AGROCLIMATOLOGICAL MODEL CLIMEX AND ITS APPLICATION FOR MAPPING OF COLORADO POTATO BEATLE OCCURRENCE

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ABSTRACT

It has been shown that life cycle of many pests depends on the climate conditions. Any change of these conditions will lead to the pest's response to this change. The response might include more survival of the species or change in the species spatial occurrence. The species chosen for this case study is the relevant pest of the potato throughout Europe, Mexico and parts of the central America (Capinera, 2001). Colorado potato beetle (*Leptinotarsa decemlineata,* Say), CPB is affected generally by the air temperature and this fact enabled application of the method of climate matching and CLIMEX software. The core of the CLIMEX approach is quantification of the ecoclimatic index (EI) over the selected region. This approach was evaluated under present climate conditions and then it was used in order to assess the potential geographic distribution in conditions of the climate change according to the chosen GCM scenario.

Key words: Temperature Index, Moisture Index, Diapause Index, Degree-days

INTRODUCTION

The significant factor influencing quantity and quality of the crop yields are pests. For the prevention of the damage caused by the pests there is realized the protective actions that require detailed knowledge about the species bionomy and its dependence on the extrinsic environmental conditions. The climate conditions belong to the key factors affecting the life cycle and the development of the considerable amount of species. Climate conditions affect e.g. the population dynamic, relative individual abundance, survival and generally the occurrence of the species. CLIMEX tries to detect the relationships between the species development and the climatic conditions; it can describe them and at the end mimic them so the result is the assessments of the potential geographic distribution of the modeled species under the imposed climate conditions. CLIMEX is the dynamical model for the simulations of the species relation to the climate conditions variability (Sutherst, Maywald, 1985). The information obtained from the simulations can be usable in the biological control, in the assessment of the risks posed by introduction of the species to the new areas and in the insights to the species behavior in the new environments and also for the prediction of the potential response of species to the climate change. In the case of CPB, CLIMEX was used to the presumption of the shift of CPB's occupied area. It allows estimate number of completed generations on the given locations under future climatic conditions and anticipated increase of air temperature.

MATERIALS & METHODS

The computer program CLIMEX version 2.0 was used to estimate the potential geographic distribution of *L. decemlineata* in relation to its currently known geographic distribution and long term average meteorological data. Out of three available CLIMEX modes the function of *Compare Locations* was applied. It allows comparison of climatology of the compared locations with regard to threshold values for the pest's development. Validation was carried out by comparing modeled and observed current pest's occurrence, obtained from field observations. Scenarios for the climate future development are based on the combination of SRES scenarios and GCM models available at IPCC DDCV (Intergovernmental Panel on Climate Change, Data distribution centre) website. In this study we applied three scenarios in order to encapture the whole amplitude of the expected climate development. They include not only scenario that assumes significant warming trend (i.e. ECHAM4), but also scenarios with somewhat lower temperature increases (i.e. HadCM3 and NCAR-PCM).

CLIMEX input

As the input CLIMEX requires long term average meteorological data i.e. long term average maximum and minimum temperatures, precipitations and relative humidity. In mentioned case study we used data for the 1961 – 2000 period.

Species characterization performed by consulting different sources of biological and entomological information on *Leptinotarsa decemlineata* (Capinera, 2001, Jones, 1984, Miller, 1956, Zacha, 1966,). This characterization represents the optimal range for species development defined in terms of climatic conditions that are sumarized in the Table 1.

Table 1 Development parameters for *Leptinotarsa decemlineata* in CLIMEX accord to Sutherst & al.

Temperature Index	
Limiting low temperature	12
Lower optimal temperature	18
Upper optimal temperature	28
Limiting high temperature	35
Moisture Index	
Limiting low moisture	0.15
Lower optimal moisture	0.35
Upper optimal moisture	0.8
Limiting high moisture	1.5
Diapause Index	
Diapause Induction Daylenght	15
Diapause Induction Temperature	12
Diapause Termination Temperature	0
Diapause Development Days	0
Summer/Winter Diapause Indicator	0
Degree-days per Generation	400

Lower temperature threshold for the embryonic development is 12 - 13°C and upper threshold is 38 – 40°C. The length of the embryonic development and hatched larvae ratio depends on the temperature and moisture, the smallest waste occur in the high moisture and temperature 25°C. Also larvae as harmful life stage are most active in temperature 25°C (Miller, 1956). The fist spring beetles emergence occurs during the May in the temperatures 14°C in the 25 cm soil depth so it's considered that can be used the value of the minimal average air temperature 8°C as the Diapause Termination Temperature. Diapause Induction Temperature was set to 13°C, which coresponds to July and August (Miller, 1956).

