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Impacts of potential climate change on damaging frost during growing season of vegetable crops in Elbe River Lowland

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- The research methods were divided into two key phases:

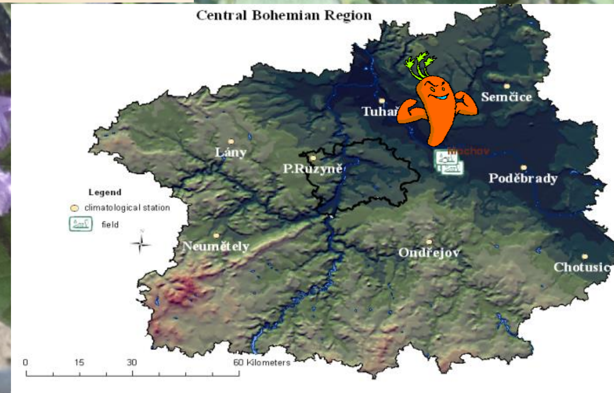
I. **practical research at farm level** including (1) testing the new thermophilic assortment of vegetables in Elbe lowland conditions; (2) to monitor the meteorological parameters on a farmer's fields; (3) to develop the terrain model of the crop fields by means of the GPS and GIS.

II. **the theoretical part of the research at regional level** deals with a new assessment of the potential impacts of climate change on the assortment of vegetable crops grown in the Elbe River lowland, one of the largest farmed regions for market vegetables in central Europe.

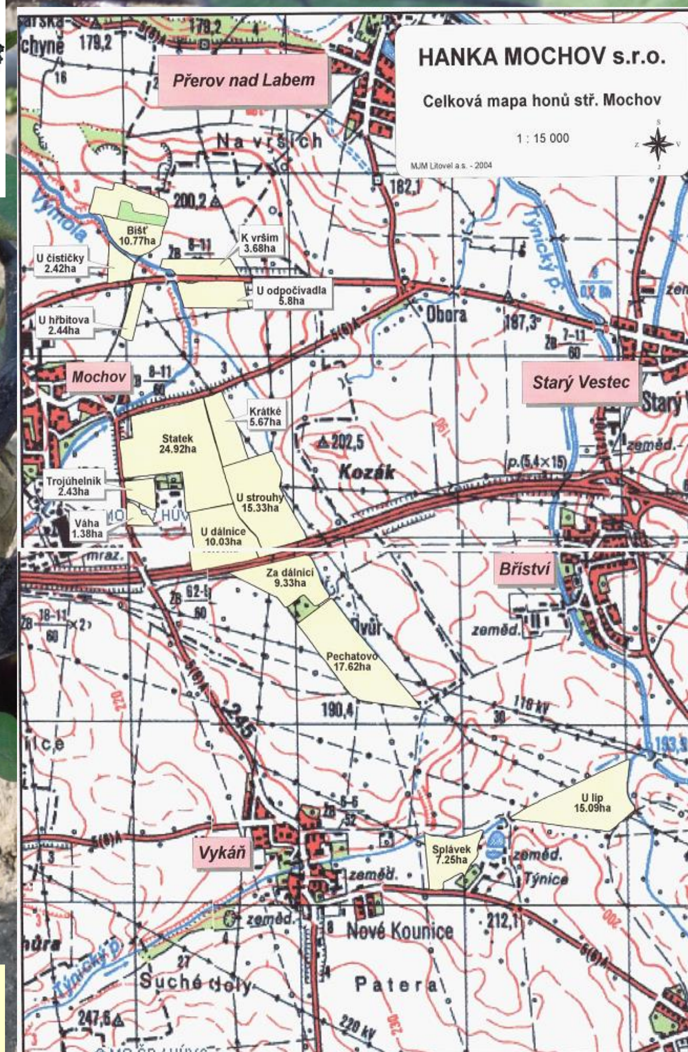
- The present research included a comprehensive analysis of the current climatic conditions (1961–2011) and possible changes in the climate in the near future (2021–2050) and at the end of the century (2071–2100) was undertaken using both observed data and ALADIN-Climate/CZ projections of the changes in the timing of frost events for the Elbe River lowland.

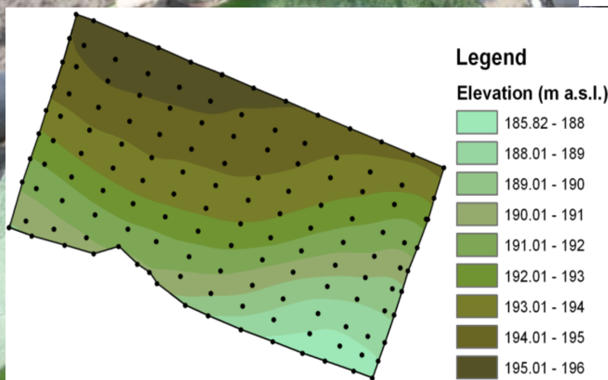
- To accomplish this:
  - ❑ a comprehensive analysis of the spatio-temporal variability of the date of the LSF, FFF and the FFP;
  - ❑ the estimation of the probability of a later date in the spring and an earlier date in the fall for various severe frost events and the length of the FFP;
  - ❑ to identify the areas with high-risk occurrences of damaging frosts during growing seasons of vegetables;
  - ❑ to assess the potential changes in the date of the LSF and FFF and the FFP based on the RCM;
  - ❑ to determine prospective areas for growing thermophile vegetables in study region.

I. Practical research at farm level

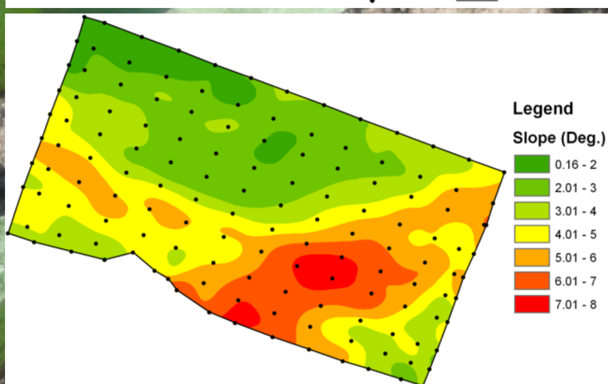


Topographic map of location fields at the farm Hanka Mochov s.r.o.





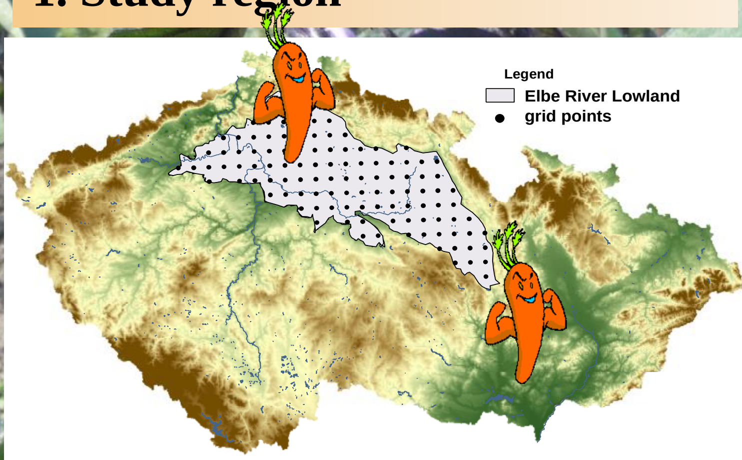
(a)



(b)

Fig. 1: (a) Digital elevation model derived from RTK-GPS data: 138 grid points collected by GPS; (b) Model of the slopes based on the interpolated elevation data.

