Predicting Heliothis (*Helicoverpa armigera*) pest population dynamics with an age-structured insect population model driven by satellite data

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Short summary

The cotton bollworm *Helicoverpa armigera* (Hubner: Lepidoptera Noctuida), known also as Heliothis, is among the most damaging agricultural insect pests in the world. This polyphagous insect is endemic in cotton, corn, tomato, hot pepper, and tobacco crops (Liu et al., 2004). The life cycle of Heliothis is temperature dependent and as such modeling its population dynamics for inte-grated pest management (IPM) purposes requires accurate temperature information throughout the area of interest, which is not always available.

We present, for the first time, a continuous age-structured insect population model driven by satellite-derived land surface temperature (LST from **MODIS**) to derive population dynamics of *H. armigera*. We validated our model with larvae counts from in-field scout reports in nine sweet corn (*Zea mays convar*) and four tomato (*Solanum lycopersicum*) crop fields in Northern Israel.

Model description

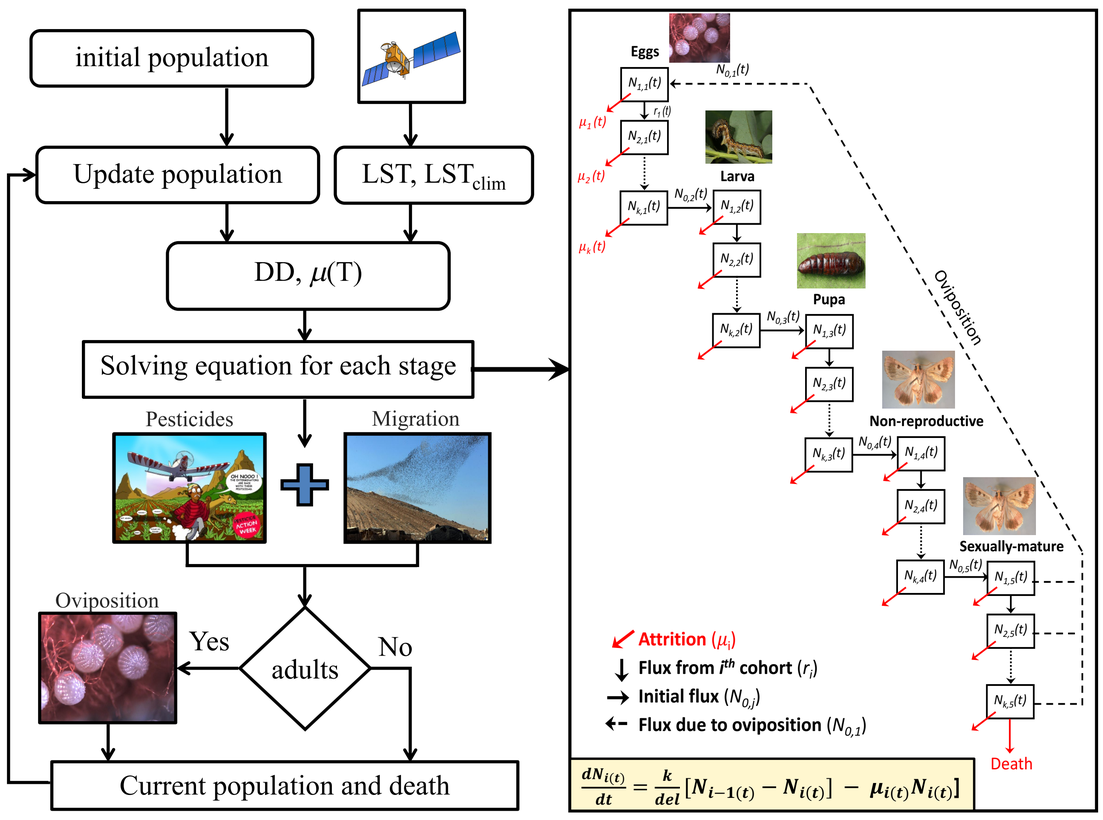

Fig.1. Schematic representation of the model procedure and corresponding input datasets (left) and the differential equation used to solve the age-mass structured *H. armigera* population dynamics (right).

