Simple visualization of climate change for improving the public perception in forest pathology

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Abstract. In several national and international meetings of forest and general plant pathology, when discussing possible causes of current arrivals of new alien pathogens in Estonia, we demonstrated the climate characteristic "monthly mean temperatures" as coloured grid-boxes, colours of which indicate the statistical relation of the definite months' characteristic to its' long time mean value. It was met with approval and evaluated as suitable and pictorial way for the visualization of shorter (until some few decades) drastically differing periods in climate warming for more trustworthy connecting of these two scientifically-experimentally only heavily connectable natural processes – climate warming and epidemics of alien forest pathogens. During the winters of the 20th century, apparently not only freezing, but also warming periods had caused serious aftermaths in forest pathology.

Key words: monthly mean temperature, invasions, alien pathogens, red band needle blight, ash dieback

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Introduction

The urgent need to mitigate and adapt to the climate change in different fields of human activities is becoming more widely understood in scientific and policy circles, but public awareness lags behind (Sheppard, 2005). Public understanding of the international efforts taken by the science for the mitigation of the all-round consequences of climate warming and, first of all, this warming itself, are often regarded as too abstract, not relevant to everybody or occurring too far in the future (Lutherbacher *et al*., 2004). For many people, climate change is only a remote problem and not the one of personal and professional concern, incl. in plant pathology (Boonekamp, 2012).

The way in which information is represented affects an individuals' interpretation and uptake. At the last decades serious efforts have been made for the rise of public awareness in the multitude of essential aspects of climate change and of related problems, often by the use of different visualization techniques. These are extending, depending of the problem and audience, from the very simple, artists' freehand sketching to the photo- and GIS (Geographic Information System) manipulations by computer imaging systems and other digital technologies, i.e. 3D object modelling, rendering and animation by computer-aided design, and image manipulation (Bostrom *et al*., 1994; Bord *et al*., 1998; Al-Godmany, 1999; Seacrest *et al*., 2000; Dockerty *et al*., 2005; Nicholson-Cole, 2005; Lester & Cottle, 2009; Jylhä *et al*., 2010).

There is a considerable evidence of the effectiveness of visualization as a teaching tool and its ability to enhance public cognition (Sheppard, 2005). The appeal of the visual format is that information presented in this way is absorbed and processed by the human brain much more efficiently than textual, numerical or even diagrammatic data (Dockerty *et al*., 2005).

Namely television has turned back the mode of human learning to an ancient age when most learning took place by what the human eye could directly see (Graber, 1990). In recent time, again, the impact of seeing is growing in teaching/learning processes, creating more realistic perception and, by that, building trust also to the numerical representations of different essential aspects and characteristics of climate change (Al-Godmany, 1999).

The aim of this work was to visualize by comparison of monthly mean temperatures of several periods, essential for actual problems in forest pathology – for better public perception of the obvious causal relations between the climate change and emergence of epidemics of currently breaking out forest diseases.

Material and methods

Monthly mean temperatures were represented by us in several national and international scientific meetings of forest and general plant pathology in the form of grid-boxes, which colours indicate the relation of the appropriate characteristic of a definite month to its long-time (1866–2011) mean value. The definite mean monthly temperatures of that long period, together with their variation characteristics are presented in Table 1.

The colour of every definite calendar month in its grid-box corresponds to the value class of standard deviation (Figures 1–3): light and dark blue – colder, red and blazing yellow – warmer than long-time mean, evaluated through the standard deviation: < 0.5 = colourless (white), 0.5–1 = light blue or red, and > 1 = dark blue or blazing yellow, respectively.

Even a relatively small (e.g. 1 °C in mean temperature) change in climate can have serious implications for a tree species, particularly if the change surpasses an environmental threshold that had previously restricted the development of certain of its pathogens (Woods *et al*., 2005). In this work the definite standard deviation limits (< 0.5, 0.5–1 and > 1) for the classification of mean monthly temperatures were selected proceeding from the same criteria.

Results and discussion

Among the environmental characteristics, it is definitely temperature that is most strongly determining climate warming, and, together with the precipitation, as a result, moving and tangling previous borders of the long-lasting Köppen climate classification zones in Europe (Jylhä *et al*., 2010) and elsewhere.