II. Methods and Materials
1. Study region



- The Elbe River lowland has traditionally been a region of cultivation of *brassica* vegetables, while south Moravia is a profitable region for *thermophilic* vegetables (e.g., tomatoes and peppers).

- The combination of changes in European agricultural commodities and ongoing climate changes (increases in temperatures) can lead to higher costs for vegetable imports and stricter requirements for the maturity and quality of yields (☞ Potop *et al*., 2012).
- In addition, favourable national agricultural policies could extend the areas suitable for *thermophile* field vegetables from the hottest regions of S. Moravia to the Elbe region.
- In addition to the types of vegetables traditionally grown in the Elbe River valley, extension of the cultivation of *thermophile* varieties has already been observed.
- This extension is closely linked to variability of the climate system (☞ Svoboda *et al*., 2003).
- Consequently, the cultivation of *thermophile* vegetables will complement the cultivation of traditional yield-stable vegetables.
- Thus, a detailed evaluation of the past long-term changes in the frost events is essential for predicting the effect of future climate variability on the range of vegetables that can be cultivated in this region.

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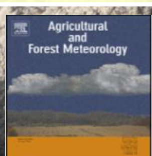
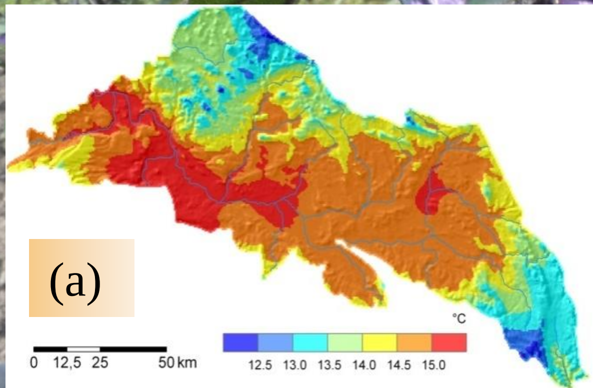
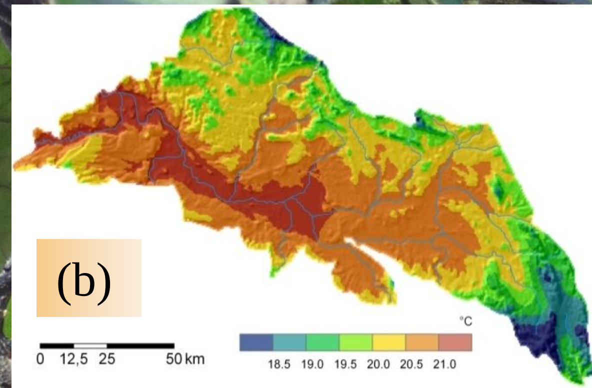


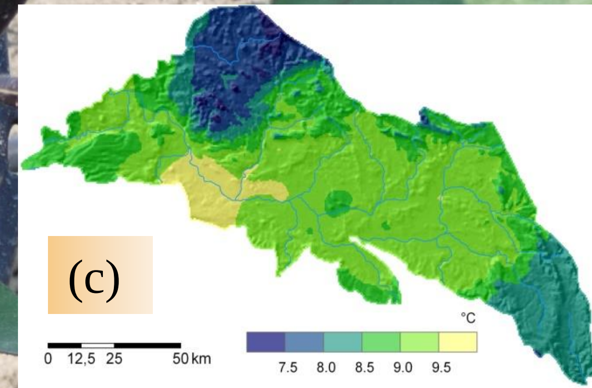
Drought evolution at various time scales in the lowland regions and their impact on vegetable crops in the Czech Republic

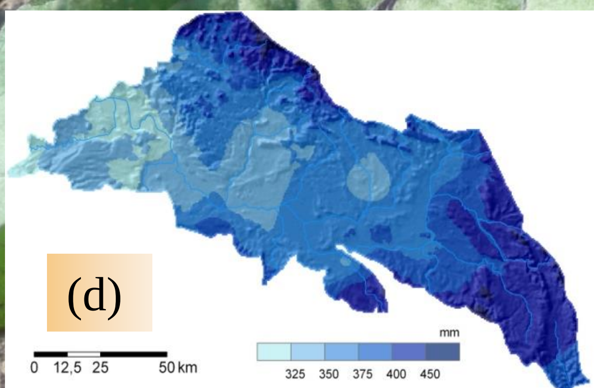
Vera Potop[a,*], Martin Možný[b], Josef Soukup[a]

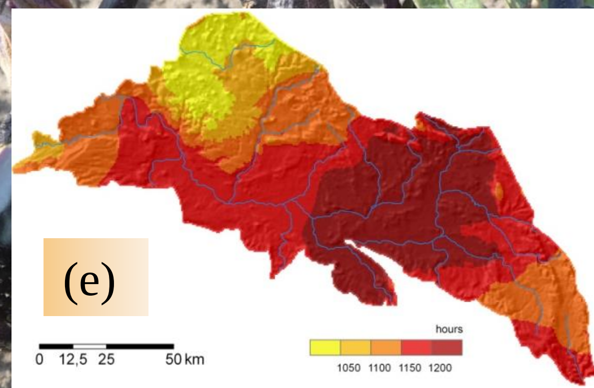
1. Study region - Evaluation of agro-climatic potential for growing vegetables











- The warmest and the lowest precipitation totals during the growing season occur in the middle to lower reaches of the Elbe River, between Poděbrady and Litoměřice.

Fig. 1. Spatially distribution of averages of mean temperature (a), maximum temperature (b), minimum temperature (c), precipitation amount (d) and sunshine (e) generated with geostatistical techniques during growing season (1961-2000).

Source: Potop V, Türkott L, Zahradníček P, Štěpánek P. 2013a. Evaluation of agro-climatic potential of Bohemian plateau (České tabule) for growing vegetables. *Meteorological Bulletin* **66 (2)**: 42–48.

II. Methods and Materials
2. Gridded datasets

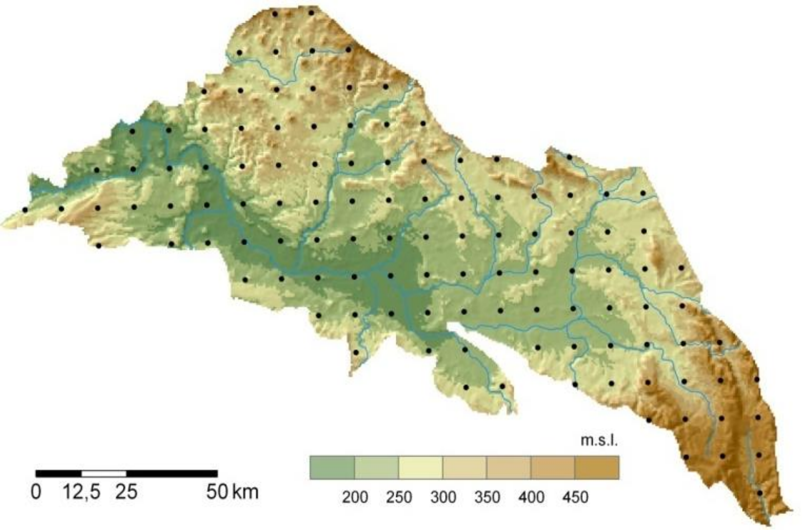


Fig. 2. Location of the 116 grid points and their elevation (m a.s.l.) situated in the Elbe River Lowland

- The study was based on gridded daily series of Tmin data at a 10-km horizontal resolution for observed (1961–2011) and future (2021–2050 and 2071–2100) climate conditions.
- A regular gridded network established by the CHMI was applied (Fig. 2) .
- High-density gridded datasets allow very precise and detailed delimitation of the area in which frosts occur in comparison with the station network datasets.
- The station network in the Polabí has significantly fewer units located primarily in non-agricultural areas, and their data series are not complete.
- ALADIN-Climate/CZ forced with the ARPEGE GCM was adopted to project level risk of the LSF, FFF and the FFP under SRES A1B scenario for two future climates (2021-2050 and 2071-2100) over Elbe River basin.
- The model was developed at the CHMI and has become the standard RCM for climate impact studies in the CR.
- SRES scenario A1B is a baseline scenario referred to in IPCC (☞ 2007).

