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*Regular research paper*

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# PINE ECOSYSTEM RESPONSE TO WARMING ALONG NORTH-SOUTH CLIMATIC TRANSECT IN EUROPE: PRESENTATION OF RESEARCH PROJECT

ABSTRACT: An attempt was made to evaluate the response of the ecosystem to changes of climate in ten pine forest stands. It was assumed that the ecosystem response to environmental change can be evaluated by examining differences in ecosystem structures and would be measured through the change in the rates of ecosystem processes. The changes of structures and rates are registered along the longest, N-S transect available on the European Continent above 50° N. This transect is within the belt crossing Northern Scandinavia (Norway and Finland up to 70°N), the Baltic States (Estonia, Latvia, Lithuania) and Eastern Poland (from 50°N). The transect covers 20 degrees of latitude and is more than 2000 km long. The difference in average annual temperature (long-term measurements) between the two extreme sites exceeds 9° C, and there is a regular southward increase of average site temperature. Precipitation does not show any regular pattern of change along the transect. Average site elevation is 86 m a.s.l., and the average forest age 110 years. All sites are dominated by an overstory of Scots pine, and in the Braun-Blanquet classification they all belong to Vaccinio-Piceetea class of forests, which are common in Europe.

During four years of study (1997, 1998, 1999 and 2000) four expeditions to the transect were organized. The following studies were conducted on each site: the origin and structure as well as physical and chemical features of soils; tree stand age, height, basal area, biomass and carbon content; vertical and horizontal structure of ground vegetation, its diversity, biomass and carbon content; litter fall, its decomposition and accumulation; and radial growth of trees.

KEY WORDS: pine forest response to warming, transect studies, macroecology

## 1. PRESENTATION OF PROJECT ASSUMPTIONS

The change in the global climate, anticipated and most probably occurring now, is expected to produce changes in the funtioning of terrestrial ecosystems. The rich ecological literature dealing with this subject has resulted in the development of a variety of proposed methods meant to evaluate the changes in ecosystems. These include laboratory treatment of individual organisms with differing doses of $CO_2$ and different thermal regimes; experiments more closely approximating natural conditions (through the "open chambers" in which various simulated climates are applied to plants or habitat fragments); studies of the reactions of ecosystems to artificially manipulated climatic conditions (i.e. the heating of the tundra soil, reported by Strömgren *et al.* 1999) or experiments in alpine tundra described by Zhang and Welker (1996). Studies of not manipulated ecosystems on natural gradient of rising temperature were selected as methodology in this program. These comparative analyses of the same type of ecosystem functioning over suitably long periods of time in different climates are probably closest to expected ecological systems response to warming. Certainly, the use of such method avoids the problems linked with extrapolation of results from the laboratory or semi-laboratory conditions to the one existing actually in the field. Also it reduces the risk that the ecosystem response to the sharp experimental intervention may be unpredictable or chaotic. At the same time we avoid "two obvious and fundamental weaknesses" of ecosystem studies discussed by Parry (1995): "*Firstly we have inaccurate information on their present-day sensitivity to climatic variability.... and secondly most impact models treat the predicted climatic anomalies as sudden changes in the climate rather than as a gradual change in the mean over perhaps several decades*".

Published scenarios and considerations on global warming repeat rather similar estimations of temperature change (starting from Bolin *et al.* 1986). We refer here to the Reports of IPCC (Intergovernmental Panel on Climate Change), chapter 13 "Europe" (acc. to Kundzewicz and Parry 1999), and we shortly summarize the selected, interesting for this paper records and indications from the models.

The instrumental record for Europe indicates a secular rise in average temperatures of about 1°C. This may be forced by greenhouse gases and have an effect on weather dependent processes in ecosystems.

Used in the IPCC Report climate change scenarios for Europe are adapted from ACACIA Project (Hulme *et al.* 1999). These scenarios base on the period 1961-90 and predict changes in mean 30-year climates for 2020s (2010-2039), 2050s (2040–2069) and 2080s (2070–2099). The predictions of temperature change for four scenarios are shown in Table 1.