Therefore conventional ready-available climatological databases generally archive time series of monthly averages (temperature) and/or totals (precipitation sums). As it is known, also the Köppen climate classification combines the same two climate parameters, having multiple impacts on the

Table 1. Mean monthly temperatures, variations and standard deviations of calendar months for the period 1866–2011, registered in the Tartu-Tõravere meteorological station.

Tabel 1. Kalendrikuude keskmised õhutemperatuurid, nende dispersioonid ja standardhälbed Tartu-Tõravere meteoroloogiajaamas.

Calendar month / *Kalendrikuu*	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Temperature (°C) / *Temperatuur (°C)*	–6.3	–6.5	–2.8	4.1	10.5	15.0	17.2	15.6	10.8	5.4	0.1	–4.1
Variation / *Dispersioon*	14.8	15.1	9.3	4.3	4.1	2.7	2.7	2.0	2.3	3.8	5.2	9.8
Standard deviation / *Standardhälve*	3.9	3.9	3.0	2.1	2.0	1.7	1.6	1.4	1.5	2.0	2.3	3.1

environment, either directly or indirectly (the last: through the soil moisture, evaporation and runoff, cf. Jylhä *et al*., 2010).

During the twentieth century, from 1901 to 2000, the average air temperature in European land areas has increased by 0.8 ± 0.3 °C (Lutherbacher *et al*., 2004), which is, obviously, a change, not perceptible in every-day life and human cognition. The cited authors also found that during the 20th century the summer temperatures did not experience systematic warming relative to the earlier centuries (1500–1900).

