THE IMPORTANCE OF PROPER SITE SELECTION FOR AGROMETEOROLOGICAL TEMPERATURE MEASUREMENTS

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Abstract. *In our research, the role and importance of the location of agrometeorological temperature measurements were studied. Our measurements aimed to find out how the measurement site influences the temperature data and thus the agrometeorological information that can be used for precision crop production, such as daily minimum, maximum, mean values (monthly averages). We examined temperature heterogeneity at micro (1-100 m scale) and meso (1-10 km scale) horizontal scales. Temperature data of year 2022, measured by 7 high-precision HOBO Pro v2 U23-002 temperature/humidity data loggers (accuracy: ±0.21°C, resolution: 0.02°C/, T90%: 5 min) installed in the close surroundings of a town (Szarvas) in the Hungarian Great Plain were evaluated. Data from the Szarvas automatic weather station of the Hungarian Meteorological Service were also used for the analyses. The monthly mean temperature on mesoscale was most consistent in November and December, with a maximum difference of only 0.1°C. This also indicates a very high accuracy of our measurements. The largest heterogeneity was found from March to August, with differences typically 0.3-0.4°C. In case of minimum temperature large horizontal heterogeneity was detected (0.2-1.4°C). Microscale variations in maximum temperature were significant in the spring and summer seasons (in monthly averages 0.6-1°C, 1.2°C in August. Based on our results, recommendations were made for the selection of sites for agrometeorological measurements and the positioning of thermometers.*

Keywords*: temperature measurement, location, microclimate, mesoclimate, site selection*

INTRODUCTION

In standard meteorological practice, air temperature is measured above low vegetation typical for the environment (mostly grass), at a prescribed distance from buildings and artificial surfaces. For WMO Class 2 stations, the prescribed distance is 30 m, within which only 10% of the distance may be artificial surfaces or buildings that can be considered as heat sources (WMO, 2008). The Class 1 siting categories are more limiting (100 m distance). In case of agrometeorological measurements, when selecting a site for measurements, the purpose of its observations must be decided first. Obstructions such as trees, shrubs and buildings should not be too close to the instruments, but there is a flexibility according to the purpose (WMO, 2012).

The Hungarian Meteorological Service stations are a good representation of their environment, i.e. the temperature data of the nearest station can be used if the crop production area does not have a specific micro- or mesoclimate (induces by local topography, near surface water, forested area, urban heat island effect, etc.). Not only the actual, but also the historical weather data are freely available for download from the Meteorological Data Repository of the organization (HMS, www.odp.met.hu).

The agronomic, i.e. agrometeorological, uses of temperature data are very diverse, due to the complex effects of temperature. The rate of plant development is primarily determined by temperature. This is the basis of the thermal time methods, which predict the occurrence of a given phenological phase when the sum of the daily thermal units, i.e. the thermal time, reaches the thermal demand of the plant (species, variety, hybrid) for the given phase. There are several variants of the method, calculations can be based on daily mean temperature, extreme values, or hourly or even higher temporal resolution data (YANG et al., 1995;

MCMASTER and WILHELM, 1997; PURCELL, 2003). In current practice, the classical method based on minimum and maximum temperatures, where these values can be corrected below or above a certain value (GILMORE and ROGERS, 1958), is still common.

The adverse effect of extreme low temperatures is well known. For many crops, frost damage is the main cause of yield loss (VITI et al., 2010; PFLEIDERER et al., 2019; YANG et al., 2022). High temperatures can also lead to yield loss through atmospheric drought or by themselves, especially when they occur during the critical phase (e.g., flowering yield set in maize) (SCHLENKER and ROBERTS, 2009; LOBELL et al., 2013; BEN-ARI et al., 2016; PEI et al., 2023).

Air temperature is a key input parameter to crop-weather models (WHITE and HUNT, 2005; YANG et al., 2004) and crop management models, and results are sensitive to the accuracy of temperature data and measurements (GARINEI et al., 2019).

Because of the agrometeorological role of air temperature, as outlined above, accurate temperature information is very important in research work and in crop production practice. The question arises to what extent the data measured at the nearest official station can be used, and what variations are typical on a meso scale. If measurements are taken, how much is the microclimate influencing the measurement. The conclusions we can draw from this will help us to find the ideal solution to meet the temperature data requirements needed for crop production.