CLIMEX output

The estimation of the CPB potential occurrence is achieved by the calculating EI (Ecoclimatic Index), which describes the overall location favorableness for the pest occurrence. EI is generated from two groups of indices: first is represented by GI (Growth Index) as a description of the population growth during the favorable year period. The GI is a thermo-hydrological index scaled from 0 to 1 and it's formed by the combination of the four weekly indices – temperature, moisture, light and diapause index (TI, MI, LI, DI).

$$GI_W = TI_W \,.\, MI_W \,.\, LI_W \,.\, DI_W$$

The GI_W describes the weekly suitability of the climate for the growth an individual population of insects. It's used to estimate the period of seasonal growth of the species without reference to life cycle stages or generations.

The annually GI scaled from 0 to 100 is calculated by this way:

$$GI_A = 100 \sum_{i=1}^{52} GI_W / 52$$

The GI_A describes the overall potential for growth, and gives an indication of the potential size or relative abundance of a species across its range as determined by climate alone

The second group of indices describes a survival of the species during the unfavorable year period, this is the group of stress indices – cold, heat, dry and wet stress (CS, HS, DS, WS) and their interactions. All indices are defined by threshold values and accumulation rates. Accumulation rate determines how quickly the species accumulates stress when climatic conditions exceed the stress threshold (Sutherst, Maywald, 2001).

CLIMEX combines growth and stress indices to generate the Ecoclimatic Index, which is scaled from 0 to 100. Locations with an EI > 25 are very favorable for population growth and persistence, EI % 10 – 25 are favorable, while EI values < 10 indicates areas of marginal suitability. An EI = 0 indicates the species cannot persist in an area under average prevailing climatic conditions (Hoddle, 2003).

$$\mathbf{EI = GI_A \,.\, SI \,.\, SX,}$$

where SI is an annually stress index and SX stress interactions.

RESULTS

The output of the model for the assessment CPB's occurrence area displays the authentic pest's occurrence under the current climate conditions after the parameter adjustment (Figure 1). Output can be presented as a map, chart or table with to promote chosen variables for the best insight and comprehension the links between the climate and pest's development. The most exact indicator of the model accuracy is the Julian date of diapause termination and initiation. It can be observed in the detail table created from the map output, the table shows diapause values at weekly steps.

We made some adjustments of the species' parameters compared to Sutherst & al Table 2. The most important of them included correction of the limiting low temperature, diapause induction temperature and underestimated diapause termination temperature in the model. Original parameters lead to improper estimation of the diapause initiation and termination witch are crucial factors for the survival and occurrence.

Table 2: The species'parameter adjustment for the specification of the simulation; the first column accord to Sutherst & al., the second column adjusted parameters for Czech Republic.

Temperature Index		
Limiting low temperature	**12**	**13**
Lower optimal temperature	18	18
Upper optimal temperature	28	28
Limiting high temperature	35	35
Moisture Index		
Limiting low moisture	0.15	0.15
Lower optimal moisture	0.35	0.35
Upper optimal moisture	0.8	0.8
Limiting high moisture	1.5	1.5
Diapase Index		
Diapause Induction Daylenght	15	15
Diapause Induction Temperature	**12**	**13**
Diapause Termination Temperature	**0**	**8**
Diapause Development Days	0	0
Summer/Winter Diapause Indicator	0	0
Degree-days per Generation	400	400

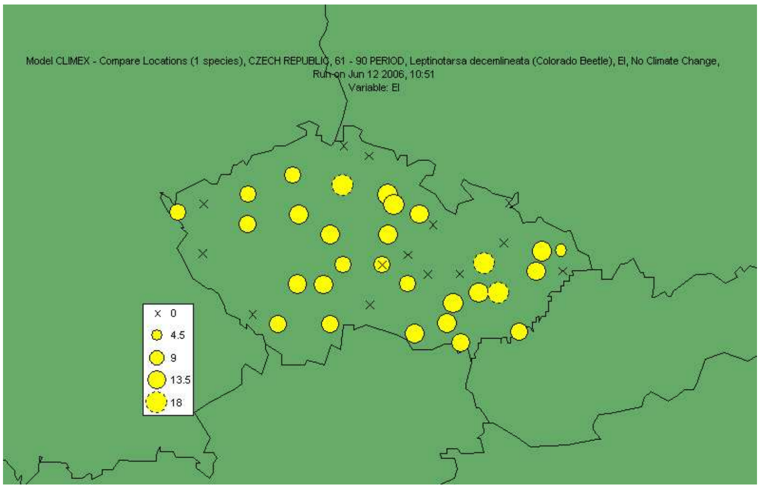

Figure 1 CPB (*Leptinotarsa decemlineata*) occurrence in the Czech Republic in 1961 – 2000 period.