Our grid-box scale was approvingly

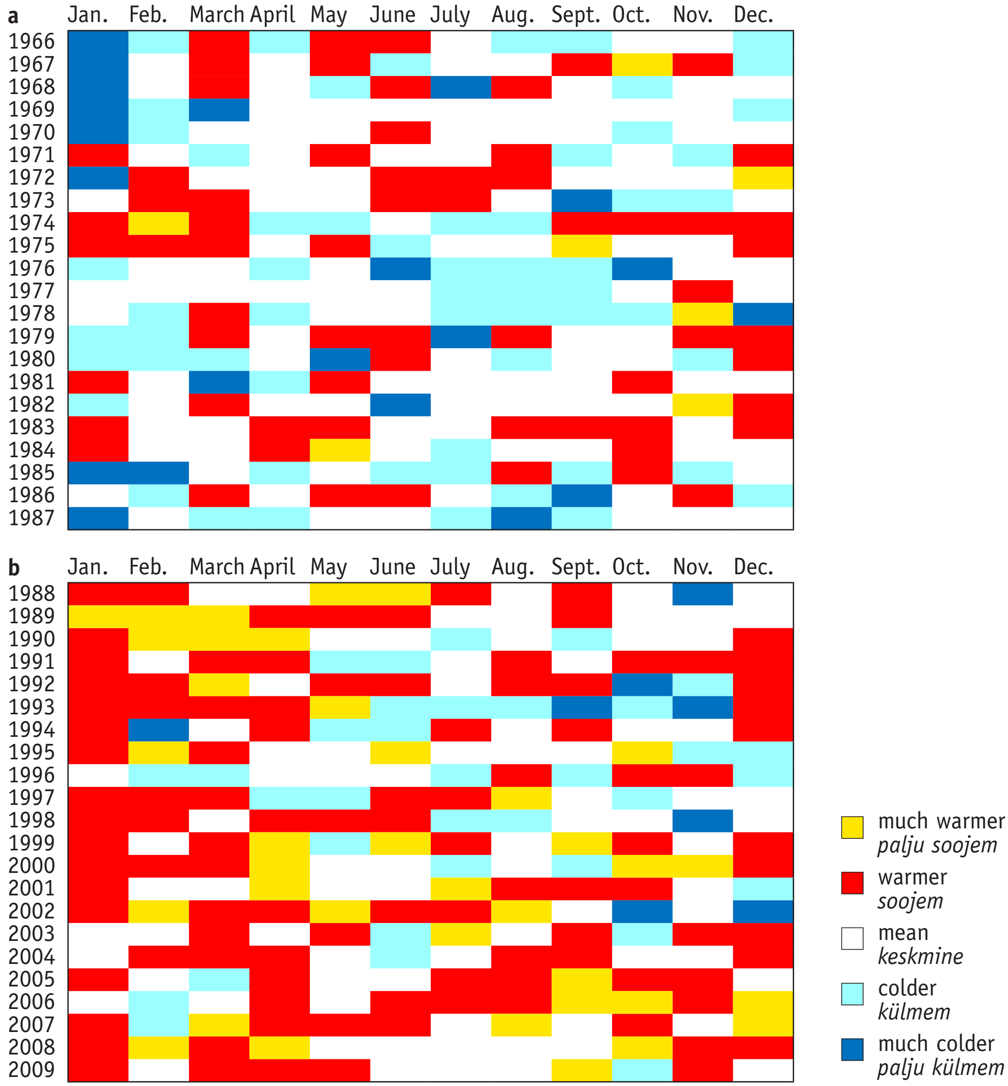

Figure 1. Visualization of climate change: Relation of air temperatures of definite months to the appropriate long period (1866–2011) means at the Tartu-Tõravere meteorological station for the periods 1966–1987 (a) and 1988–2009 (b).

Joonis 1. Kliimamuutuse visualiseerimine: konkreetsete aastate (vastavalt 1966–1987 ja 1988–2009) kalendrikuude keskmiste õhutemperatuuride suhted vastavate kuude pikaajalistesse (1866–2011) keskmistesse Tartu-Tõravere meteoroloogiajaamas.

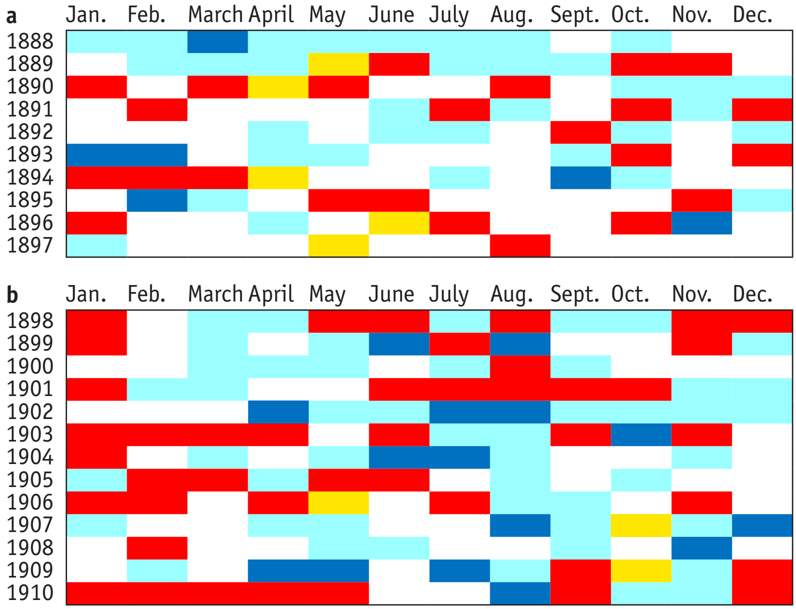

Figure 2. Relation of air temperatures of definite months to the long-time (1866–2011) means for the period 1888–1897 (a) and for the subsequent, immediately preceding the worlds' first record of *Cytosporina septospora* Dorog. (syn. *Dothistroma septosporum*) period 1898–1910 (b). At the later period (b) the winters were visibly warmer. Colours – cf. Figure 1.

Joonis 2. Aastate 1888–1897 ja 1898–1910 kalendrikuude keskmiste õhutemperatuuride suhted vastavate kuude pikaajalistesse (1866–2011) keskmistesse. Värvused – vt. joonis 1.

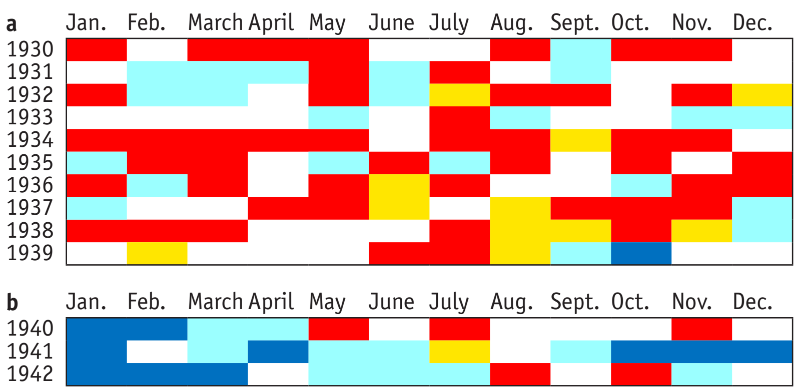

Figure 3. Relation of air temperatures of definite months to the appropriate long periood (1866–2011) means at the Tartu-Tõravere meteorological station for the period 1930–1939 (a) and following three years, 1940–1942 (b). This drastically cold (especially winters) period (b) followed an unusually warm decade (a). Colours – cf. Figure 1.