Study area

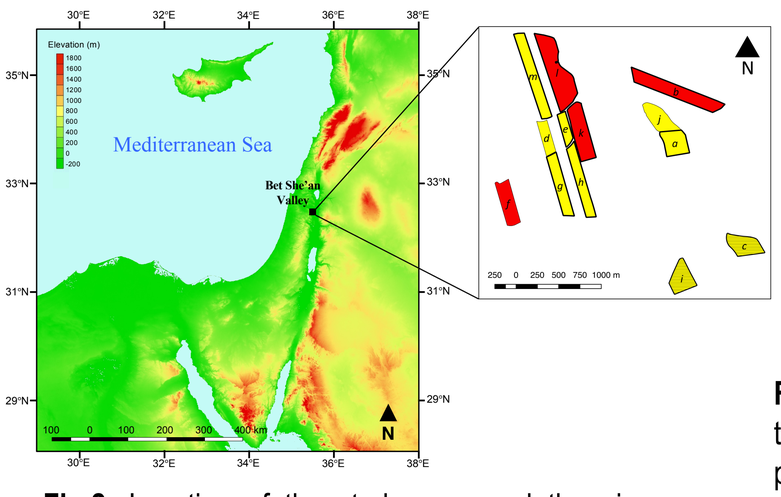

Fig.2. Location of the study area and the nine corn (yellow) and four tomato (red) fields in Bet She'an Valley, Northern Israel. Studied fields are differentiated by lowercase lettering (***a – m***), while fields with in situ data used for validation are bordered with a solid bold line (fields ***a, b, e, g, h, k, l*** and ***m***). Control (corn) fields ***c*** and ***i*** were used to estimate the initial ('background') number of reproductive adult individuals in the model at the other seven corn fields.

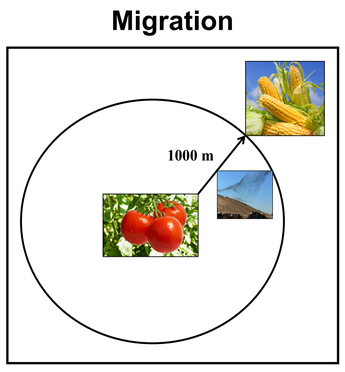

Fig.3. A schematic representation of the observed adult population migration patterns from tomato to neighboring corn fields in the study area. Migration took place only up to a limited distance of 1000 m (Cohen et al. 2015).

Results

First, modeled populations of a single generation of the five life stages of Heliothis were simulated with neither migration nor pesticide application under long-term average temperature conditions (LST_{clim}). Shown in **Fig. 4** are the normalized populations (i.e. actual population of each stage divided by its maximum population size) of the different life stages.

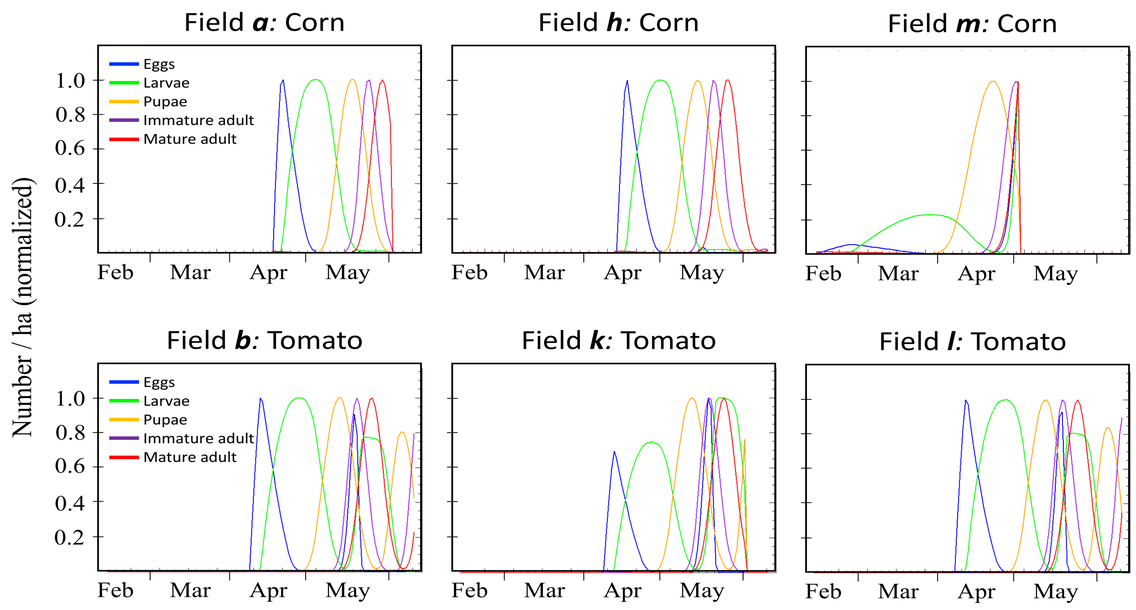

Fig.4. Modeled normalized populations of *H. armigera* in corn and tomato fields. Simulations did not include migration and mortality due to pesticide application.

Table 1. Pearson's-*r* and RMSE scores of the regressions of modeled vs. observed (in situ) larvae populations. Statistically significant (P<0.05) scores are indicated with an asterisk.

