CAN WE ANTICIPATE WHAT CLIMATE CHANGE DOES TO THE RECREATIONAL POTENTIAL OF THE LANDSCAPE?

Jan Deutscher, Lenka Šipanová
Department of Landscape Management , Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1, 61300 Brno, Czechia

https://doi.org/10.11118/978-80-7701-087-0-0056

Abstract
One of the most important factors that condition recreational potential of the landscape is landcover. At the same time, the existence of landcover types is heavily impacted by climatic conditions. In this article, we try to find links between landcover type changes in the future and their expected effect on recreational potential. Current landcover types are taken over from the CORINE inventory and predicted future climate date was purchased from the Czech Hydrometeorological Institute. The study Is performed in an upland experimental catchment representing similar areas in the Czech Republic. By analysing water requirements of landcover types via their potential evapotranspiration and available precipitation we conclude their current status quo and sustainability. Using predicted future climatic data, we track the increasing water requirements to the tipping point towards negative water balance. This indicates the need for change in landcover. There we arrive at a new sustainable status quo and discuss the associated changes in recreational potential between the two points in time.

Key words: Corine landcover, climate modelling, water balance, tipping point

Introduction
Climate change is one of the driving environmental factors in land cover change and both are intricately connected. In the conditions of Central Europe, forest ecosystems are the most affected (Cherubini et al., 2018). Forests meanwhile do not only produce wood and other non-wood products, but they are also responsible for several important ecological functions, notably recreational activities, and the psychic health of the population. Increasing temperatures, changes in precipitation patterns, and more extreme climatic events lead to decreasing forest stability. Under these conditions, their ability to fulfil their expected ecological and recreational roles is limited.

In this paper, we analyse water requirements of current landcover types via their crop coefficients, potential evapotranspiration (Allen et al., 1998) and available precipitation. Using predicted future climatic data, we track the increasing water requirements to the tipping point towards negative water balance. This indicates the need for change in landcover. There we arrive at a new sustainable status quo and discuss the associated changes in recreational potential between the two points in time. The climatic data were obtained from the Czech Hydrometeorological Institute, and they are an experimental combination of their global and local models which should be well suited to predict future local climate including the expected hydroclimatic extremes associated with climate change. The modelling exercise in this case is burdened with a lot of uncertainty being based on climatic models and evapotranspiration models with no real-world verification possible. Therefore, the results are not analysed using extensive statistical methods, rather a simple linear trend is used as an indication of expected changes. This paper aims to simply start a conversation of possible future scenarios using unique beyond state-of-the-art climate predictions.

Material and methods
The material for this experiment was the Nová Říše catchment (Figure 1.). It is the headwater catchment of the Řečice river located north of the Nová Říše reservoir and the streamflow in its discharge outlet is monitored by CHMI since 1980. The catchment is mainly covered by forest, almost 70 percent of total area which is 16,8 km^2 (Table 1) and is found in mean altitude of around 600 m a.s.l. Its soils consist mostly of the B hydrological category of soils (Janeček et al., 2012) and steep slopes represent more than 20% of total catchment area. These conditions can be described as indicative of a typical upland region. This catchment is used as a representative of other similar location in the CR.

Tab. 1: Basic hydrogeographic characteristics of the Nová Říše experimental catchment

Experimental Catchment Nová říše	
Catchment area	16,8 km^2
Mean altitude	602 m a.s.l.
Slope	Percentage of total area
Less than 10 %	78.45
More than 10 %	21.55
Hydrological cathegory of soils	Percentage of total area
B	85
C	15
Landcover cathegory	Percentage of total area
2.1.1. Arable land	17.83
2.3.1. Meadows	4.99
2.4.3. Arable land with vegetation	4.33
3.1.2. Coniferous forest	63.85
3.1.3. Mixed forest	4.15
3.2.4. Shrubs	4.85