Joonis 3. Aastate 1930–1939 ja 1940–1942 kalendrikuude keskmiste õhutemperatuuride suhted vastavate kuude pikaajalistesse (1866–2011) keskmistesse. Värvused – vt. joonis 1.

accepted and evaluated by the colleagues in plant and forest pathology as easily remembered and convenient way for the visualization of the shorter, drastically differing neighbouring periods. From the theoretical spectrum of human responses to visual information (Sheppard, 2005) this gridbox scale should definitely address the cognitive response.

Climate and recent situation in forest pathology

During some few last decades, many different species of forest trees in different countries, incl. in northern Europe have been nearly simultaneously colonized by different invasive pathogens. This process has been often but only cautiously connected with the climate warming: in conifers e.g. the quarantine disease red band (or Dothistroma-) needle blight (e.g. Lewis & Welsh, 2005; Woods *et al*., 2005, Kirisits & Cech, 2006; Archibald & Brown, 2007; Hanso & Drenkhan, 2007, 2008; Watt *et al*., 2009; Fabre *et al*., 2011), in deciduous trees e.g. the devastating Chalara-disease of ash (Schumacher *et al*., 2007; Kowalski & Holdenrieder, 2008; LaPorta *et al*., 2008; Bakys *et al*., 2009; Drenkhan & Hanso, 2009b, 2010b). However, not everybody is ready to certify the substantially causal relations of these invasions with climate change. To give an absolutely perfect scientific verification to the classification of the recent climatic warming as to a factor, triggering or at least essentially supporting the arrivals of new pathogens, is nearly unrealistic, but to neglect the obvious dependence between the climate warming (visualized in Figures 1, 2 and 3) and colonization of Estonia by several fungal pathogens should be injurious to the science (cf.: in this case science as a powerless agent!) and, especially, to the practice of forest pathology and protection.

Similarly, first arrivals and records in Estonia of *Lecanosticta acicola* (Thüm.) Syd. on *Pinus ponderosa* Dougl. ex Laws. and *P. mugo* Turra, *Diplodia pinea* (Desmaz.) J. Kickx (syn. *Sphaeropsis sapinea* /Fr.: Fr./ Dyko and Sutton) on *Pinus nigra* Arnold, *Phaeocryptopus gaeumanni* (Rohde) Petrak on *Pseudotsuga menziesii* (Mirb.) Franco, *Hymenoscyphus pseudoalbidus* on *Fraxinus excelsior* L., *Cryptosporella betulae* and *Prosthemium betulinum* Kunze on *Betula pendula* Roth and *Pezicula sporulosa* Verkley on *Quercus robur* L. (Drenkhan & Hanso, 2009a, 2009b, 2010a, 2010b; Hanso & Drenkhan, 2009, 2010; Hanso & Drenkhan, 2004), *Melampsoridium hiratsukanum* S. Ito ex Hirats. on *Alnus incana* (L.) Moench (Hanso & Hanso, 2001), *Viscum album* L. on *Acer platanoides* L. (Kukk, 2007), *Didymascella thujina* (E.J. Durand) Maire on *Thuja occidentalis* L. (M. Hanso, pers. comm.), etc. were apparently related to the long-lasting period of climate- (seasonally especially: winter-) warming.

Long-lasting, uncontrolled introduction of alien tree species (or alien genets of the native species) has provided several of these invasive alien pathogens with their most proper nourishment already before their actual arrival in Estonia, helping them here, first, to colonize the new areas, and second, to be adapted to the new environment (e.g. by transfers to the native tree species). Severe winter temperatures (cf. Figures 1 and 2), which obviously had kept them away before, had disappeared during the latterly decades and removed by that the last obstacle from the way of these, mostly known as southern, alien pathogens. Two hard summer droughts in Estonia in 2002 and 2006 (in Central and Western Europe in 2003 and 2006) created in Estonia the weather environment, which resembled that of Central rather than Nordic Europe. Most of the shown above alien for Estonia species of forest pathogens can be classified as “southern” ones for they have been known in Central Europe already for a much longer time. Obviously, also native host trees, not acclimated to the abrupt and hard climate change, lost a lot in their resistance.