II. Methods and Materials

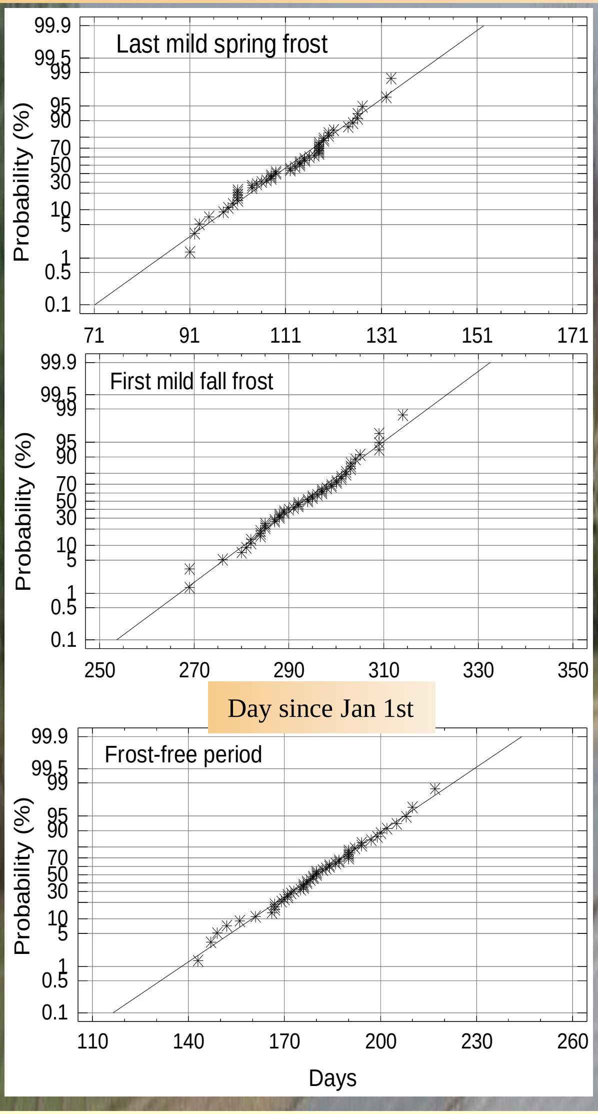
3. Determining the dates of the last spring, the first fall frosts, and the length of frost-free period

- For each grid-point and for each year, the first and the last frost day and the FFP were identified (☞ Potop *et al.*, 2013d).
- The three degrees of frost severity were defined with regard to the physiological requirements of the vegetable types (☞ WMO, 1997):
  - **Mild frost**: daily Tmin of **0.0 to -1.1°C**
  - **Moderate frost**: daily Tmin of **-1.2 to -2.2°C**
  - **Severe frost**: daily Tmin below **- 2.2 °C**
- According to the timing, the ending of the LSF and the beginning of the FFF, we can divide the earliness into three categories:
  - **early**
  - **mean**
  - **late** ending/beginning.

Source: Potop V, Zahradníček P, Türkott L, Štěpánek P, Soukup J. 2013d. Risk analysis of the first and last frost occurrences during growing season of vegetables in the Elbe River lowland. *Időjárás* (in printing).

II. Methods and Materials

4.The estimation of frost dates and the length of the FFP probabilities



- The aim here is to summarise the probability for all grid-points of the three classes of frost severity at a later date in the spring and earlier date in the fall and the probable length of the FFP.
- The Pearson distribution used to analyse the risks (probabilities) of the first/last occurrences of frosts and the FFP.
- Probability information on frost events is used to estimate the chances that a damaging event will or will not occur in the long term (i.e. over several years).
- The chances are then used to decide if the crop should be planted, if it is profitable to invest in insurance, or if frost protection is cost-effective.

Fig. 3. Probability paper fit with Pearson type III distribution for the mean dates of the LSF, FFF and length of the FFP over the Elbe River lowland as a whole.

The mean dates of the last spring frost and the first fall frosts for various probability levels over the Elbe River lowland as a whole.

Probability %	Last mild spring frost	Last moderate spring frost	Last severe spring frost	First mild fall frost	First moderate fall frost	First severe fall frost
96	20 May	13 May	6 May	22 Sep	29 Sep	4 Oct
90	**12 May**	**5 May**	**28 Apr**	30 Sep	7 Oct	11 Oct
80	5 May	27 Apr	21 Apr	7 Oct	14 Oct	18 Oct
75	3 May	25 Apr	19 Apr	9 Oct	17 Oct	21 Oct
67	28 Apr	20 Apr	15 Apr	13 Oct	21 Oct	25 Oct
50	22 Apr	13 Apr	8 Apr	20 Oct	29 Oct	1 Nov

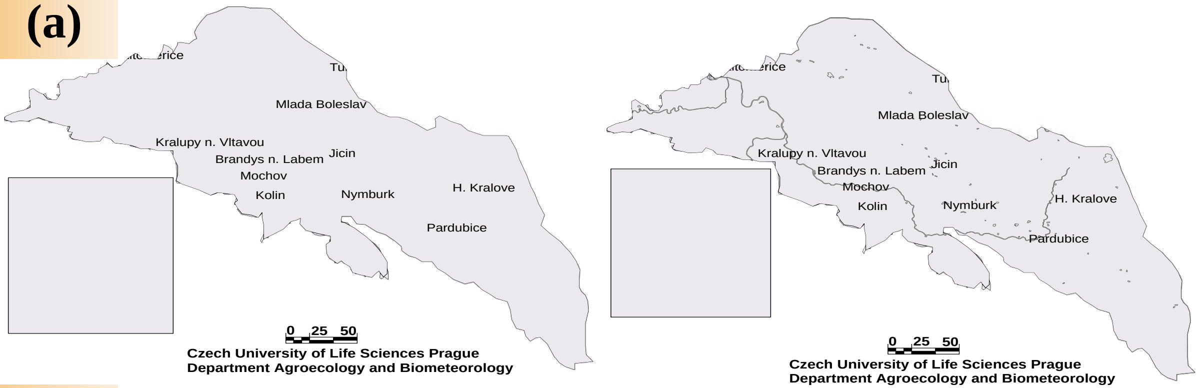
- **Dates for the beginning and ending frost associated with each of the preselected probability levels was computed.**
- For the fall season (harvest period), the probability level represents the risk of having a temperature as cold or colder on or later than the computed date.
- For the spring season (sowing/planting period), we calculated the probability of spring frosts on this date (x) and before.
- The **90%** probability level for the spring season is computed to be **April 28** at the severe intensity.
- This means that 9 years out of ten a temperature as cold as or colder than −2.2°C is expected to occur on or earlier than April 28 during the spring season.

Source: Potop V, Zahradníček P, Türkott L, Štěpánek P, Soukup J. 2013d. Risk analysis of the first and last frost occurrences during growing season of vegetables in the Elbe River lowland. *Időjárás* (in printing).