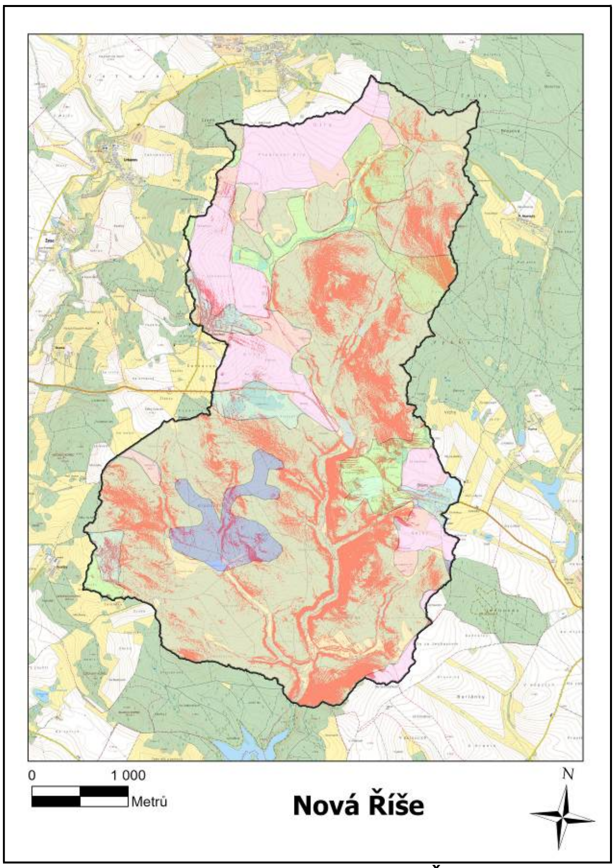

Fig. 1: Situation and localisation map of the Nová Říše experimental catchment

Our goal was to rely on maximum simplification and the use of freely accessible data from public specialized databases, we mainly used the following:

1. Research Institute for Soil Monitoring and Protection, v. v. i. (https://mapy.vumop.cz/mapa.php) – a large amount of information on soils in the Czech Republic is available here. For the purposes of the

project, we primarily used hydrological soil groups as an indicator of infiltration rate relevant for the realistic representation of water behaviour in the soil environment.

2. CORINE Land Cover mapping (https://landcover.cenia.cz/corine-land-cover/) – this is a pan-European mapping initiative in which the landscape is divided into specific land cover classes. Currently, data from 2018 is available. The land cover categories allow us to easily determine land use within the watershed. Individual categories may exhibit specific behaviours in relation to the water balance and evapotranspiration.

3. Czech Office for Surveying, Mapping and Cadastre (ČUZK) (https://geoportal.cuzk.cz/) – orthophotos and a digital terrain and relief model (DMR) are available here, which was used to determine basic slope and aspect ratios.

Climatic data

We obtained a set of experimental climate data (daily precipitation and temperature) from the Czech Hydrometeorological institute (CHMI) based on their Aladin climate projection model. The data are localised for the area of the catchment and represents a very long period 2015 – 2100. We used two different scenarios: RCP 4.5 and 8.5. to simulate an optimistic (4_5) and a realistic (8_5) climate scenario to allow better interpretation of the results.

Evapotranspiration

We used the climatic data to run a simulation of potential evapotranspiration development in the catchment area. We used the FAO56 paper guidelines to calculate it (Allen et al., 1998). We used the CORINE landcover categories and their respective crop coefficients to calculate actual evapotranspiration for each day (Nistor et al., 2018). From these daily values we than calculated yearly amounts.

Results

Here we present the results of climatic analyses of changing evapotranspiration and overall water balance in an upland experimental catchment until the and of the 21st century.

For the optimistic RCP 4,5 scenario, the changes in the water balance are not too profound (Figure 2.). The analyses of the linear trends indicate that temperature is steadily rising by 0,02 °C each year with ca 42 % accuracy, which is similar to evapotranspiration which also increases by 0,48 mm per year and 44 % accuracy. This increase in evapotranspiration seems to be off set by slightly increasing precipitation. The potential tipping seems to occur at around 2060 when the increase in temperature and evapotranspiration both seem to accelerate. It is likely that for the upcoming 20-40 years (2020s-2060s), the landscape should remain stable as is with no drastic changes in land cover. After 2060s however, it is likely that large scale changes in land cover will be needed.