Climate a century ago and the worlds' first record of Dothistroma needle blight

The agent of the Dothistroma needle blight was first recorded and described as a new species (*Cytosporina septospora* Dorog.) by M. Doroguine in 1911 in St. Petersburg, North-Western Russia (Doroguine, 1911), i.e. in the close neighbourhood to Estonia and Finland. Drenkhan *et al*. (2013) consider it possible that at the time of the first sampling and describing of the fungus to the science a century ago, the fungus may have had actually much wider range in the Nordic area than only St. Petersburg.

We decided to look at the mean monthly temperatures of that period registered in Tartu meteorological station, visualizing for comparison again two preceding to the worlds' first record of this fungus periods: the earlier (Figure 2a) and the immediately preceding one (Figure 2b). Again, similarly to the recent, i.e. scientifically documented first record of the fungus in Estonia in 2006 (cf. Figures 1a and b), we could see a series of much warmer winters of the immediately preceding period than before it (cf. Figures 2a and b). In Turku, Finland also the growing season (with mean daily temperatures above 5 °C) started at the years of that immediately preceding period (1900–1910) later, with the lower than normal sums of effective temperatures, commonly characterizing the growing seasons of that area (Carter 1998). It was a factor, apparently supporting to the emergence even of an epidemic that time, although any documented evidence about the massive occurrence of the just discovered fungal species and the scale of damage to pines is lacking.

Climatically most severe period of the 20th century

After a decade (1931–1940) of comparatively warm weather in northern Europe (e.g. Vedin, 1990), extending in Estonia at all years' seasons (Figure 3a), in February 1940 a record-cold air temperature (–43.5 °C) was registered in Estonia. Starting with 1940 (with a short preceding "warning" in October 1939), the extremely cold period lasted during a couple of years (Figure 3b). During several earlier centuries, never before similar long series of extremely cold months as it happened from October 1941 until March 1942, both incl., had been registered in Estonia.

As it coincided with the Second World War, no proper investigations were carried out, concerning the extent of connectible with the climate damages on forest and verdant trees. However, some few pilot investigations were published here before and at the very beginning of the occupation of Estonia by the Soviet army, which happened already before the war. Hard damages of common ash and common oak stands were registered in Estonia immediately after this extremely cold winter of 1939/1940 (Mathiesen, 1940). Hard damages on ash trees, even somewhat resembling the current situation, were noticed nearly at the same time also in Lithuania (pers. comm. by Kestutis Grigaliunas), but no literature sources of that time about the attributable to climate change damages on trees could be found available in the neighbouring countries (Finland, Lithuania, Latvia and Russia), also involved in one or another way in that political crises.

Conclusion

Visualization of shorter drastic periods of some essential climate warming characteristics (like monthly mean temperatures) has improved the cognitive reception by the wider audiences of specialists in forest and general plant pathology, concerning the obviously causal relation of some extreme climatic periods with the first arrivals of economically important alien fungi and/ or epidemics caused by them. Divided by a century both first records (for the whole world and for Estonia, respectively) of the agent of Red belt needle blight *Dothistroma septosporum* on pines, but also the first registration of the disastrous *Hymenoscyphus* *pseudoalbidus* on ash species can be connected with the preceding extremely warm periods (especially: winters). On the contrary, the previous disastrous suffering of ash trees in history during the record-cold period 1940–1942 could be caused by an abrupt freezing, which, however, followed to a long-lasting series of mild winters. Consequently, the both, extreme freezing, but also warming periods during the winters of the 20th century had caused serious forest pathological aftermaths. Fully correct scientific-experimental verification of these relations is unrealistic, but the ignorance of these obvious connections between the climatic extremes and drastic events in forest pathology should be injurious to the applied, practical outputs of the science of forest and general plant pathology.

