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Transition to forest may threaten 20% of European peatlands

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Contact:
ype.vander.velde@vu.nl

Many northern European landscapes, including western Russia, are covered either by carbon-rich wetlands on thick peat soils, or by forests typically on thin organic soils – depending on the climatic and hydrological conditions. This study suggests that climate change and drainage can cause persistent shifts from one ecosystem to the other. Due to climate change, forests could overgrow peatlands on approximately 20% of European raised bogs, leading to the release of around 4% of European soil organic carbon. In addition, water conservation measures to restore degraded raised bogs will only be possible in 10% of Europe – where the climate still allows them to initiate and to outcompete forests.

Scientists have estimated that more than 65% of global soil organic carbon is found above latitude 35° north, which passes through the Mediterranean Sea, Southern Greece and Cyprus. Peat soils, in particular, store high levels of organic carbon which does not decompose in the waterlogged soil. However, if the vegetation changes the soil can dry out, releasing much of this stored carbon. This can happen as a result of changes in climatic conditions or because of human activities such as land drainage and forestry operations. This study aims to identify areas within Europe where peatland is at greatest risk from this process.

The researchers focus on areas that are capable of supporting either peatland or forest (which only supports a thin organic soil layer). The interplay between climate, subsurface, and local hydrological conditions control which state occurs – or whether both states are potentially stable for a particular landscape setting. In the latter situation, referred to by researchers as 'forest–peatland bistability,' the past trajectory and specific feedback processes determine which state currently prevails. The researchers argue that substantial areas of Europe are bistable in this way.

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Working from the bistability hypothesis, the researchers developed a landscape-scale model – incorporating vegetation, soil organic carbon and water and carbon cycling – to identify areas of Europe likely to support peatlands at risk of transitioning into forest under a trajectory of a warming climate and increased drainage. They use a proxy variable, which they refer to as 'groundwater flux', to represent the combination of physical factors affecting the flow of water through the soil. A negative value indicates that water drains into the soil; a positive value shows that it drains out of the soil (for instance in river valleys); and a near-zero value suggests overall water retention. By modelling groundwater flux against biomass (which is low in peatlands and high in forests) the researchers identify hydrological conditions compatible with both ecosystems.

The researchers identify four peatland types, but focus on raised bogs as the type at greatest risk of conversion to forest (and also covering extensive areas with a deep peat layer). By comparing quantified aspects of ecosystem resilience, the researchers classify zones capable of supporting raised bogs into three categories of sensitivity.

- **Highly sensitive areas** may already show signs of starting to shift to forest – they are very challenging to restore to peatland and are particularly susceptible to the effects of climate fluctuations or altered water-management regimes.
- **Sensitive areas** – where forests can still stabilise even with positive groundwater flux (water flowing into the soil) and where restoration of raised bogs would only be successful if water-storage measures and continued deforestation took place simultaneously.
- **Robust areas** – where forests can only exist under negative groundwater flux (high levels of drainage) and restoration of raised bogs would require less intensive intervention – by restoring the local hydrology.

Based on this model, the researchers report that 34% of European land could support raised bogs, consisting of 10% robust, 14% sensitive and 10% highly sensitive areas. The researchers estimate that these highly sensitive areas include more than 500 individual peatlands, and, if converted to alternative landscapes, could release up to 24 petagrams of carbon into the atmosphere – around 4% of Europe's organic soil carbon.

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The researchers acknowledge that their model does not incorporate the size of individual raised bogs, which can affect resilience, or soil temperature – thereby influencing ecosystem state. Nonetheless, they argue that the results demonstrate the importance of adopting a landscape perspective in peatland research and conservation activities. This requires considering interactions with landscape properties such as water-cycle processes and competing ecosystem states, they say. Without this perspective, they argue, policy efforts will be hampered in their attempts to address carbon storage, water management and biodiversity issues through peatland management.