Climate change is expected to be greatest at high (>50°N) latitudes (Broccoli *et al.*,1998; Rind 1999). According to some calculations forests of these latitudes contain ~25% of terrestrial aboveground C and ~60% of terrestrial belowground C (Dixon *et al.* 1994).

In gradient-related ecosystem research, stability is assumed in all environmental factors except for the one studied, which varies gradually but sufficiently to modify the functioning of the ecosystem. The correlation between the changes in the factor being studied and the observed departures in the structures – functions of the ecosystem is considered to express the cause-effect relationships. Ideally, ecosystems that are selected carefully to be similar may also be treated like the same ecosystem subjected to the gradually changing intensities of a given factor. Gradients in space are thus considered, within limits, as substitutes of gradients in time, which would affect the ecosystem if it experienced the increasing action of the factor under consideration.

The response of ecosystem to the environmental stress can be measured via the responses in the main processes occurring within them, including mainly the production and decay of matter (Breymeyer 1997, Breymeyer and Laskowski 1999). As the rates of ecosystem processes are measurable, the responses of ecosystems to stress are also measurable.

Along the transect studied, the functioning of ecosystems was evaluated by rates of following processes:

Table 1. The four scenarios of global temperature rise (Estimates are for the 2050-2055). Temperature and sea-level changes assume no aerosol effects and are calculated from a 1961–90 baseline. C is annual carbon emissions from fossil energy sources, ΔT is change in mean annual temperature (McCarthy *et al.* 2001)

| Scenario name/ climate sensitivity | Global population (billions) | C emissions from energy (GtC) | Global ΔT (°C) |
|---|---|---|---|
| B1-low/1.5°C | 8.76 | 9.1 | 0.97 |
| B2-mid/2.5°C | 9.53 | 11.7 | 1.58 |
| A1-mid/2.5°C | 8.54 | 14.7 | 1.63 |
| A2-high/4.5°C | 11.67 | 18.8 | 2.64 |

• measuring litter fall, the rate of its decomposition and accumulation;

• measuring the tree ring increments as an index of wood production during last 100 years (mean age of pine on our stands);

• evaluating the different litters accumulation in forest bottom;

• determinig the actual pine trees growth;

• determining the organic carbon accumulation in different soil layers.

The studied structural features of forest ecosystems refer to soil and vegetation. The registered composition and structure of vegetation were used to group plant communities according to phytosociological classification. The forests in Poland and in Central and Western Europe have been described and classified by using the Braun-Blanquet system, and the maps of natural vegetation of Poland and Europe have been established. The forests studied in our program have been described in accordance with this classification and any departures from expected pattern were registered (for the detailed description see Degórski 2003, Nagel *et al.* 2003; Pärn 2003, Roo-Zielińska 2003, Solon 2003, Solon and Roo-Zielińska 2003, papers in this volume). Sala *et al.* (2000) and Chapin *et al.* (2000) suggest that global warming will modify the structure of the temperate and boreal forest seriously.

The present volume consits the fourth set of papers introducing the results from our transect studies.The first collection was printed in 1998 as Proceedings of the "International Symposium on Air Pollution and Climate Change Effects on Forest Ecosystems", Feb. 5–9,1996, Riverside, CA, Eds: A. Bytnerowicz, M. Arbaugh and S. Schilling; the second collection entitled "Changes in Forests on the Climatic and Air Pollution Gradients in Poland ", was printed as part of Environmental Pollution 98 in 1997 (Breymeyer *et al.* 1997); and third collection printed in 1998 under the title "Pine Forests in Central European gradient of continentality and pollution – geoecological studies" was edited by A. Breymeyer and E. Roo-Zielinska (1998).