III. Results and Discussion

1. The spatiotemporal evolution of date of the last spring and first fall frosts for various severities and length of the frost-free period

(a)



(b)

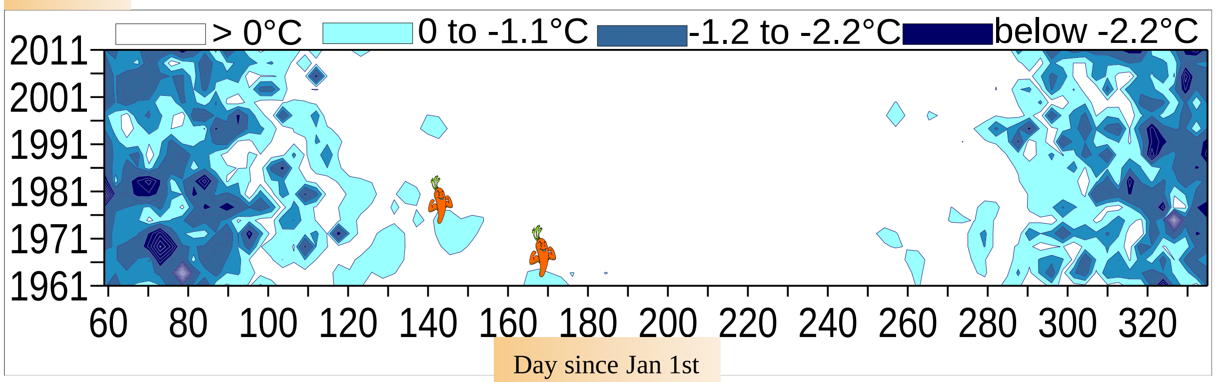
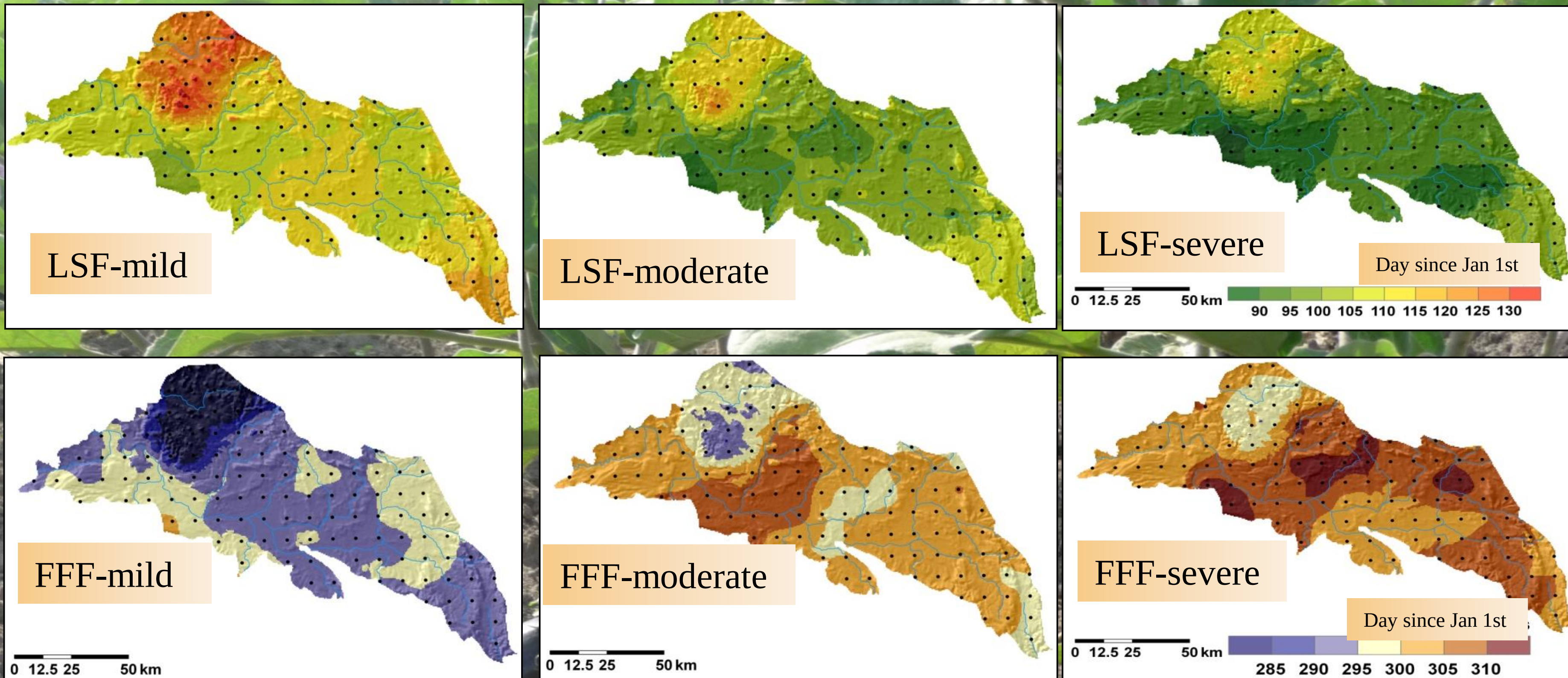


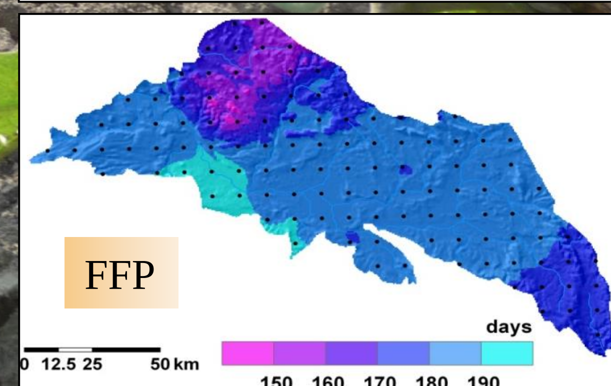
Fig. 4: **(a)** Maps of the latest ending of spring frost and the earliest beginning fall frost, and **(b)** the spatiotemporal evolution of dates of the LSF and FFF for various severities and the FFP derived from Tmin at 116 grid-points x 51 years x 365 days in Polabí (1961-2011).

- The LSF occurred most frequently between April 5 (95 day) and May 2 (122 day).
- Extremely late occurrences of mild spring frosts, reaching up to the month of June, were observed in 1962 (18 June),1975 and 1977 (June 6).
- Severe frosts in June did not occur in any of the grid points during the entire study period.
- At higher elevation, the earliest beginning of the FFF ranges between Sep 10 and 18 (1973, 1977 and 2003 years).

1. Spatial variability of mean date of the last spring frost (LSF), first fall frost (FFF) and the length of the frost-free period (FFP) in Elbe River lowland



- The length of the FFP (ranges fom 141 to 221 days) depends on the earliness of the LSF and the onset of the FFF (Fig. 5).
- From the perspective of field *thermophile* vegetables, it is mainly advantageous to shift the beginning date of the FFP in the spring months rather than its length.



Source: Potop V, Zahradníček P, Türkott L, Štěpánek P. 2013c. Spatial variability of late spring and early autumn frosts for different severity during growing season of vegetable crops in Elbe River lowland (Polabí). *Meteorological Bulletin* (in printing).

The regional catalogue of frosts (1961-2011)

- ➢A catalogue of the mean dates of the spring and fall frosts for the three frost severities and degrees of earliness, as well as the length of the FFP was developed.
- ➢In the last two decades, the LSFs were concentrated into categories of early and mean ending.
- ➢From 1961 to 1980, the majority of cases were recorded in the mean and late ending categories of LSF.

Source: Potop V, Türkott L, Zahradníček P, Štěpánek P. 2013b. Temporal variability of late spring and early autumn frosts during growing season of vegetable crops in Elbe River lowland (Polabí). *Meteorological Bulletin* (in printing).