For the prediction of the potential CPB geographic distribution under the expected climatic conditions the CLIMEX runs were performed with monthly means modified according to the appropriate climate change scenarios. As it is apparent from Fig. 2-7 expansion of the CPB potential niche under the changed climate together with higher number of completed generations and EI's increase is likely. The largest expansion and increase of the EI value is depicted by the Fig. 2 and 5 which are based on combination of ECHAM4 and A2 SRES scenarios., The most moderate increase is recorded in the NCAR model (Fig. 4, 7) using the same SRES.

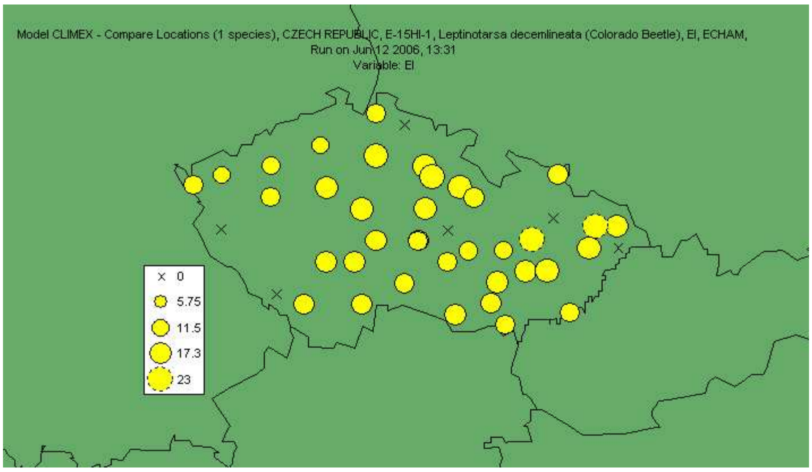

Figure 2 CPB (*Leptinotarsa decemlineata*), value of the EI in the simulation for ECHAM, year 2015.

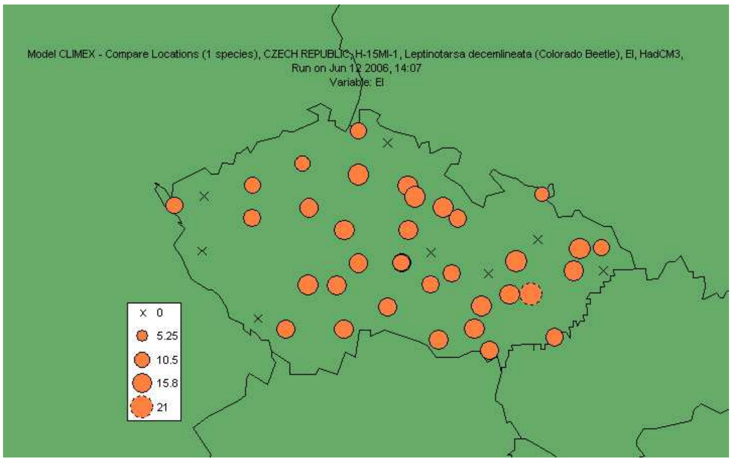

Figure 3 CPB (*Leptinotarsa decemlineata*), value of the EI in the simulation for HadCM3, year 2015.

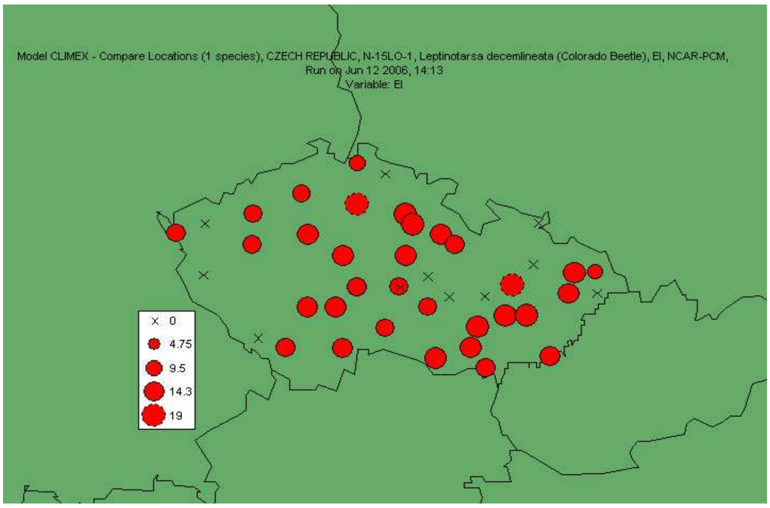

Figure 4 CPB (*Leptinotarsa decemlineata*), value of the EI in the simulation for NCAR-PCM, year 2015.