## 2. TRANSECT DESCRIPTION

The respective studies were performed by an international team of ecologists and geographers in the years 1997–2000 at 10 pine forest stands distributed along the transect crossing the Eastern and Northern Europe in the N-S direction, at the length of roughly 2 000 km. The transect was situated between Northern Finland (the parallel of 69°, the vicinity of Kevo, the Field Station for Arctic Studies of the Turku University) and South-Eastern Poland (the parallel of 50°N, the vicinity of the town Zamość) (Table 2, Fig. 1). In 1999–2000 samples were also taken from a Norwegian site located even farther North in the Stabbursdalen Park (N 70°08'59", E 24°47'17"). The climatic data gathered for this location were from the weather station Banak, situated on the fjord, where winters are more mild; we are looking for climatic measurements closer to our study stand.

The transect represents a regular, distinct warming with the southward movement

Table 2. Localization of 10 study sites in geographical regions

| Site No. | Localization | Site symbol | Geographic position |
|---|---|---|---|
| 1. | The Stabbursdalen Region (Norwegian Lapland) | NO1 | (N 70°08', E 24°47') |
| 2. | The Kevo Region (Finnish Lapland) | FN1 | N 69°44', E 27°01' |
| 3. | The Oulu Region (Oulu Lowland) | FN2 | N 64°43', E 26°01' |
| 4. | Punkaharju (Finnish Karelia) | FN3 | N 61°39', E 29°16' |
| 5. | The Parnara Valley (Estonian Lowland) | ES1 | N 58°18', E 24°59' |
| 6. | The Lower Dvina Valley (Kurland Lakeland) | LT1 | N 56°37', E 24°53' |
| 7. | The Vilnius-Zejmy Lowland (Lithuanian Lakeland) | LI1 | N 55°25', E 26°01' |
| 8. | The Augustów Forest (Augustów Plain) | PL1 | N 53°52', E 23°18' |
| 9. | The Białowieża Forest (Bielsk Upland) | PL2 | N 52°55', E 23°27' |
| 10. | The Solska Forest (Biłgoraj Plain) | PL3 | N 50°28', E 22°59 |

along it (Table 3). The difference in average annual temperature between the two extreme sites is 9°C. At its northernmost end, the transect reaches the limits of geographic occurrence of forest with the Scots pine, while at the southern extreme we encounter the last lowland examples of such forest stands. The study sites are located in Norway (one), Finland (three), Estonia (one), Latvia (one), Lithuania (one) and Poland (three) (Fig.1.) The site selection was based on overall similarity with respect to plant species composition, pine age, elevation, and soil type and morphology. All sites are dominated by an overstory of Scots pine. Although the relative abundance of groundcover species varied from site to site, *Vaccinium* spp., *Cladonia* spp., and *Pleurozium schreiberi* are common at all sites. The average stand age was 110 years (range of 66–178 years), and the average stand elevation 86m (range of 52–123 m). All soils are sandy with similar origin (i.e. glacial outwash and fluvial accumulation), similar horizon development and pH, and may be classified as either podzolic or rusty podzolic. More information can be found in Degórski (2003), Roo-Zielińska (2003), Solon (2003).