MATERIAL AND METHODS

In our research, we studied the role and importance of the location of agrometeorological temperature measurements. Our measurements aimed to find out how the measurement site influences the temperature data and thus the agrometeorological information that can be used for precision crop production, such as daily minimum, maximum, mean values (monthly averages). We examined temperature heterogeneity at micro (10 m scale) and meso (1-10 km scale) horizontal scales. Temperature was measured by high-precision HOBO Pro v2 U23-002 temperature/humidity data loggers (accuracy: ±0.21°C, resolution: 0.02°C/, T90%: 5 min). The sensors were placed in self-designed shelters, which are of similar efficiency to the Vaisala weather shelters used in the automatic stations of the Hungarian Meteorological Service. The average daily maximum, minimum and mean values during the summer test period did not differ by more than 0.1°C in case of of the two shelters.

Measurements were set at 7 points in the Szarvas area (*Figure 1*). In our study, we evaluated data for the full year 2022 without data gaps. We also used data from the HMS automatic meteorological station in Szarvas. In total, 4 out of 8 gauges were located close to each other (50-200 m distance) at site E, but in different microenvironments ranging from WMO class 1 gauging site classification (E1 and E2) to a closed site under significant microclimatic influence of nearby trees (E4). The other measuring locations (A, B, C, D) and E1 were at least WMO Class 2 sites to investigate mesoscale variations (1-10 km distance).

Figure 1. Location of temperature measurements in the surroundings of Szarvas, Hungary

RESULTS AND DISCUSSIONS

The monthly mean temperature on a mesoscale (A, B, C, D, E1, maximum distance 8 km) was most homogeneous in November and December, with a maximum difference of only 0.1°C (*Table 1*). This also indicates a very high accuracy of the measurements. From March to August and in October, maximum deviations of 0.3-0.4°C were observed. September does not fit into this range, showing a less heterogeneous spatial distribution. At the microclimate level (measuring sites E1-E4, maximum distance 200 m), similar yearly averages were obtained (micro: 0.29°C, meso: 0.28°C), smaller from March to August and larger from September to February than at the larger horizontal scale (meso). In all cases, the lowest monthly mean temperatures were recorded at site E4, which is partly bordered by a forest, shaded in the evening and partly in the morning and subject to a strong microclimate influence.

Table 1

Monthly (yearly) mean temperature values (°C) at 8 sites in the surroundings of Szarvas (Hungary) in 2022. Values of Δ1 and Δ2 show the largest differences in mesoscale and microscale.

month	A	B	C	D	E1	E2	E3	E4	Δ1	Δ2
1	0.4	0.4	0.3	0.5	0.4	0.4	0.1	0.0	0.18	0.39
2	5.0	4.9	4.9	5.1	4.8	4.9	4.7	4.5	0.26	0.41
3	5.7	5.3	5.4	5.6	5.3	5.4	5.2	5.2	0.36	0.20
4	9.9	9.7	9.8	9.8	9.8	9.9	9.9	9.7	0.28	0.18
5	18.1	17.8	18.0	18.0	17.9	18.0	17.9	17.7	0.37	0.37
6	23.7	23.6	23.4	23.5	23.2	23.3	23.3	23.1	0.43	0.15
7	24.5	24.7	24.3	24.4	24.3	24.4	24.2	24.1	0.36	0.29
8	24.4	24.6	24.2	24.4	24.3	24.4	24.3	24.2	0.38	0.22
9	16.5	16.6	16.4	16.6	16.4	16.5	16.3	16.1	0.16	0.39
10	13.3	12.9	13.1	13.2	13.2	13.3	13.1	13.0	0.34	0.36
11	6.8	6.8	6.8	6.8	6.8	6.8	6.7	6.6	0.09	0.19
12	3.3	3.3	3.2	3.3	3.3	3.4	3.1	3.1	0.14	0.31
year	12.6	12.5	12.5	12.6	12.5	12.6	12.4	12.3	0.28	0.29

The largest spatial differences in monthly averages of daily minimum values ranged from 0.2°C (November) to 1.4°C (May) on mesoscale. The coldest measurement site B is elevated slightly lower than the others. In addition, the proximity of surface waters (oxbow in the east, fish ponds in the west) may also contribute to the reduction of the night-time cooling. On microscale, there were small overall differences (typically 0.2-0.7°C), with the wind protected site being the coldest. From March to June (and October), the difference between Δ1 and Δ2 is particularly pronounced (*Table 2*).