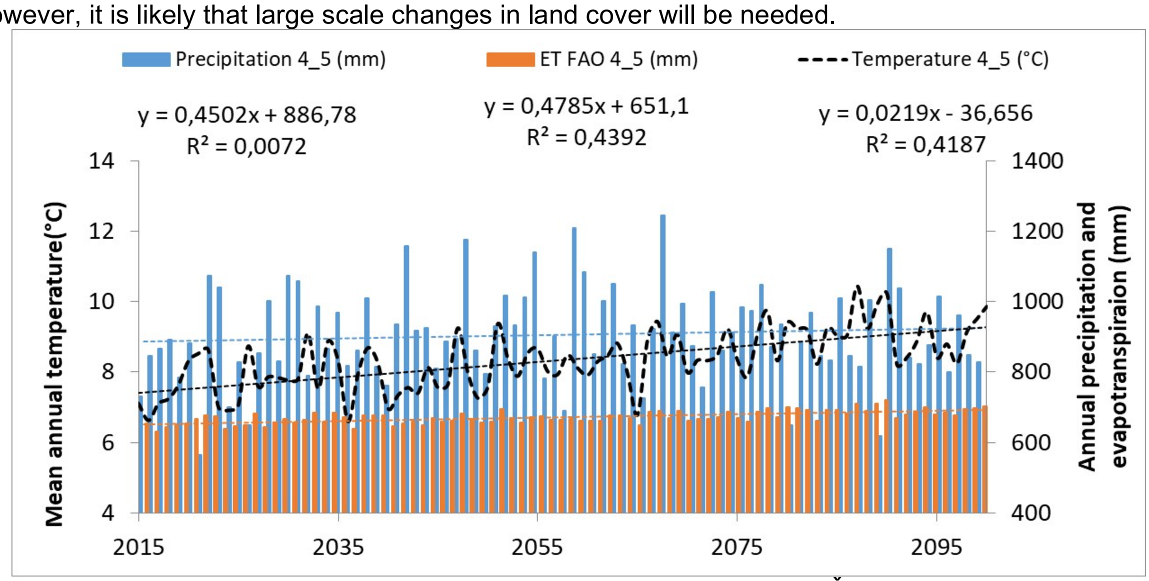

Fig. 2: Evapotranspiration development in the 21st century in the Nová Říše catchment according to the RCP 4,5 scenario

For the more realistic RCP 8,5 scenario, the changes in the water balance are more profound and occur significantly faster. The analyses of the linear trends indicate that temperature will be steadily rising by 0,05 °C each year with ca 68 % accuracy, which is again similar to evapotranspiration which will increase by 1,1 mm per year and 66 % accuracy. The potential tipping seems to occur already at around 2050 when the increase in temperature and evapotranspiration both seem to accelerate. It is therefore likely that already after the next 20-25, large scale changes in land cover will be needed. By the end of the century (2080) the evapotranspiration demands start to be so high that even the slightly increasing precipitation does not fully cover them. This indicates extensive changes in the landscape and a shift of climax vegetation from forest towards steppes.