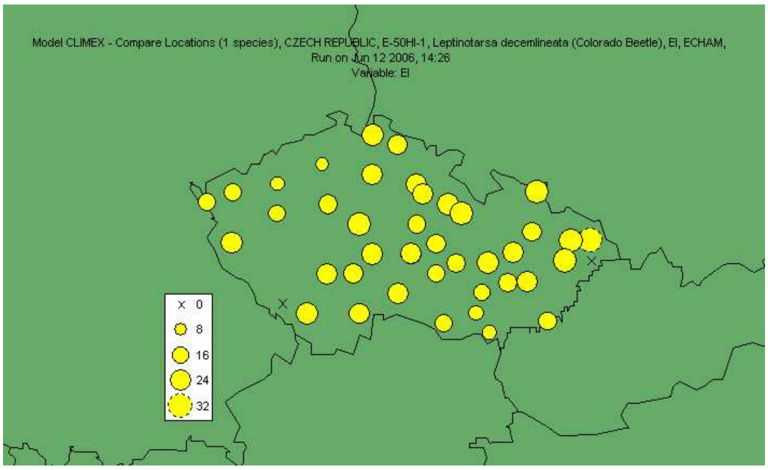

Figure 5 CPB (*Leptinotarsa decemlineata*), value of the EI in the simulation for ECHAM, year 2050.

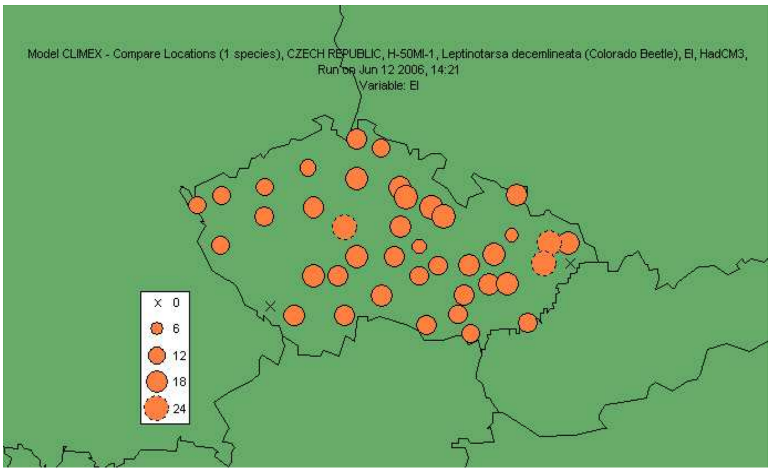

Figure 6 CPB (*Leptinotarsa decemlineata*), value of the EI in the simulation for HadCM3, year 2050.

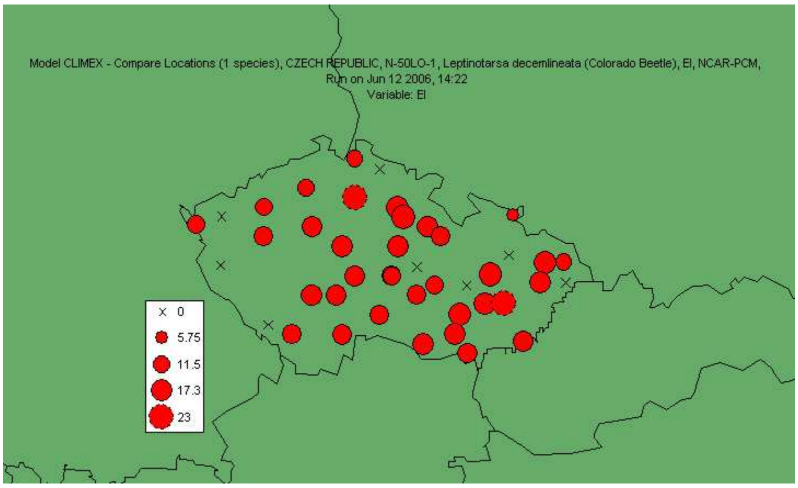

Figure 7 CPB (*Leptinotarsa decemlineata*), value of the EI in the simulation for NCAR-PCM, year 2050

CONCLUSION

Performed study tries to estimate the shift in the CPB's occurrence area following the expected climate change. CLIMEX model was applied in order to simulate CPB's development and occurrence dependence on temperatures. All of three chosen climate change scenarios indicated marked shift of CPB's potential niche to higher altitudes thus predicting increase of the infestation pressure. Our results also indicate increase in number of generations for example in the warmest locality of the Czech Republic Lednice from the partial second generation (1.77) in current conditions to almost two generations (1.99) according to the NCAR 2050 model and almost three generations (2.96) according to the ECHAM 2050 model. However significant changes are to be expected also at colder locations. For example in Liberec where under the current climate EI equals to zero (i.e. CPB is not present), climate change along lines of NCAR scenario leads by 2050 to EI equaling to 11.5 and the number of generations 1.13 that means completed first generation. According to the ECHAM 2050 scenario there can be almost two generations (1.92) with EI 24 expected.

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