Analyzing climate impacts on insect pests using phenology modeling and geographic information system implemented in the Insect Life Cycle Modeling (ILCYM) software

Tropentag 2013

"Agricultural development within the rural-urban continuum"

September 17 - 19, 2013, Stuttgart-Hohenheim

Jürgen Kroschel[1]
Henri E. Z. Tonnang[1,2]
Henry Juarez[1]
B. Le Ru[2]
R. Hanna[3]

[1]Agroecology/IPM
Integrated Crop and Systems Research Program,
International Potato Center,
P.O. Box 1558, Lima 12, Peru
j.kroschel@cgiar.org

[2]icipe, Nairobi, Kenya
[3]IITA, Ibadan, Nigeria

The Challenge

Climate change will precariously affect agricultural production and the livelihood of farmers in developing countries by unpredictably changing the abundance of insect pests. On average, 30 to 50% of the yield losses in agricultural crops are caused by pests despite the application of pesticides to control them. Climate, especially temperature, has a strong and direct influence on insect development and is considered under climate change the dominant abiotic factor directly affecting herbivorous insects. Early predictions of pest risks could help to adapt to climate change by developing and supporting farmers with adequate pest management strategies.

Our Approach

The International Potato Center (CIP) developed the Insect Life Cycle Modeling (ILCYM) software as an open-source computer tool which supports the development of pest phenology models and to map and quantify changes on global and regional scales under current and future climates.

ILCYM Modeling Concept

Insects require a certain amount of heat to develop from one developmental stage to another in their life-cycle. Besides development, other processes that determine an insect species' life history, such as survival and reproduction, are also strongly influenced by temperature. The relationship between insect development and temperature is best described by process-based phenology models. The conceptual framework of ILCYM is based on the application of temperature-dependent nonlinear relationships for representing all insect life cycle processes. It has three main modules: the model builder, the validation and simulation module, and the potential population distribution and risk mapping module.

Life table parameters

ILCYM calculates: the net reproduction rate R_0(♀/♀), mean generation time T (days), intrinsic rate of increase r_m; finite rate of increase e^{r_m} and the doubling time $Dt = Ln(2)/r_m$.

Risk indices

From life table parameters, three indices are estimated: The establishment risk index (*EI*), the generation index (*GI*) and the activity index (*AI*).

Temperature inclusion in the phenology model

Using cosines approximation of temperature, the risk indices can be mapped under present and projected SRES emission scenarios (e.g., SRES-A1B) for predicting responses to present and future climates.

Predictions of global risks 2000 - 2050

(A) The case of the potato tuber moth

The potato tuber moth, *Phthorimaea operculella* (Lepidoptera: Gelechiidae) is an invasive potato pest with origin in South America (Fig. 1).

Figure 1. The potato tuber moth, *Phthorimaea operculella*, causes damage (mines) on potato leaves and tubers; its center of origin is South America, but today the pest occurs in more than 90 countries worldwide.

A potential range expansion into temperate regions of the northern hemisphere as well as in tropical mountainous regions is predicted for the potato tuber moth (Fig. 2).

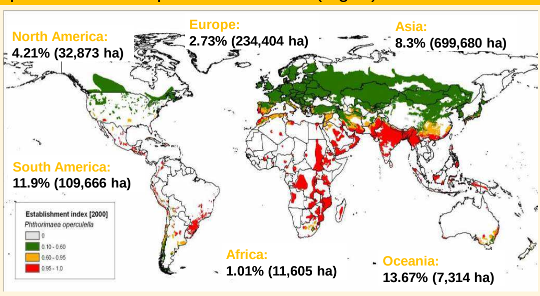

Figure 2. Change in establishment and future distribution (%, ha) of the potato tuber moth, *Phthorimaea operculella,* in potato production systems worldwide according to model predictions, using the establishment risk index for the years 2000 and 2050. Indices of >0.6 are associated with permanent establishment.

The pest damage potential of the potato tuber moth may progressively increase in all regions where the pest prevails today with an excessive increase in warmer cropping regions of the tropics and subtropics (Fig. 3).