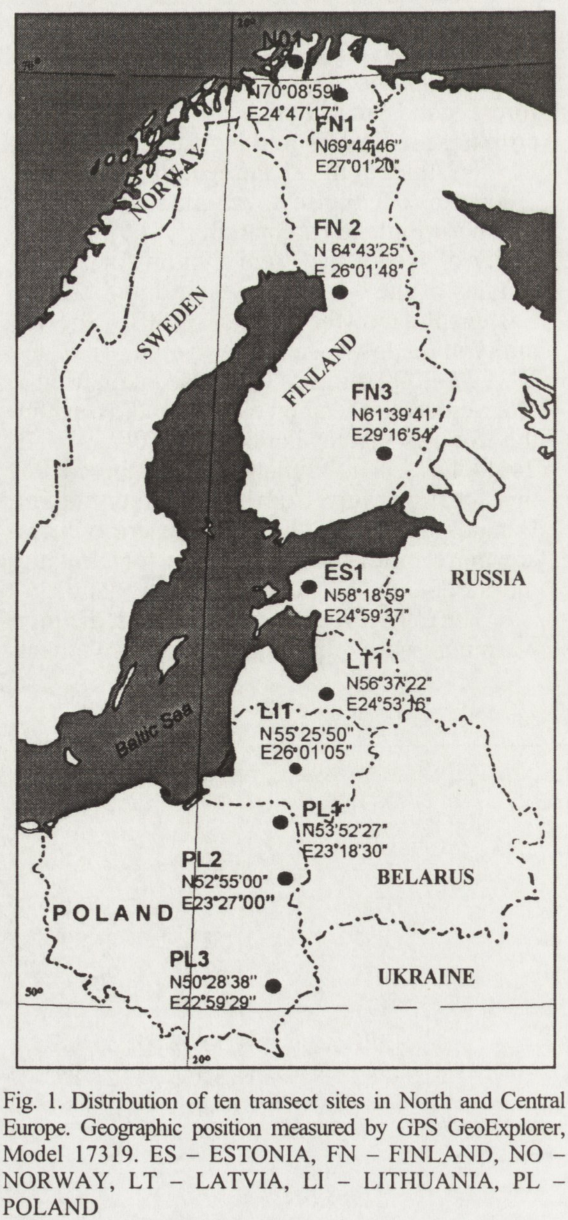



Fig. 1. Distribution of ten transect sites in North and Central Europe. Geographic position measured by GPS GeoExplorer, Model 17319. ES – ESTONIA, FN – FINLAND, NO – NORWAY, LT – LATVIA, LI – LITHUANIA, PL – POLAND

## 3. CLIMATIC CONDITIONS

The data from the nearest national weather stations in the vicinity of each of the ten study sites were used to characterize the climate. Long term averages were used as the basic information characterizing annual temperature and precipitation for each site; for 8 sites the 7-10 year means from the decade of the 1990s were available too (Fig. 2, 3, 4, Table 3). The trends are shown in Fig. 2, 3, and the simple correlation coefficients in Fig. 4 A,B.

It was shown that both the long-term and the 7–10-year temperatures are associated in a significant manner with the geographical location of the study sites – Fig. 2, 4A). As we move southward along the transect the air temperatures increase, with the

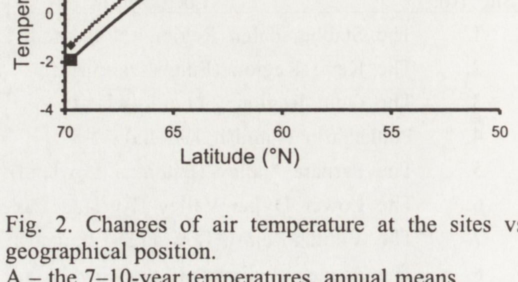
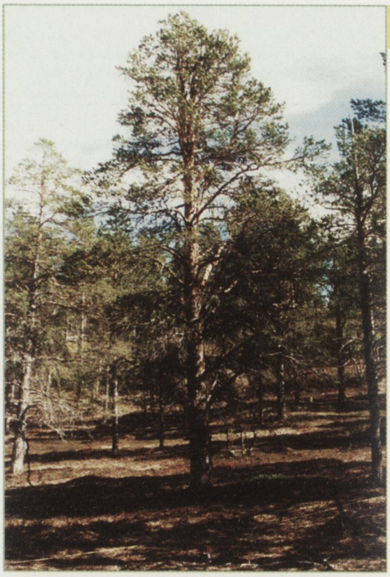



Fig. 2. Changes of air temperature at the sites vs. geographical position.
A – the 7–10-year temperatures, annual means.
$y = -0.0221x^2 + 2.2238x - 48.713$; $R^2 = 0.98$.
B – the long-term temperatures, annual means.
$y = -0.02x^2 + 1,9579x - 41.084$; $R^2 = 0.98$
Dashed line – trend of the 7–10-years mean temperatures. Solid line – trend of the long term temperatures.