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Kliimamuutuste visualiseerimise lihtne viis seoste paremaks tajumiseks metsapatoloogias

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Kokkuvõte

Nii Eestis kui välismail toimunud metsa- ja/või üldise taimepatoloogia konverentsidel oleme oma ettekannetes uute invasiivsete haiguste saabumise põhjuslike seoste sidumiseks kliimamuutustega olnud korduvalt sunnitud kasutama lihtsat näitlikustamise viisi, sest rangelt teaduslik-eksperimentaalselt vastavaid seoseid tõestada on praktiliselt võimatu. Samas aga vastavate seoste ignoreerimine oleks nii teadusele kui praktikale rakenduslikult kahjulik.

Näitlikustamine võimendab esitatavate seoste tunnetuslikku retseptsiooni, materjali haaramist ja töötlemist inimajus märksa paremini kui tekstiline, numbriline või isegi diagrammiline esitlusviis. Just televisioon on tänapäeval sügavalt mõjutamas retseptsiooni ja seda protsessi võib isegi võrrelda antiikajaga, mil suurim tähtsus õppimisprotsessis oli sellel, mida inimene oma silmaga nägi.

Käesolevas töös esitatud kliimamuutuste lihtne näitlikustamine seisneb lühemate perioodide (kuni paar aastakümmet) kalendrikuude keskmiste õhutemperatuuride statistilises (standardhälbe) võrdlemises pikaajalise perioodi (antud töös 1866–2011) keskmistega ja vastava suhte esitamises värvilisena: punane ja leekiv-kollane – soojem, hele- ja tumesinine – külmem kui pikaajaline keskmine. Kriteeriumideks on vastavate kuude standardhälvete suurused: < 0,5 – värvuseta (valge), 0,5–1 – vastavalt punane või helesinine, > 1 – leekivkollane või tumesinine.

Teatavasti juba 1 °C-ni ulatuv keskmise õhutemperatuuri muutus võib osutuda metsapatoloogias kriitiliseks, kui näiteks seni takistuseks olnud madal talvine õhutemperatuur on takistanud mõne lõunapoolse patogeeni invasiooni Eestisse. Lõunapoolse päritoluga võõr-puuliikide kontrollimatu introduktsiooniga Eestisse on neile invasiivsetele patogeenidele juba ette tagatud neile oma kodumaalgi sobivaim olnud „toidulaud” ja kui nüüd ka seni takistuseks olnud madalad õhutemperatuurid enam takistuseks pole, on invasioon vältimatu.

Punavöötaud (haigusetekitaja *Mycosphaerella pini*, anamorf *Dothistroma septosporum*) mändidel ja saaresurm (*Hymenoscyphus pseudoalbidus*, anamorf *Chalara fraxinea*) kui tänapäeval akuutseimad, kuid niisamuti karantiinne pruunvöötaud (*Mycosphaerella dearnessii*, anamorf *Lecanosticta acicola*), seni eestikeelse nimeta haiguse tekitaja *Diplodia pinea* (syn. *Sphaeropsis sapinea*), ebatsuugapudetõbi (*Phaeocryptopus gaeumannii*) ja elupuu-pudetõbi (*Didymascella thujina*) okaspuudel, kuid samuti lehtpuude uued patogeenid *Cryptosporella betulae* ja *Prosthemium betulinum* kaskedel, *Pezicula sporulosa* tammel, *Melampsoridium hiratsukanum* leppadel ja *Viscum album* vahtral on ilmselt kliimamuutuse mõjul meile saabunud või olnud vähemalt mõjutatud sellest.

Punavöötaudi tekitajat kirjeldati esmakordselt 1911. aastal Peterburis. On oletatud, et *D. septosporum* võis tol ajal esineda ka meil. Käesolevas töös demonstreerime, et kõnealuse seene esmaleiule oli eelnenud märksa soojemate talvedega periood, analoogselt tema esma-avastamisega Eestis 2006. aasta materjalis.

Ka möödunud sajandi karmima talveilmastikuga perioodile (1940–1942) eelnes märksa pehmemate talvedega aastakümme.

Käesolevas töös paarikaupa vastandatud, vahetult üksteisele järgnevad, paarikuni paarikümne aasta pikkused, drastiliselt erinevate õhutemperatuuridega perioodid peaksid lugejat veenma kliimamuutuste ilmselt olulises rollis metsa- ja üldises taimepatoloogias, eriti aga selle rakenduslikus väljundis; olukorras, kus rangelt teaduslikult on vastavaid seoseid tõestada praktiliselt võimatu.

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