Crop type	Field	Pearson's-*r*	RMSE
Corn	***a***	0.95*	0.12
	e	0.85	0.23
	g	0.85	0.25
	h	0.57	0.34
	m	0.74*	0.29
Tomato	***b***	0.95*	0.15
	k	0.96*	0.13
	l	0.91*	0.15
Mean		**0.85[a]**	**0.21[a]**
Std		0.13	0.08

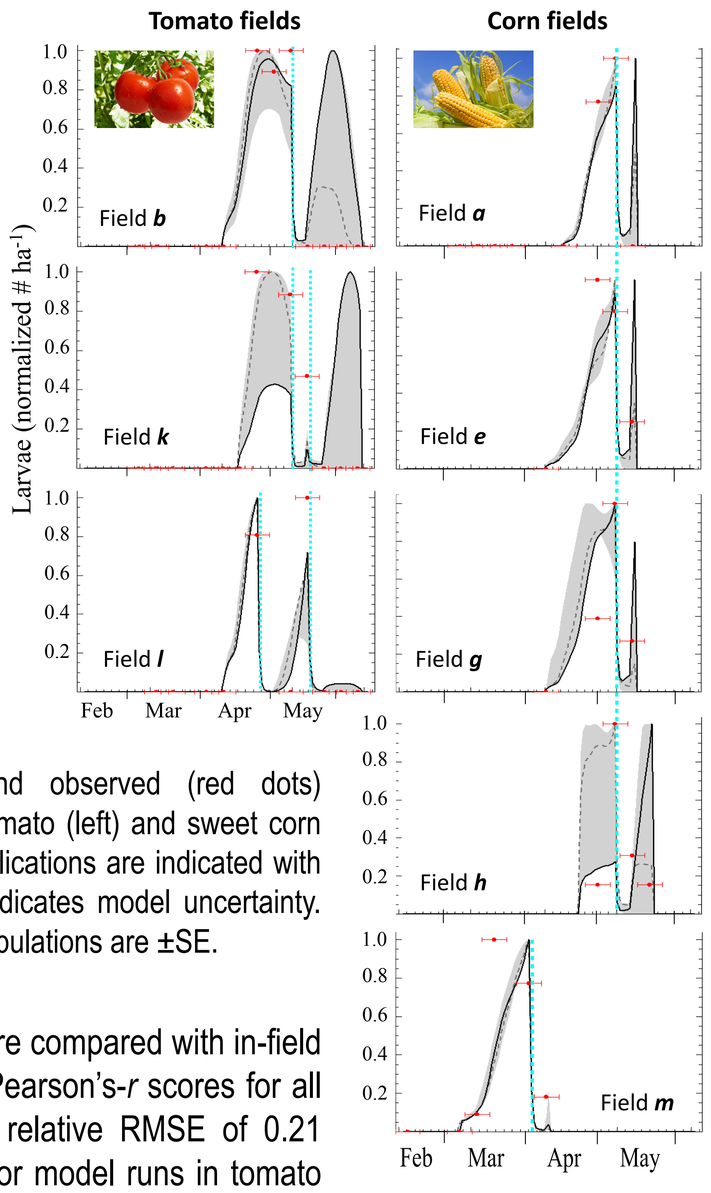

Fig.5. Modeled (black lines) and observed (red dots) normalized larvae populations in tomato (left) and sweet corn (right) fields. Dates of pesticide applications are indicated with dashed blue lines. Shaded area indicates model uncertainty. Horizontal error bars in observed populations are ±SE.

Simulated larvae populations were compared with in-field observations (**Fig. 5**). Average Pearson's-*r* scores for all fields was 0.85 ± 0.13 with a relative RMSE of 0.21 (**Table 1**). The average scores for model runs in tomato fields were r = 0.94 ± 0.03 and RMSE = 0.25; and r = 0.79 ± 0.14 and RMSE = 0.14 in corn fields.

Conclusions

Our model captured well Heliothis population dynamics as well as the effect of pesticide application and adult population migration patterns. Results were consistent with field observations of the larvae population showing the great potential of these kinds of models driven by satellite data in the use of IPM applications.

References

Blum M., Lensky I.M., Rempoulakis P., Nestel D., 2015. Modeling insect population fluctuations with satellite land surface temperature. *Ecol. Model.* 311, 39–47.

Liu Z., Li D., Gong P., Wu K., 2004. Life Table Studies of the Cotton Bollworm, Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) on Different Host *Plants, Environ. Entomol.* 33, 1570–1576.

Cohen Y., Hezroni A., Goldshtein E., Geula F., Shaltiel L., Lensky I.M., Alon T., Raviv R., Blum M., 2015. Improving areal pest management in the northern valleys in Israel (No. 458-534–13). Report. Agricultural Engineering Institute, ARO, Israel