**NO1**

N 70°08’59”
E 24°47’17”



**FN1**

N 69°44’46”
E 27°01’20”

**FN2**

N 64°43’25”
E 26°01’48”

**FN3**

N 61°39’41”
E 29°16’54”

**ES1**

N 58°18’59”
E 24°59’37”

**LT1**

N 56°37’22”
E 24°53’16”

**LI1**

N 55°25’50”
E 26°01’05”

**PL1**

N 53°52’27”
E 23°18’30”

**PL2**

N 52°55’00”
E 23°27’00”

**PL3**

N 50°28’38”
E 22°59’29”

**FN1**

**PL3**

Ten forest sites from the most northern (NO1 and FN1) to the most southern (PL2 and PL3).

Two last photographs with green labels present the soil profiles from limits of transect ranges: northern FN1 and southern PL3.

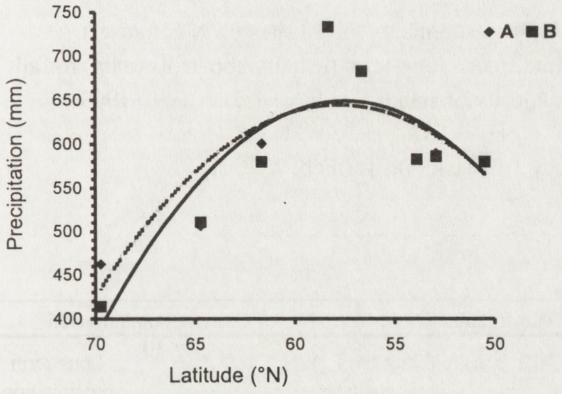



Fig. 3. Changes of precipitation in relation to geographical position of the sites.
A – the 7–10-year precipitation sums, annual means.
$y = -1.4646x^2 + 169.22x - 4243.4$; $R^2 = 0.60$.
B – the long-term precipitation sums, annual means.
$y = -1.7161x^2 + 197.2x - 5016.1$; $R^2 = 0.76$.
Dashed line – trend of the 7–10-years precipitation.
Solid line – trend of the long term precipitation.

temperatures of the decade of 1990s being higher than the long-term averages (this warming appears as the more pronounced at the northern sites). With respect to precipitation no regular changes in this variable were observed, related to the geographical position (Figs 3, 4B). A clear increase of precipitation levels at the Estonian, Latvian and Lithuanian sites is connected with the location close to the Baltic Sea. Thus, the very high correlation and the highly regular trend indicate that the primary climatic factor along the transect considered is constituted by the thermoclimate. The detailed list of the weather stations, from which the measurements were obtained, as well as the complete account of these measurements are given in Table 3.

