including a team of researchers from the PAS Institute of Dendrology in Kórnik, in collaboration with scientists from the Poznań University of Life Sciences and the Department of Forest Resources, Center for Forest Ecology at Minnesota University in the United States.[1]

They have plotted out the distribution of 12 tree species found in European forests, both deciduous and coniferous, for various climate change scenarios. They used data on the distribution of individual tree species from the Global Biodiversity Information Facility, EUFORGEN, and inventory data. They also took into account 19 bioclimatic variables. The model envisages three climate change scenarios for the years 2061–2080: optimistic, intermediate and pessimistic – including the various responses of individual tree species for the three different climate change scenarios. The studied species were divided into three groups (although in fact they are two functional groups): "winners," "losers" and "aliens" (with alien species also functionally being "winners"). The "winners" group includes the common fir, beech, common ash, pedunculate oak and sessile oak, which are, for the most part, late succession species. The "losers" group includes the silver birch, European larch, Norway spruce and Scots pine, mainly pioneering species, while the third group consists of the Douglas fir, red oak and black locust.

Due to the pace of climate change, most species will have to deal with significantly reduced areas of habitats suitable for their existence. The greatest threat is to species growing further south. Regardless of the extent of climate change, the ecological impact will be significant. These changes will have a huge impact on nature protection, in particular the preservation of biodiversity, as well as forest management.

Unfortunately, nearly all scenarios predict dramatic consequences for our Central European forests. It can be said that among the analyzed trees native to Poland, all will end up on the losing side.

Act with caution

And so it is certain that our forests will change. Will we actively participate in this change, helping them adapt (by planting in accordance with the predicted changes)? Will we fight to maintain the status quo of the current forest structure (still planting native trees based on local provenance), or will we leave everything to nature (not doing anything, allowing natural succession in deforested areas to take place)? Much will depend on communication between scientists, naturalists (including foresters) and politicians, as well as the pressure from the wood industry, whose interests often influence political decisions.

We are undoubtedly facing a difficult decision of whether we should wait or act. Considering that our forest regeneration cycle takes about 100 years, we should really start taking action now. Foresters are aware of these threats, but it is difficult to expect a multi-billion-zloty seed harvesting industry – including the system of storing, cultivating, distributing, planting and managing seeds – to change overnight based on predictions.

So before we go planting 500 million, or 16 billion trees, we need to know what trees to plant and where, so that decades from now they can properly perform their "climate functions" as CO_2 and dust absorbers, air humidifiers, water reservoirs, natural air conditioners, etc. And in order to learn this, we need to design appropriate studies and carry them out urgently, because when it comes to climate change, there is no time to waste.

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[1] Dyderski M.K., Paź S., Frelich L.E., Jagodziński A.M., How much does climate change threaten European forest tree species distributions? *Global Change Biology* 2018, 24 (3), 1150–1163.