Year	Mild spring frost			Moderate spring frost			Severe spring frost			Frost-free period, days	Mild autumn frost			Moderate autumn frost			Severe autumn frost		
	Early	Mean	Late	Early	Mean	Late	Early	Mean	Late		Early	Mean	Late	Early	Mean	Late	Early	Mean	Late
1961	1 Apr			28 Mar			18 Mar			217			5 Nov			21 Nov			20 Nov
1962		28 Apr			22 Apr			9 Apr		173		19 Oct			25 Oct			26 Oct	
1963		28 Apr			17 Apr			8 Apr		169		14 Oct			23 Oct			9 Nov	
1964		23 Apr			2 Apr			27 Mar		167	8 Oct				25 Oct			1 Nov	
1965		28 Apr			3 Apr			29 Mar		166		12 Oct		15 Oct			18 Oct		
1966	11 Apr			2 Apr				28 Mar		202			30 Oct		3 Nov			31 Oct	
1967		28 Apr			19 Apr			4 Apr		177		23 Oct			4 Nov				14 Nov
1968		17 Apr			10 Apr			14 Apr		194		28 Oct			24 Oct			2 Nov	
1969		18 Apr			17 Apr			21 Apr		178		15 Oct				12 Nov		7 Nov	
1970		1 May			18 Apr			7 Apr		147	26 Sep			15 Oct				8 Nov	
1971		29 Apr			20 Apr			13 Apr		149	26 Sep			9 Oct			7 Oct		
1972	10 Apr				10 Apr				26 Apr	180	8 Oct			11 Oct			7 Oct		
1973			6 May		20 Apr			9 Apr		161		15 Oct			24 Oct		13 Oct		
1974		22 Apr		2 Apr				18 Apr		171	11 Oct				26 Oct			5 Nov	
1975		25 Apr			8 Apr			30 Mar		172		15 Oct			29 Oct			28 Oct	
1976			4 May			25 Apr			30 Apr	177			30 Oct			17 Nov			26 Nov
1977			12 May			24 Apr		19 Apr		143	3 Oct				25 Oct				24 Nov
1978			4 May			3 May		13 Apr		176		28 Oct			5 Nov				13 Nov
1979			7 May			6 May		3 Apr		152	7 Oct			15 Oct			18 Oct		
1980			12 May			7 May			26 Apr	156		15 Oct			23 Oct			28 Oct	
1981		30 Apr				24 Apr		20 Apr		176		24 Oct			3 Nov			9 Nov	
1982		30 Apr				26 Apr		20 Apr		182		30 Oct			8 Nov			6 Nov	
1983	9 Apr			2 Apr				28 Mar		190		17 Oct			28 Oct			28 Oct	
1984		26 Apr			20 Apr			19 Apr		184		28 Oct				13 Nov			29 Nov
1985		25 Apr			11 Apr			16 Apr		179		22 Oct			21 Oct			24 Oct	
1986	3 Apr				4 Apr			14 Apr		190	11 Oct				31 Oct				18 Nov
1987		24 Apr			8 Apr			27 Mar		184		26 Oct			4 Nov			3 Nov	
1988		22 Apr			15 Apr				25 Apr	190			29 Oct		30 Oct			27 Oct	
1989	10 Apr			30 Mar			23 Mar			190		18 Oct			7 Nov				16 Nov
1990		26 Apr			5 Apr			11 Apr		183		27 Oct			31 Oct			26 Oct	
1991			6 May		21 Apr			13 Apr		167		21 Oct			27 Oct			23 Oct	
1992		16 Apr			14 Apr			13 Apr		179		13 Oct		16 Oct			12 Oct		
1993	11 Apr				8 Apr			10 Apr		187		16 Oct			18 Oct			27 Oct	
1994		22 Apr			11 Apr			4 Apr		167	8 Oct			12 Oct			7 Oct		
1995		28 Apr			9 Apr			1 Apr		180		26 Oct			25 Oct			30 Oct	
1996		18 Apr			16 Apr			11 Apr		200			4 Nov		5 Nov				20 Nov
1997		24 Apr			20 Apr				23 Apr	170		12 Oct			21 Oct		20 Oct		
1998	11 Apr				2 Apr			6 Apr		199		28 Oct			6 Nov			12 Nov	
1999		15 Apr			14 Apr			28 Mar		186		19 Oct			26 Oct			21 Oct	
2000	4 Apr				3 Apr		16 Mar			210			31 Oct			28 Nov			18 Nov
2001		16 Apr			14 Apr			2 Apr		208			10 Nov			11 Nov		7 Nov	
2002	8 Apr				6 Apr			10 Apr		194		21 Oct			3 Nov			4 Nov	
2003		14 Apr			5 Apr			12 Apr		180		12 Oct			19 Oct		17 Oct		
2004		18 Apr			9 Apr		19 Mar			187		23 Oct			20 Oct			24 Oct	
2005		28 Apr			10 Apr				22 Apr	190			5 Nov			11 Nov		22 Oct	
2006	11 Apr				4 Apr			6 Apr		197		27 Oct			31 Oct			30 Oct	
2007		28 Apr			17 Apr			9 Apr		176		22 Oct		15 Oct				6 Nov	
2008		13 Apr			12 Apr			30 Mar		192		23 Oct			4 Nov			7 Nov	
2009	2 Apr			27 Mar			26 Mar			205		25 Oct			2 Nov				20 Nov
2010		18 Apr			10 Apr			28 Mar		175	11 Oct			15 Oct				23 Oct	
2011		29 Apr				28 Apr		5 Apr		171		19 Oct		17 Oct			20 Oct		

III. Results and Discussion

2. Inter-annual variations of area-averaged LSF, FFF and the FFP in Elbe River lowland for 1961-2011

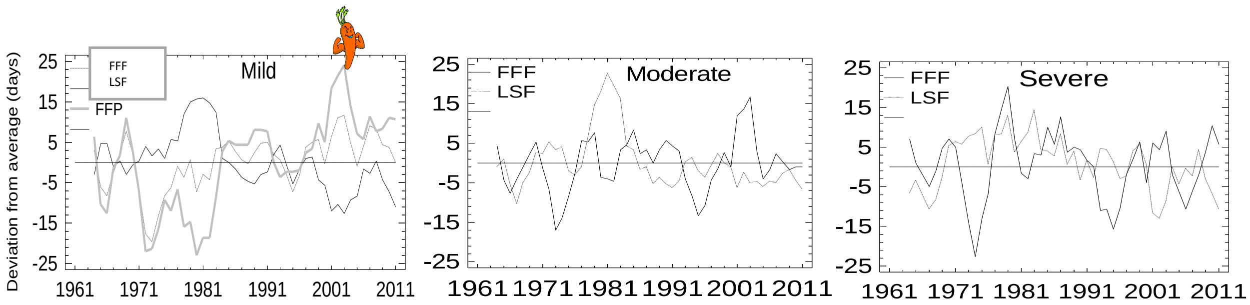


Fig. 6. Inter-annual variations of area-averaged LSF, FFF and the FFP.
The values have been smoothed with a 5year moving average filter and plotted as a deviation (days) from the period average (1961-2011).
Positive values indicate dates later in the year (fall and spring occurrences) or a greater number of days (length).