Table 2

Monthly (yearly) average of minimum temperature values (°C) at 8 sites in the surroundings of Szarvas (Hungary) in 2022. Values of Δ1 and Δ2 show the largest differences in mesoscale and microscale.

month	A	B	C	D	E1	E2	E3	E4	Δ1	Δ2
1	-3.2	-3.5	-3.4	-3.0	-3.5	-3.4	-3.8	-4.0	0.56	0.67
2	0.0	-0.2	-0.1	0.2	0.0	0.1	-0.3	-0.5	0.37	0.56
3	-0.9	-1.7	-1.4	-0.8	-1.7	-1.9	-1.8	-2.0	0.90	0.35
4	4.1	3.6	4.1	4.4	4.2	4.2	4.1	3.9	0.78	0.36
5	11.3	10.2	11.2	11.6	11.4	11.4	11.1	10.9	1.37	0.51
6	15.9	14.8	15.7	15.8	15.3	15.2	15.1	15.0	1.05	0.32
7	17.2	16.5	17.1	17.3	16.8	16.6	16.5	16.3	0.78	0.56
8	18.1	17.7	17.9	18.0	17.7	17.7	17.4	17.4	0.39	0.33
9	12.4	12.0	12.2	12.6	12.4	12.5	12.0	12.0	0.62	0.50
10	8.6	7.7	8.4	8.7	8.5	8.5	8.3	8.2	0.96	0.38
11	4.1	3.9	4.1	4.1	4.0	4.0	3.9	3.8	0.18	0.23
12	0.1	-0.1	0.1	0.3	0.3	0.4	0.1	0.0	0.41	0.43
year	7.3	6.7	7.2	7.4	7.1	7.1	6.9	6.7	0.70	0.43

Microscale variations in maximum temperature were significant in the spring and summer seasons (in monthly averages 0.6-1°C, 1.2°C in August) (*Table 3*).

Table 3

Monthly (yearly) average of maximum temperature values (°C) at 8 sites in the surroundings of Szarvas (Hungary) in 2022. Values of Δ1 and Δ2 show the largest differences in mesoscale and microscale.

month	A	B	C	D	E1	E2	E3	E4	Δ1	Δ2
1	4.5	4.5	4.4	4.3	4.2	4.2	4.2	4.3	0.32	0.11
2	10.9	10.9	10.8	10.5	10.6	10.6	10.8	11.0	0.38	0.43
3	12.4	12.3	12.2	11.9	11.9	12.0	12.2	12.6	0.52	0.70
4	16.2	16.0	16.0	15.5	15.4	15.5	15.9	16.1	0.79	0.75
5	25.1	25.1	24.8	24.3	24.2	24.3	24.8	24.8	0.90	0.55
6	31.1	31.4	30.6	30.4	30.2	30.2	30.9	31.3	1.18	1.17
7	32.0	32.5	31.5	31.5	31.3	31.5	32.0	32.1	1.17	0.84
8	31.3	31.8	31.0	31.0	31.0	31.2	31.6	31.9	0.83	0.92
9	21.9	22.1	21.6	21.5	21.4	21.5	21.8	21.8	0.75	0.46
10	19.4	19.3	19.0	18.9	18.6	18.7	18.9	19.1	0.73	0.47
11	10.6	10.6	10.4	10.3	10.3	10.3	10.2	10.4	0.34	0.21
12	6.9	7.0	6.9	6.8	6.7	6.7	6.6	6.8	0.34	0.21
year	18.5	18.6	18.3	18.1	18.0	18.1	18.3	18.5	0.7	0.6

The most wind sheltered site E4 was the warmest, while the site E1 in the middle of the grassland was the coolest. There are no significant differences in the cloudier months with the least solar radiation (November-January), only 0.1-0.2°C. On the larger horizontal scale, a very regular annual cycle with early winter minimum and early summer maximum is recognisable, and these differences typically slightly exceed the microscale differences, with an annual average of 0.1°C.

Overall, it can be concluded that the differences due to differences in the microenvironment can be larger than between stations in open environments up to 10 km apart. This was found in the winter months of 2022 for minimum temperatures, in some months for maximum temperatures (February-March and August), and in the autumn and winter months for mean temperatures. Accordingly, the choice of measurement site must be made with care to obtain temperature data that are representative of the region.

CONCLUSIONS

Many of the agrometeorological models used in practice (e.g. models describing crop development, growth, yield) are calibrated with meteorological data specific to the region, and thus require such data - measured outside the canopy- for the calculations. The use of data from the nearest official meteorological station is usually appropriate for this purpose. If there is a presumed mesoclimatic difference from the area of cultivation (e.g. different soil type, topography, different vegetation cover, greater distance, etc.), it is advisable to install an own monitoring station with sufficent shelter, high accuracy thermometers and an environment free of disturbing microclimatic influences (e.g. nearby buildings, trees, locally different topography, etc.).

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