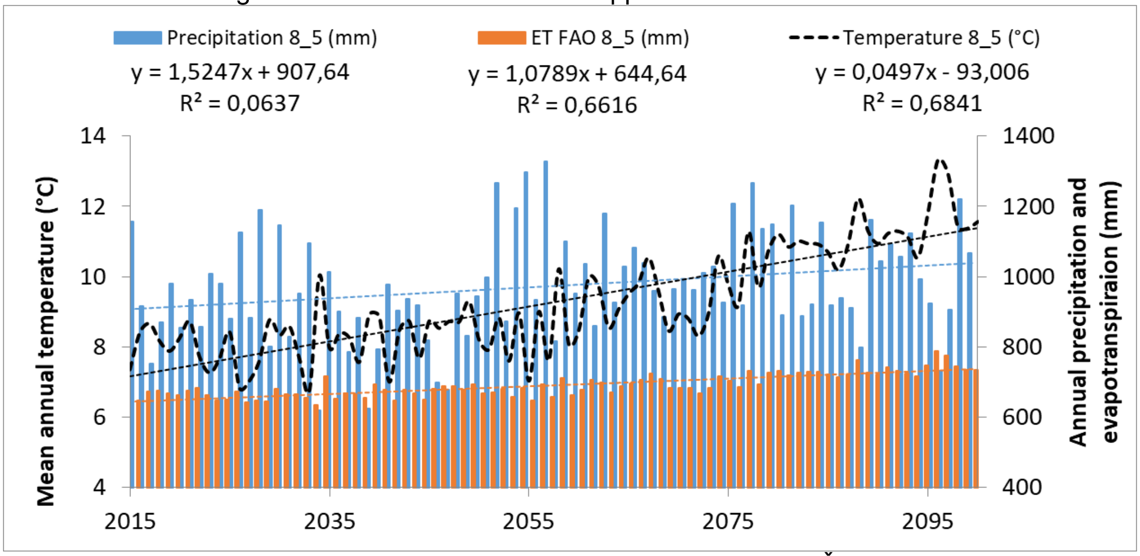

Fig. 3: Evapotranspiration development in the 21st century in the Nová Říše catchment according to the RCP 8,5 scenario

Discussion

Using the analysis of climatic projections, we were able to look into the future of the landscape and landcover types in the experimental catchment. We were able to identify tipping points when the evapotranspiration demands the current landcover types will be simply too high to sustain. According to which climate scenarios was used, already in the 2040s or 2050s the first tipping point could be reached. It is likely that the coniferous forests now covering more than 60 % of the catchment area will be very drought stressed and most of it will have to be replaced by some other form of landcover type (most likely different type of forest with less evapotranspiration demands and better drought resistance). At the same time, the arable land now covering more than 20 % will be in need of ever-increasing irrigation for sustenance. In the realistic RCP 8,5 scenario another tipping point was identified occurring in the 2080s when the very existence of forest cover seems questionable. It is likely that during this time, the forest as we know them will be very hard to keep alive and manage. A large-scale change from forest to steppe landscape cover can be expected.

It is important to understand that the recreational potential of forests and steppes can be significantly different. Forest ecosystems offer increased shading, more pleasant microclimate, aesthetic pleasure and greater feeling of cover and safety, which all support a range of recreational activities and psychic regeneration. On the contrary, steppes offer an open landscape with long views and specific biological richness, however due to higher exposition to sunlight, extreme heats, fierce winds, and limited shelter opportunities, their recreational potential is lower, or more seasonally dependent. Notably, large-scale deforestation to steppes in these latitudes can cause significant changes in other environmental benefits, notably: warming of regional climate up to +1°C in the summer months (Cherubini et al., 2018); the loss of microrelief supporting soil water recharge (Juřička et al., 2022); and the loss of stemflow supporting hotspots of infiltration (Hemr et al., 2023). All these secondary effects can play a role in further accelerating the negative climate changes. The difference in the recreational function of these ecosystems therefore lies not only in their physical characteristics, but also in visitors' preferences and specific environmental conditions. While forests are perceived as more versatile and comfortable for recreation, steppes represent a more specific type of landscape suited to less demanding or specialized forms of leisure activities.

Conclusion

Using unique beyond state-of-the-art climate predictions of local climate, we performed an analysis of actual evapotranspiration demands of current landcover types in an experimental catchment. We used freely available geographical data and standard FAO procedures to offer the most potential reusability of our approach. We were able to identify two tipping points when the evapotranspiration demands the current landcover types will be simply too high to sustain which will lead to largescale changes in land cover. We expect the move from forest climax towards steppes. These changes will have a profound effect on recreational potential since both ecosystem types are significantly different in what they offer the population in case of recreational activities. Most notably we expect a loss in the psychological health and regeneration which is uniquely attributed mostly towards forest ecosystems.