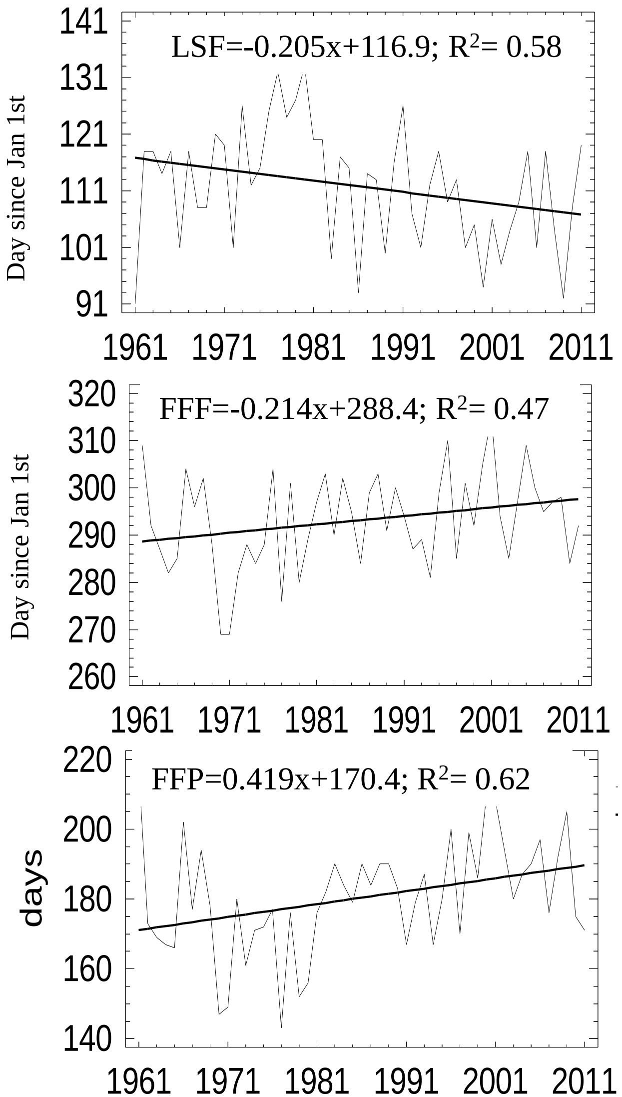
- Asymmetric long-term variations in LSF and FFF led to increases in the FFP.

- The temporal evolution of the FFP anomalies displays two distinct periods: a shortening of the FFP in the 1960s and an intensified lengthening of the FFP since the 1980s.

- An early ending of spring, together with the late onset of fall frosts, provides suitable conditions for sowing/planting of field vegetables, as well as their ripening and harvesting.

III. Results and Discussion

3. Trends of changes in the LSF, the FFF and the length of the FFP



- The linear trends of the start, end and length of the FFP are plotted (Student's one-tailed t-test at the 95% significance level).
- Overall, the LSF displays a decreasing trend, whereas the FFF displays an increasing tendency.
- The dates of the LSF have advanced by 2.1 days/decade.
- The fall dates are delayed up to 2.1 days/decade, whereas the FFP is lengthening by up to 4.2 days/decade.

☞ These changes are consistent with those in central Europe (Menzel *et al*. 2003).

- The consequences to agriculture from these changes include a reduced risk of spring and fall frost damage to crops and a lengthened GS for vegetables.
- However, regional frost series suggests that the FFP exhibits a large amount of inter-annual variability.

III. Results and Discussion

4. The estimation of frost dates and the length of the FFP probabilities from 1961 to 2011

- At the 50% probability level, the length of the FFP is 180 days.

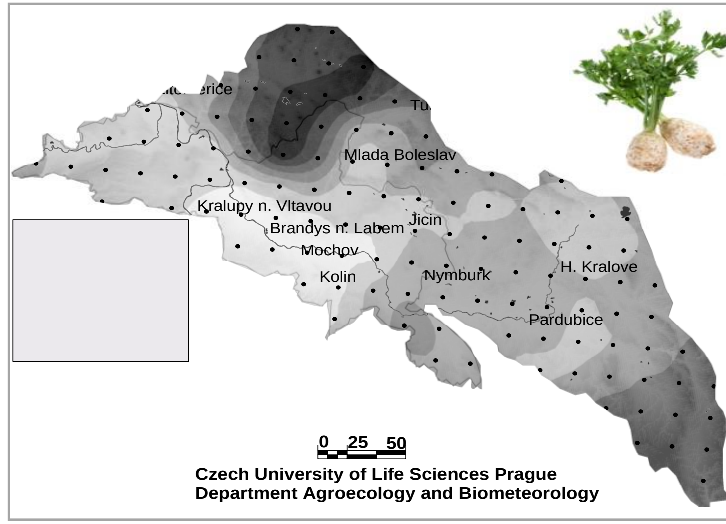
- Among the field vegetables, *root* types have the longest GS (e.g., *celeriac* - planting to technical harvest is ~ 200 days).

- There is a 90% chance that a FFP will be ≤ 200 days, but there is only a 10% chance that the period will be longer than 200 days.

- To maximise the yield potential of vegetables, it is necessary to use the special agro-technical measures, which leads to increases in the cost of cultivation.

- The mean duration of the FFP in the study region allows for the planting of *leaf* and some *brassica* vegetables more than once per season and repeated harvesting.

- This information can be used for risk analyses by decision markers.



- From an agronomic point of view, *thermophilic* vegetables should be planted after 15 May to minimise the risk of frost damage.
- There is 25% chance of the occurrence of dangerous spring frosts during the planting of field vegetables after May 3, but after May 15, the risk is only 10%.
- During Sept and the first half of Oct, there is low risk of damage to field vegetables from severe fall frosts.

5. Risk occurrences of damaging last spring frosts during sowing/planting for thermophilic, cold-resistant and frost-resistant vegetables

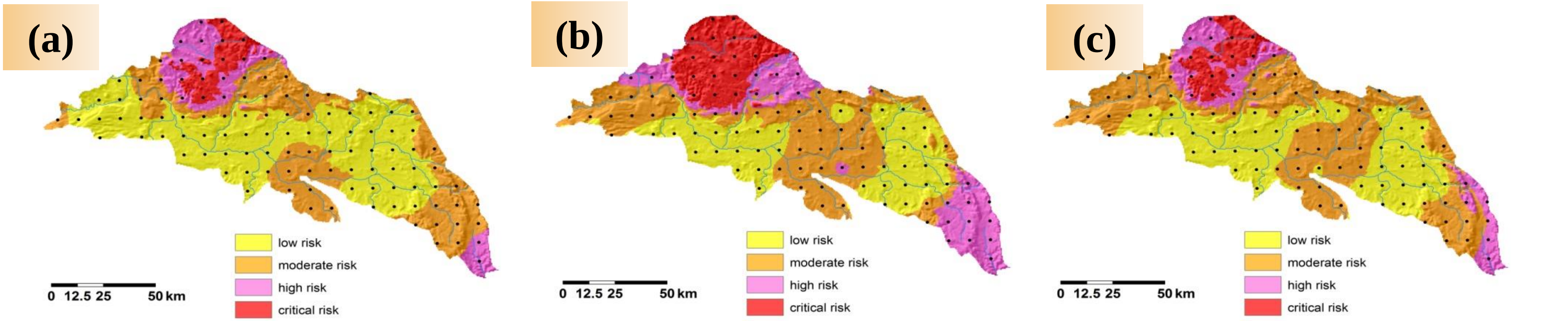
- The aim here is to identify the areas with high-risk occurrences of damaging LSF during the sowing/planting period of vegetables.

- The wide range of vegetables grown in the studied region can be divided into three basic types according to their sensitivity to low temperatures:

I. thermophilic vegetables - suffer heavy damage from low temperatures at all development stages (☞ Petříková & Malý, 2003);
II. cold-resistant vegetables - can tolerate a short period of temperatures slightly below 0°C;
III. frost-resistant vegetables - can tolerate a frost of less than -2.2°C, depending on development stage (☞ Malý *et al*., 1998).

