Winter hardiness zones and the warming of the coldest night of the year in the Netherlands

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Abstract

The USDA plant hardiness zone, printed on virtually every plant label, is defined as the 30-year mean of the lowest temperature recorded each year. Using the homogenized daily minimum temperature series (version 2.0, 2026) of the five principal KNMI stations in the Netherlands (1901/1907-2022/2026), we compute annual extreme minima under two year conventions (calendar year, the USDA convention, and a July-June frost year) and compare three 30-year climate normal periods: 1931-1960, 1961-1990 and 1991-2020. The national mean of the annual extreme minimum was nearly unchanged between the first two periods (-10.73 to -10.67 degrees C) and then rose by 2.0 degrees C in a single generation to -8.66 degrees C (calendar year; +2.5 under the frost-year convention), roughly three times the warming of the autumn seasonal mean over the same step. As a result the Netherlands as a whole shifts from zone 8a to 8b. Three of the five stations shift robustly by half a zone under both year conventions and both homogenization versions (De Kooy 8a to 8b, Eelde 7b to 8a, Vlissingen 8b to 9a); De Bilt and Beek end within 0.5 degrees C of the 8a/8b boundary and are reported as boundary cases, not as shifts. Trends over the full series are 0.26 to 0.34 degrees C per decade (Mann-Kendall, $p < 0.05$ at all stations on the primary series). All data, methods and code are openly available.

1. Introduction

Hardiness zones translate winter climate into planting advice: they are the operative standard on plant labels and in horticultural references worldwide. The zone system of the United States Department of Agriculture (USDA) assigns half zones of 5 degrees Fahrenheit width based on the 30-year mean annual extreme minimum temperature; the official 2023 map uses the 1991-2020 window. Cold extremes respond faster to warming than seasonal means, so hardiness zones are a sensitive, widely understood lens on climate change in the garden. This paper quantifies that shift for the Netherlands over more than a century, as a companion to our earlier study of autumn warming and the bulb-planting window (van Rossenberg, 2026).

2. Data

We use the homogenized daily minimum temperature (TN) series, version 2.0 (January 2026), of the five principal KNMI stations: De Bilt (260), De Kooy (235), Eelde (280), Vlissingen (310) and Beek (380). The homogenization is peer reviewed (De Valk and Brandsma, 2026) and both the report and the source code are public. Series start in 1901 (De Bilt) or 1907 and run through 31 December 2022, for De Bilt through 22 January 2026. Each file carries the raw observations, the 2016 homogenization (version 1) and the 2026 homogenization (version 2). All headline figures use version 2; version 1 serves as a robustness check. Raw values are never used for trends. The homogenization mainly adjusts measurements before roughly 1950-1970, so the 1961-1990 and 1991-2020 normals are practically identical in both versions.

3. Methods

The annual extreme minimum is the lowest TN value within a year. We count primarily per calendar year, the convention behind the official USDA map, and repeat everything per frost year (1 July through 30 June, labeled by starting year) as a consistency check; headline claims must hold under both. A year only counts when fully observed (at least 365 daily values), since a gap could hide the coldest night. Missing years are war years: De Kooy lacks 1944-1945 and Vlissingen 1944-1945 and 1947 (calendar-year counting); every station-generation cell retains at least 27 of 30 years. Zones follow the USDA definition with boundaries converted exactly from whole degrees Fahrenheit (the 8a/8b boundary is -9.44 degrees C). A generation mean within 0.5 degrees C of a boundary is flagged as a boundary case and never claimed as a zone shift. The national figure is the unweighted mean of the five stations. Trends over the full series use the Mann-Kendall test and Sen's slope on the annual extremes.

