The tundra is melting

Disturbing its vegetation has a dramatic impact on the tundra. Within a couple of years the permafrost is affected and the ground literally collapses. With massive additional emissions of the greenhouse gas methane as a result. **TEXT** NIENKE BEINTEMA **PHOTOGRAPHY** BINGXI LI, WAGENINGEN UR

The endless tundra in the arctic region looks like a changeless landscape, literally frozen in time. Yet this region is extremely vulnerable to collapse. One small change can have a big impact, as Monique Heijmans and her colleagues from the Nature Management and Plant Ecology chair group discovered. They removed the shrubs from 50 trial plots and monitored the plots for several years. The effect was dramatic: the permafrost, the permanently frozen subsoil, began to thaw and the tundra subsided. The area started to emit methane, a greenhouse gas 30 times stronger than carbon dioxide. This discovery merited publication last November in the authoritative journal *Nature Climate Change*.

One quarter of the surface of the northern hemisphere has permafrost in the soil, mainly in Canada and Siberia. The permafrost forms an impenetrable layer, metres deep. Only the top few decimetres of the tundra thaw in the summer. Plant roots, animal life, fungi and bacteria are all restricted to this uppermost layer. The permafrost

‘Small interventions can bring about big climate effects’

explains why the Arctic soil is so swampy in many places. The upper layer is badly drained because of the frozen ground beneath it. The result is the unique ecosystem of the Arctic lowland tundra, with its shrubs, grasses, mosses and lakes.

COLLAPSE

‘It is not news that the tundra is vulnerable,’ says Monique Heijmans. ‘The people who live or do research here know that. But our study has now made people in a much wider circle sit up and listen. The results show that it doesn’t take much to cause a literal collapse.’

Heijmans and her colleagues have been working since 2007 in the remote Kytalyk Wildlife Reserve in the Yakutia region in north-eastern Siberia, about 6500 km east of Moscow. A vast area full of lakes, rivers and their flood plains. ‘I think it’s beautiful,’ says Heijmans. ‘It is gently rolling thanks to old river beds and former lakes. The skies are very beautiful. Especially in the middle of the night when the sun doesn’t go down.’

The researchers set up a long-term experiment in the reserve. ‘We had 10 circular trial plots of 10 metres across,’ explains Heijmans. ‘In half of the plots we cut down the shrubs above the ground.’ These shrubs were *Betula nana*, dwarf birch, which forms a closed canopy at a height of no more than 20 centimetres. ‘We left the other bushes and grasses.’

They chose this experiment because it was clear that there is an interaction between tundra shrubs, climate and the state of the tundra. Heijmans: ‘In some places the ground is subsiding because of the thawing permafrost, after which the shrubs drown in pools of water. What will be the consequences of the loss of those shrubs? Will the thaw speed up then? That question is also relevant in the context of direct human disturbance to the tundra. In places where oil is being extracted or where seismic exploration is going on in search of oil, large tracts of tundra are stripped of their vegetation. That is also done for other infrastructure such as roads, buildings and airports. With this in mind, the Wageningen team wanted to do experimental research into the precise role of these shrubs.

INSULATING BLANKET

Within a year changes were taking place below the bare plots. The permafrost thawed to 5 centimetres deeper than usual and that increased to 15 centimetres over the four years of the experiment. The plots began to subside and became inundated. After five years they had subsided by more than 16 centimetres. In the depressions more than 10 centimetres more snow stayed lying than on the control plots. ‘That snow forms an insulating blanket,’ explains Heijmans. ‘The soil therefore does not freeze as hard in the winter as it normally would.’ In other words: a self-reinforcing process had been set in motion.

And not only because of the insulating snow. The newly formed lakes are also darker than the surrounding tundra, and absorb more sunlight and therefore heat. This reinforces the warming and with it the thawing of the permafrost.

‘What’s more, we took measurements that showed that the wet, disturbed tundra emitted methane,’ says Heijmans, ‘whereas the control plots actually store methane. On a world scale, then, what you see here is another self-reinforcing effect on global warming.’

Enormous quantities of organic material are stored in

the permafrost, containing as much carbon as all the currently living plants and animals in the world put together: more than 1600 gigatonnes. If the permafrost thaws, some of this carbon gradually seeps into the air in the form of greenhouse gas, as fungi and bacteria in the thawed soil break down the organic material which was hitherto stored in the permafrost. And it is not just carbon dioxide that is released, but methane as well.

MOTION ADOPTED

The news drew attention last November, including from the Dutch daily newspaper *De Volkskrant*. The very next day the Dutch Party for the Animals and the Socialist Party tabled a motion which was subsequently adopted. The motion asked the Dutch government to make a stand at international climate negotiations for keeping the arctic region free of oil and gas extraction. 'In itself, we shouldn't expect too much of that,' says professor Frank Berendse, group leader and senior author of the article in *Nature Climate Change*. 'The economic interests are enormous and anyway, there are powerful players like the US and Russia in that debate, and their attitude is none too cooperative, to put it mildly. But it is still important that politicians pay attention to unexpected feedback loops. And to the fact that small interventions can bring about big climate effects.'

Heijmans agrees. 'It is a very clear first signal,' she says, 'but now of course we want to take this further. We want to look at what happens in the long term. And colleagues from Amsterdam and Switzerland are working on measuring methane emissions on a far bigger scale. Of course you would like to be able to translate these small-scale experiments to a bigger scale – and ideally to other ecosystems as well.' Big differences can be observed even within the tundra ecosystems, she emphasizes.

ABSORBING HEAT

The shrub vegetation in Alaska, for example, is expanding now that temperatures are rising, without the tundra there collapsing. 'This is because it is higher, drier tundra,' says Heijmans, 'where the plants don't drown if the permafrost thaws. The shrubs are different too, and taller.' However, the shrubs in Alaska create a reinforcing effect of their own: they are darker than their surroundings, so they absorb heat. They also trap more snow than bare tundra does, so that the ground does not freeze as hard. 'So it is difficult to generalize,' concludes Heijmans. 'You will have to conduct specific experiments per region. That is a good example of how unbelievably complex that ecology is.'

'This study illustrates the enormous importance of long-term research,' says supervisor Frank Berendse. 'We have monitored these tundra plots for seven years, and we are still doing so. But less and less funding is available for this kind of research.' Everything has to deliver immediate results, he notes. 'In slow-growing ecosystems such as the tundra, especially, it is often a slow process.' ■

'SHORTS ARE NOT AN OPTION'

Monique Heijmans and five colleagues have been spending a couple of weeks every summer in a very remote part of north-eastern Siberia. 'We stay at a field station in a wildlife reserve that you can only reach by boat,' she says. Once there, you can only get around on foot, because it is a very swampy area.'

The researchers work in amongst the water birds and sometimes see Siberian cranes, reindeer, arctic foxes, wolves and muskoxen. Now and then a brown bear passes by as well. 'But most of all we see mosquitoes,' laughs Heijmans. 'You have to wear a mosquito net the whole time, otherwise it is unbearable. And that is quite a nuisance because it can easily be 30 degrees in the summer. But even then shorts are not an option.'

The field station consists of a few wooden huts and containers. Electricity comes from solar panels, water from the stream. A local cook prepares the meals over a wood stove. In the summer there is hardly any human activity in the area. Very occasionally a villager comes by to pick berries or fish. 'They often share some of their catch with us. The fish is delicious.'