- According to the % values of LSF occurrence during the sowing/planting of thermophilic, cold-resistant and frost-resistant vegetables, 4 types of frost risk areas were defined:
  - Low
  - moderate
  - high
  - critical.

Frost risk maps for last spring frosts during sowing/planting of thermophilic (a), cold-resistant (b) and frost-resistant (c) vegetables over the Elbe River Lowland (1961-2011).



The risk level of the damaging spring frosts (in %)

Altitude m a.s.l.	Thermophilic t_{min} <-0.1 after 15 May			Cold-resistant t_{min} <-2.2 after 15 April			Frost-resistant t_{min} <-2.2 after 1 April		
	mean	min	max	mean	min	max	mean	min	max
below 250	**4.5**	**0**	15.4	30.6	19.2	48.1	**57.0**	38.5	73.1
251-300	**11.3**	**0**	38.5	41	15.4	82.7	67.4	40.4	94.2
above 300	15.4	1.9	34.6	46.2	32.7	67.3	74.3	61.5	90.4

- The critical and high risks **after May 15** are related to high altitudes and frost hollows, whereas low frost risk is observed in the lower areas.
- At higher altitudes, areas with zero incidences of negative temperatures were found, which may allow for the possible expansion of **thermophilic vegetable** growth.
- A severe LSF during **planting of cold-resistant v.** has occurred every second year at higher altitudes. Most vegetable growing areas fall within the low and moderate risk categories for severe frosts.
- The occurrence of severe frosts during the **planting of frost-resistant v.** in the growing area is, on average, 57%. → Despite the considerable resistance of these vegetables to low temperatures, it is necessary to cover plants with non-woven textile.

6. Projected changes in dates of the spring and fall frosts and the length of FFP for two future climates (under A1B) across the Elbe lowland as a whole.

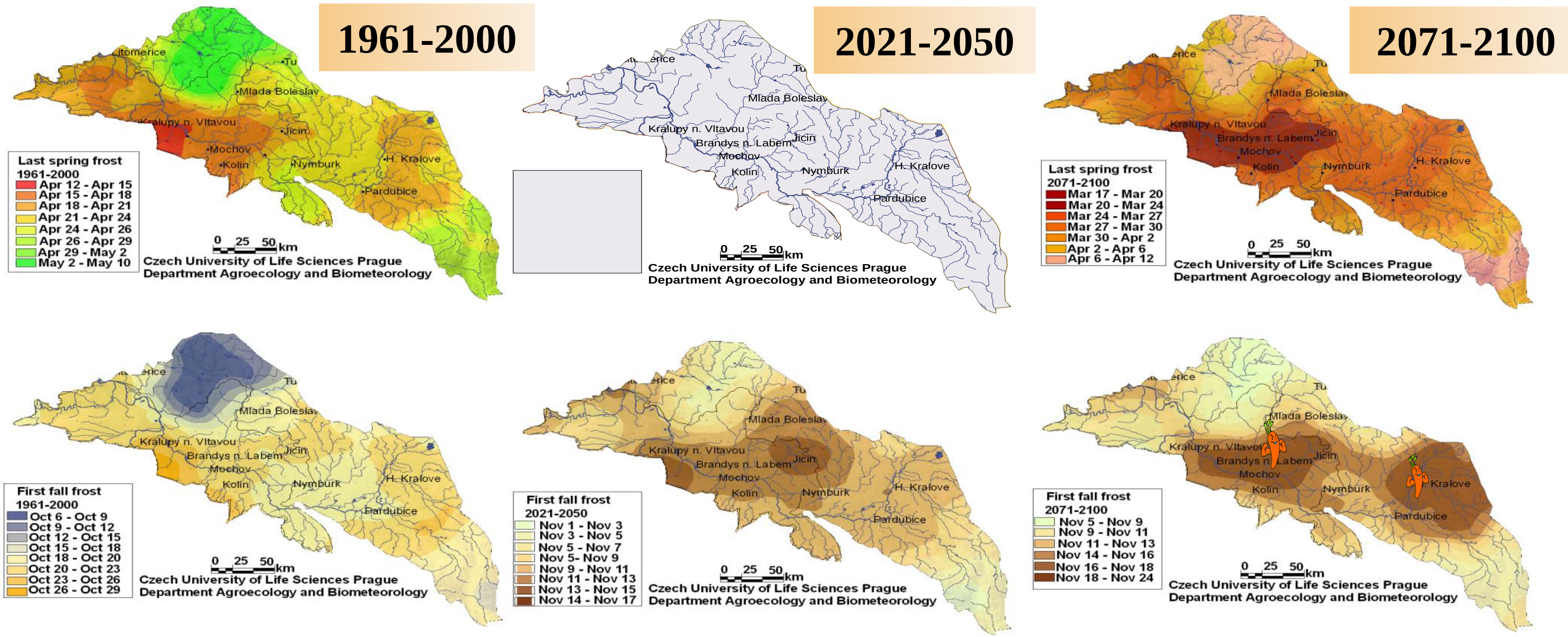
	Last mild spring frost	Last moderate spring frost	Last severe spring frost	First mild fall frost	First moderate fall frost	First severe fall frost	Frost-free period
2021-2050	**advance 14**	**advance 14**	**advance 12**	**delay 21**	**delay 21**	**delay 18**	**increase 35**
2071-2100	**advance 25**	**advance 28**	**advance 26**	**delay 25**	**delay 25**	**delay 21**	**increase 50**

- The dominant dates of LSF and FFF for the entire study region are projected to be significantly advanced and delayed, respectively, compared with the current climate.
- The FFP is projected to lengthen considerably by the end of the 21st century compared with the mid-21st century.
- Projected future climate conditions could result in significant shifts in the median LSF and FFF to earlier and later dates, respectively, relative to the current climate.

☞ These results agree with other studies conducted at a European scale (e.g., Rosenzweig et al. 2003; Chmielewski *et al.* 2004).

Source: Potop V, Zahraniček P, Türkott L, Štěpánek P, Soukup J. 2013f. Potential impacts of climate change on damaging frost during growing season of vegetables. *Scientia Agriculturae Bohemica* (under review).

Spatial distribution of projected changes in the date of the LSF and FFF



- According to the ALADIN-Climate/CZ simulation, the most significant shifts in the dates of the beginning and end of the frosts are projected to occur in hilly areas.
- 2021-2050 - the ending of the LSF in the traditional grown vegetable regions will be shift in the second half of April.
- 2071-2100 - the ending of the LSF in the hottest areas will be a significant shift in the second half of March.
- At the end of the 21st century will be profiled two the main areas with a late onset of FFF:
  - traditionally located in Middle Elbe lowland
  - a newly created region at the Východolabská and Orlická plateaus.