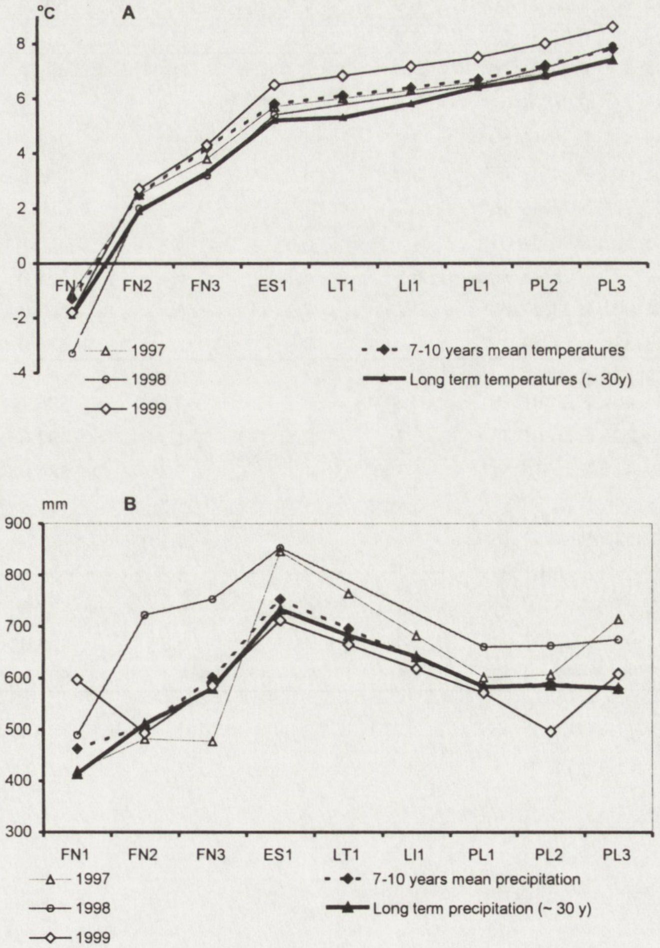



Fig. 4. Annual, long-term and 7–10-year temperatures (A) and precipitation (B) at nine sites (see Fig. 1).

Table 3. Geographic position, temperature and precipitation measurements for 10 sites on N-S transect (see Fig. 1). Climatic data were collected for following time spans: long-term (usually above 30 years) for all stands; 7-10 years annual means from decade of 90s for majority of stands; study years, i.e. 1997-1999 annual means - for majority of stands.
Description of climatic data collected for transect stands by J. Wolski (as for Feb. 7, 2001)

| Year | Stands | Geographic position | Temperatures °C | | | Precipitation mm+G25 | | |
|---|---|---|---|---|---|---|---|---|
| | | | Annual | 7-10 years mean | Long-term temperatures | Annual | 7-10 years mean | Long-term precipitation |
| 1997 | FN1 | N 69°44' 46"; E 27°01' 20" | -1.1 | -1.3 | -1.9 | 419.4 | 462.5 | 414.1 |
| | FN2 | N 64°43' 25"; E 26°01' 48" | 2.5 | 2.5 | 1.9 | 481.2 | 506.8 | 510.6 |
| | FN3 | N 61°39' 41"; E 29°16' 54" | 3.8 | 4.2 | 3.3 | 476.7 | 600.7 | 579.8 |
| | ES1 | N 58°18' 59"; E 24°59' 37" | 5.7 | 5.8 | 5.2 | 845.8 | 753.1 | 733.5 |
| | LT1 | N 56°37' 22"; E 24°53' 16" | | | 5.3 | | | 683,0 |
| | LI1 | N 55°25' 50"; E 26°01' 05" | | 6.6 | 5.8 | | 690.1 | 641.6 |
| | PL1 | N 53°52' 27"; E 23°18' 30" | 6.6 | 6.7 | 6.4 | 601,0 | 582.3 | 582.9 |
| | PL2 | N 52°55' 00"; E 23°27' 00" | 6.9 | 7.2 | 6.8 | 606,0 | 589.5 | 586.1 |
| | PL3 | N 50°28' 38"; E 22°59' 29" | 7.4 | 7.8 | 7.4 | 714,0 | 579.1 | 580,0 |
| 1998 | FN1 | N 69°44' 46"; E 27°01' 20" | -3.3 | -1.3 | -1.9 | 488.9 | 462.5 | 414.1 |
| | FN2 | N 64°43' 25"; E 26°01' 48" | 2,0 | 2.5 | 1.9 | 722.5 | 506.8 | 510.6 |
| | FN3 | N 61°39' 41"; E 29°16' 54" | 3.2 | 4.2 | 3.3 | 753.2 | 600.7 | 579.8 |
| | ES1 | N 58°18' 59"; E 24°59' 37" | 5.4 | 5.8 | 5.2 | 852.5 | 753.1 | 733.5 |
| | LT1 | N 56°37' 22"; E 24°53' 16" | | | 5.3 | | | 683,0 |
| | LI1 | N 55°25' 50"; E 26°01' 05" | | 6.6 | 5.8 | | 690.1 | 641.6 |
| | PL1 | N 53°52' 27"; E 23°18' 30" | 6.5 | 6.7 | 6.4 | 661,0 | 582.3 | 582.9 |
| | PL2 | N 52°55' 00"; E 23°27' 00" | 7.1 | 7.2 | 6.8 | 663,0 | 589.5 | 586.1 |
| | PL3 | N 50°28' 38"; E 22°59' 29" | 7.9 | 7.8 | 7.4 | 675,0 | 579.1 | 580,0 |
| 1999 | NO1 | N 70°08' 59"; E 24°47' 17" | | | 0.6 | | | 345,0 |
| | FN1 | N 69°44' 46"; E 27°01' 20" | -1.8 | -1.3 | -1.9 | 596.7 | 462.5 | 414.1 |
| | FN2 | N 64°43' 25"; E 26°01' 48" | 2.7 | 2.5 | 1.9 | 492.6 | 506.8 | 510.6 |
| | FN3 | N 61°39' 41"; E 29°16' 54" | 4.3 | 4.2 | 3.3 | 584.9 | 600.7 | 579.8 |
| | ES1 | N 58°18' 59"; E 24°59' 37" | 6.5 | 5.8 | 5.2 | 711.8 | 753.1 | 733.5 |
| | LT1 | N 56°37' 22"; E 24°53' 16" | | | 5.3 | | | 683,0 |
| | LI1 | N 55°25' 50"; E 26°01' 05" | | 6.6 | 5.8 | | 690.1 | 641.6 |
| | PL1 | N 53°52' 27"; E 23°18' 30" | 7.5 | 6.7 | 6.4 | 571,0 | 582.3 | 582.9 |
| | PL2 | N 52°55' 00"; E 23°27' 00" | 8,0 | 7.2 | 6.8 | 496,0 | 589.5 | 586.1 |
| | PL3 | N 50°28' 38"; E 22°59' 29" | 8.6 | 7.8 | 7.4 | 608,0 | 579.1 | 580,0 |