References

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *Fao, rome*, *300*(9), D05109.

Hemr, O., Vichta, T., Brychtová, M., Kupec, P., Žižlavská, N., Tomášová, G., & Deutscher, J. (2023). Stemflow infiltration hotspots near-tree stems along a soil depth gradient in a mixed oak–beech forest. European Journal of Forest Research, 142(6), 1385-1400.

Cherubini, F., Huang, B., Hu, X., Tölle, M. H., & Strømman, A. H. (2018). Quantifying the climate response to extreme land cover changes in Europe with a regional model. Environmental Research Letters, 13(7), 074002.

Janeček, M. a kol. (2012): Ochrana zemědělské půdy před erozí, metodika, Česká zemědělská univerzita Praha, Praha, 113 s., ISBN 978-80-87415-42-9.

Juřička, D., Valtera, M., Deutscher, J., Vichta, T., Pecina, V., Patočka, Z., ... & Pařílková, J. (2022). The role of pit-mound microrelief in the redistribution of rainwater in forest soils: a natural legacy facilitating groundwater recharge?. European Journal of Forest Research, 141(2), 321-345.

Nistor, M. M., Man, T. C., Benzaghta, M. A., Nedumpallile Vasu, N., Dezsi, Ş., & Kizza, R. (2018). LAND COVER AND TEMPERATURE IMPLICATIONS FOR THE SEASONAL EVAPOTRANSPIRATION IN EUROPE. Geographia Technica, 13(1).

Acknowledgement

This research was created as a part of the FESTIVAL project (TQ10000001) with the state support of the Technology Agency of the Czech Republic within the Water4all Programme.
I would like to thank Mr. Sherzod Ruzmetov for providing a useful Excell spreadsheet for the evapotranspiration calculations (https://github.com/sherzodr/agriclimuz).

Souhrn

S využitím jedinečných klimatických předpovědí místního klimatu, které přesahují současný stav techniky, jsme provedli analýzu skutečných požadavků na evapotranspiraci u stávajících typů povrchového pokryvu v experimentálním povodí. Využili jsme volně dostupné geografické údaje a standardní postupy FAO, abychom zajistili co největší potenciál pro opětovné použití našeho přístupu. Podařilo se nám identifikovat dva bod zlomu, kdy budou požadavky na evapotranspiraci u stávajících typů povrchového pokryvu prostě příliš vysoké na to, aby je bylo možné udržet. V závislosti na použitých klimatických scénářích by prvního bodu zlomu mohlo být dosaženo již v 40. nebo 50. letech 21. století. V realistickém scénáři RCP 8,5 byl identifikován další bod zlomu, k němuž dojde v 80. letech 21. století, kdy se samotná existence lesního porostu jeví jako nejistá. Lze očekávat rozsáhlou změnu krajinného pokryvu z lesního na stepní.
Očekáváme přechod od zralého lesního porostu ke stepi. Je důležité si uvědomit, že rekreační potenciál lesů a stepí se může výrazně lišit. Lesní ekosystémy nabízejí větší stín, příjemnější mikroklima, estetický zážitek a větší pocit úkrytu a bezpečí, což vše podporuje celou řadu rekreačních aktivit a psychickou regeneraci. Naopak stepi nabízejí otevřenou krajinu s dalekými výhledy a specifickým biologickým bohatstvím, avšak kvůli vyšší expozici slunečnímu záření, extrémním vedrům, prudkým větrům a omezeným možnostem úkrytu je jejich rekreační potenciál nižší, resp. více závislý na ročním období. Rozdíl v rekreační funkci těchto ekosystémů tedy nespočívá pouze v jejich fyzikálních vlastnostech, ale také v preferencích návštěvníků a specifických podmínkách prostředí. Zejména očekáváme ztrátu v oblasti psychického zdraví a regenerace, která je jedinečným způsobem připisována především lesním ekosystémům.

Contact:
Jan Deutscher
E-mail: Jan.deutscher@mendelu.cz