Economic damage starts to occur when >4 generations develop/year. Today, >4 generations are developed on 30.2% (5.9 million ha) of the total potato production area worldwide; this can potentially increase to 42% (8.3 million ha).

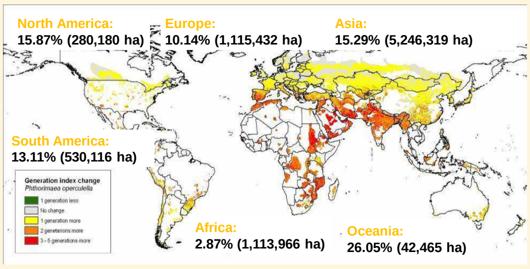

Figure 3. Change in the abundance (damage potential) (%, ha) of the potato tuber moth, *Phthorimaea operculella,* in potato production systems worldwide according to model predictions, using the generation index for the years 2000 and 2050 and the absolute generation index change.

(B) The case of the spotted stem borer

The spotted stemborer, *Chilo partellus* (Lepidoptera: Crambidae) is an invasive cereal pest with origin in India (Fig. 4).

Figure 4. The spotted stemborer, *Chilo partellus*, causes damage on maize and sorghum leaves and stems; its center of origin is India, but today the pest occurs in most lowland areas in East and Southeastern African countries,

Under future temperature scenarios the spotted stem borer will potentially disappear from most dry lowland areas of East Africa and expand into most higher elevated areas in East and Southeastern African countries (Fig. 5A, B).

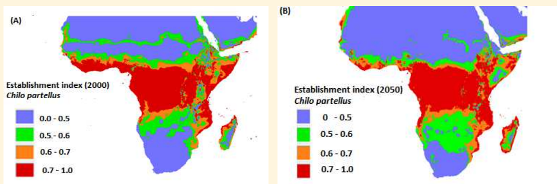

Figure 5. Change in establishment of the spotted stem borer, *Chilo partellus,* in Africa according to model predictions, using the establishment risk index for the years 2000 and 2050.

Model predictions indicate a potential increase in the number of spotted stem borer generations in the year 2050, which indicates that higher pest infestations and yield losses may occur (Fig. 6A, B).

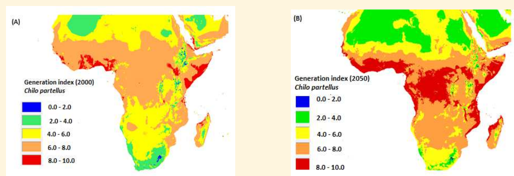

Figure 6. Change in the number of generations/year of the spotted stem borer, *Chilo partellus,* in Africa according to model predictions, using the generation risk index for the years 2000 and 2050.

Conclusions

- ILCYM is proposed as a very helpful software and tool in pest risk assessments and for adaptation planning in integrated pest management.
- The software supports the analysis of life table data and the development of phenology models for a wide range of insect pests and natural enemies of different orders and families.
- Currently, we investigate climate impacts on 22 pests of cassava, maize, potato, sweetpotato, fruits and vegetables and 12 related parasitoids used in biological control.

References

Kroschel, J., M. Sporleder, H.E.Z. Tonnang, H. Juarez, P. Carhuapoma, J.C. Gonzales & R. Simon (2013): Predicting climate change caused changes in global temperature on potato tuber moth *Phthorimaea operculella* (Zeller) distribution and abundance using phenology modeling and GIS mapping. Journal of Agricultural and Forest Meteorology 170: 228-241.

Sporleder M, H.E.Z. Tonnang, P. Carhuapoma, J.C. Gonzales, H. Juarez, J. Kroschel (2013): Insect Life Cycle Modeling (ILCYM) software – a new tool for regional and global insect risk assessment under current and future climate change scenarios, CABI Publishing; pp 412-427.

Funded by:

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

The ILCYM software and manual can be downloaded from www.cipotato.org/ilcym