Observed the length of the frost-free period

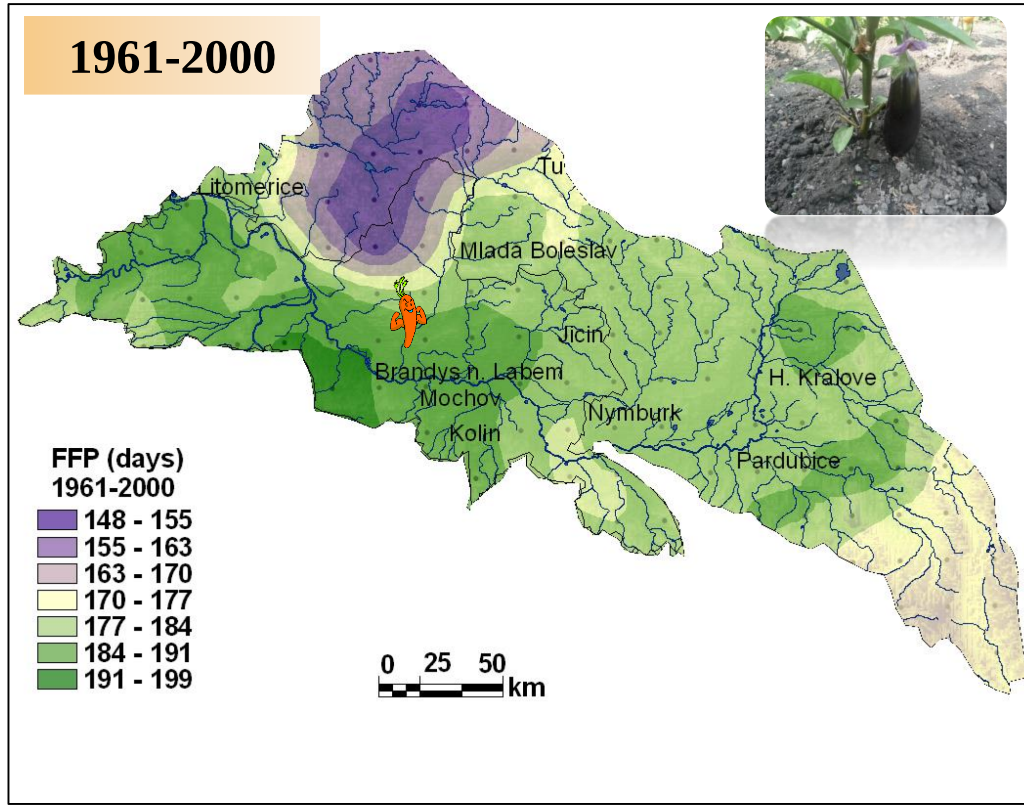
The regional observed frost map reveals three basic regions of FFP:

I. the longest FFP (>184 days) - located on the NE Prague plateau and is connected to the warmest areas of the middle Elbe River valley.

Furthermore, this area shifts ⇨ the middle Poohří.

II. moderate FFP - a contiguous area in the central part of the ER basin from the M. Boleslav ⇨ the Orlická plateau.

III. the shortest FFP - the transition area between the frost hollows of the Kokořín and Ralská hills in conjunction with the Svitavská hills.

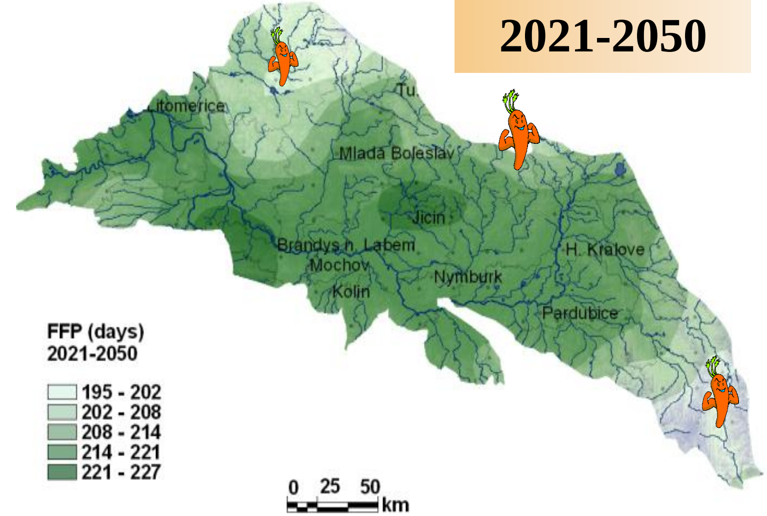


As a practical recommendation, the authors suggest that the first two regions may be suitable for the cultivation of thermophilic vegetables in conjunction with an irrigation system that would ensure profitable yields (Potop *et al*., 2013e).

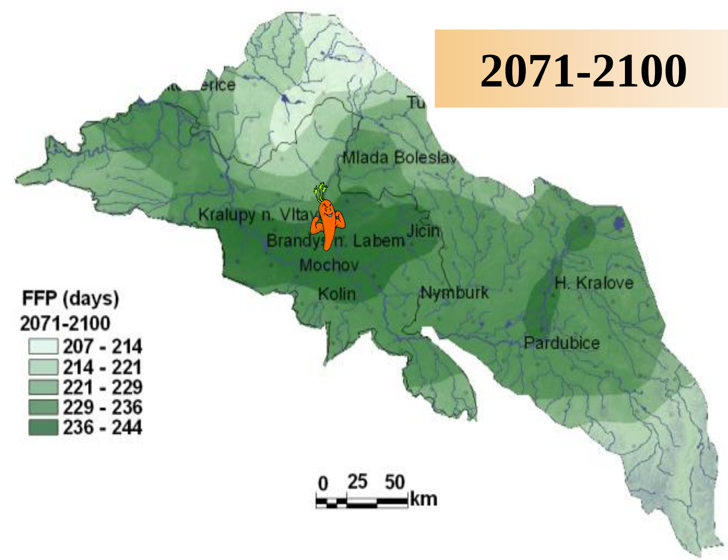
Under projected future climate conditions - FFP

- According to the ALADIN-Climate/CZ simulation for the period 2021–2050, in hilly areas (Ralská, Jičínská, Svitavská) the FFP will correspond to that of the warmest areas in the current climate.
- At the end of the 21st century, the FFP in the hottest areas will be significantly lengthened (longer than 220 days).
- The lengthening of the FFP and the flat topography of the Východolabská and Orlická plateaus will create favourable conditions for the expansion of vegetables areas, mainly towards the eastern part of the Elbe River basin.
- The results also suggest potential for a northerly expansion of vegetables cultivation, although most of the lands to the north of the current frontier will remain only marginally suitable for growing field vegetables due to their complex terrain.

2021-2050



2071-2100



Spatial distribution of projects of the length of FFP under the A1B scenario for the two future climate periods (2021–2050 and 2071–2100).

IV. Summary and Concluding remarks

Under the current climatic conditions

⇨ Our results have demonstrated an earlier LSF, a later FFF, and a longer FFP in the studied region.

⇨ The severe spring frosts in the period of 1981-2011 ended earlier than in the period of 1961-1980; consequently, the end of the 20th and the beginning of the 21st century is a suitable period for the growth extension of varieties of vegetables with longer growing seasons and higher demands on temperature.

⇨ Increasing the length of the FFP could result in earlier planting of vegetables, ensuring maturation and allowing the possibility of multiple cropping.

⇨ The extension of the FFP in the Polabí may also greatly reduce the frost risks to vegetable crops and bring economic benefits to Czech agricultural producers.

⇨ In terms of the growth of field vegetables, a late spring frost remains as risk factor, but the degree of risk has decreased.

⇨ These changes can be particularly beneficial for thermophile vegetables (e.g., tomato, eggplant, pepper and melon) in lowlands.

IV. Summary and Concluding remarks

Under projected future climate conditions

- A climate warming scenario suggests lengthening of the FFP in the coldest areas of the study region to the level of the warmest areas in the current climate.
- According to the ALADIN-Climate/CZ simulation, profitable cultivation vegetables area will be significantly extended from middle Elbe River lowland ⇨ the eastern part of Bohemian plateau.
- The ALADIN-Climate/CZ simulation reveals that by the end of this century, Czech farmers could be growing their crops for **up to two months longer!!!!**
- We concluded, in agreement with recent and current studies, that the Elbe River lowland can become a major producer of a large assortment of vegetables in the CR and significantly increase its competitiveness in the production of market vegetables.

This will happen when the national agricultural policy will support of local vegetable producers and also regulate of the imports of vegetables!