LEGEND AND DATA SOURCES (the name of local settlement is in brackets):

NO1 (95350) (Banak)
Long-term data from 1961-1990 provided by courtesy of dr Gustav Bjørbœk

FN1 (Kevo):
7-10 years mean (1990-1999 without 1996)
Long-term data from 1962-1999
*Kevo Subarctic Research Station, University of Turku*
*"Meteorological Yearbook of Finland",*
*Finnish Meteorological Institute,* data provided by courtesy of dr Jaakko Helminen

FN2 (Muhos), FIN3 (Punkaharju):
7-10 years mean (1990-1999)
Long-term data from 1961-1999
*"Meteorological Yearbook of Finland", Finnish Meteorological Institute, Helsinki*
*Muhos Research Station,* data provided by courtesy of dr Eero Kubin
*Punkaharju Research Stationdata,* data provided by courtesy of dr Juhani Haggman
*Finnish Meteorological Institute,* data provided by courtesy of dr Jaakko Helminen

ES1 (Tipu):
7-10 years mean 1990-1999
Long-term data from (1945-1999)
*Meteo Station Viljandi,* data provided by courtesy of dr Henn Pärn

LT1 (Jaunjelgava):
Long-term data from (1955-1995)
*Latvian State Forest Service, Institute of Forest Inventory, Meteo Station Skriveri,* date provided by courtesy of dr M. Sipols

LI1 (Ignalina):
7-10 years mean (1990-1996)
Long-term data from 1945-1996
Data provided by courtesy of dr R. Juknys

PL1 (Mały Borek "Suwałki"), PL2 (Browsk "Białystok"), PL3 (Józefów "Zamość"):
7-10 years mean (1990-1999)
Long-term data from 1951-1970 and 1990-1995
Monthly Agrometeorological Review, Warsaw, Institute of Meteorology and Water Management and Chomicz (1977).

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