4. Results

Nationally the mean annual extreme minimum was stable for half a century (-10.73 in 1931-1960, -10.67 in 1961-1990) and then rose by 2.01 degrees C in one generation to -8.66 degrees C (Table 1); under the frost-year convention the step is +2.55 degrees C (-10.91 to -8.36). The Netherlands as a whole thereby moves from zone 8a to 8b under both conventions. Three stations shift robustly by half a zone under both year conventions and both homogenization versions: De Kooy (8a to 8b), Eelde (7b to 8a, the largest step at +2.51 degrees C, leaving zone 7 after nearly a century) and Vlissingen (8b to 9a, the first Dutch principal station in zone 9). De Bilt (0.31 degrees C below the 8b boundary; 0.03 under the frost-year convention) and Beek (0.12 below; 0.15 above under the frost year) are boundary cases and are not counted as shifts. Trends are significant at all five stations on version 2 (Table 2). Illustrative extremes from the same series: in calendar year 2020 Vlissingen recorded no frost at all (annual minimum +0.4 degrees C; likewise +0.1 in 1988); at De Bilt a night of -15 degrees C or below occurred twice in 1991-2020 (1997 and 2012, the latter -18.9) against six times in 1961-1990, and the share of years with a coldest night of -10 degrees C or below fell from 22 of 30 to 14 of 30.

Station	1931-1960	1961-1990	1991-2020	Zone shift
De Bilt	-11.43 (8a)	-11.69 (8a)	-9.75 (8a)	boundary case (0.31 below 8b)
Vlissingen	-7.63 (8b)	-6.69 (8b)	-5.13 (9a)	8b to 9a
Eelde	-12.87 (7b)	-13.51 (7b)	-11.00 (8a)	7b to 8a
De Kooy	-10.14 (8a)	-9.71 (8a)	-7.84 (8b)	8a to 8b
Beek	-11.59 (8a)	-11.74 (8a)	-9.56 (8a)	boundary case (0.12 below 8b)
Netherlands	**-10.73 (8a)**	**-10.67 (8a)**	**-8.66 (8b)**	**8a to 8b**

Table 1. Mean annual extreme minimum temperature (degrees C) per 30-year period with USDA zone, calendar-year convention, homogenization version 2.

Station	Sen's slope (C/decade)	Mann-Kendall p
De Bilt	+0.28	0.0041
Vlissingen	+0.31	0.0006
Eelde	+0.26	0.0370
De Kooy	+0.34	0.0005
Beek	+0.27	0.0115

Table 2. Trend of the annual extreme minimum over the full series (calendar year, version 2).

5. Discussion and limitations

Two robustness notes. First, under the 2016 homogenization (version 1) the long-term trend at Eelde is not significant (p of roughly 0.10 to 0.13), while it is under version 2; the generational step itself stands under both versions. Second, De Kooy's 1931-1960 zone lies on the 8a/8b boundary (8a under version 2; under version 1 within 0.2 degrees C of 8b in the calendar year and just inside 8b in the frost year); we therefore lead with the generational temperature steps, which are insensitive to these choices. Limitations: the annual extreme minimum is inherently volatile, which is precisely why the USDA framework averages over 30 years; a single severe night such as February 2012 (-18.9 degrees C at De Bilt) still occurs within the mildest generation. A hardiness zone measures winter cold only: it says nothing about winter wetness, snow cover, microclimate or summer heat, and Dutch winter wetness in particular often decides the fate of borderline garden plants. The practical advice to lift tender summer bulbs therefore stands; what changes, especially along the coast, is the margin of that decision. We measure what happened in the series; for attribution we refer to the KNMI.

6. Data and code availability

The study page (in Dutch), interactive and embeddable charts, downloadable tables (zones and mean extremes per station and period; annual extreme minima per station and year, under both year conventions and both homogenization versions), the full method description and the analysis script are available at https://bollanda.nl/onderzoek/winterhardheidszones. All results are licensed CC BY 4.0 with attribution to Bollanda. Revision of 25 September 2026: the count of nights of -15 degrees C or below at De Bilt in 1961-1990 is corrected from four to six, the -10 count is stated as "-10 or below" (one year reached exactly -10.0), and the

note on De Kooy's 1931-1960 zone under version 1 is made precise. Zones, generational means and trends are unchanged.

References

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