Effectively Control the Risks of Colorado Potato Beetle in the Potato Industry: A Spatial Approach

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Abstract

Our study focuses on modeling Colorado potato beetle (CPB) outbreaks and damage caused in Maine. The approach is to evaluate CPB outbreak frequency in a spatio-temporal framework. A block bootstrapping method with has been used to evaluate the CPB damage on a experimental field of potatoes. Although the bootstrap (Efron 1979) method can handle independent observations well, the strong autocorrelation of CPB outbreaks brings about a major challenge. Motivated by bootstrapping overlapped blocks methods in an autoregressive time series scenario (Kunsch 1989) and block bootstrapping method of dependent data from a spatial map (Hall 1985), we adopted a method to bootstrap overlapping spatio-temporal blocks. By selecting an appropriate block size, the spatial-temporal correlation can be eliminated.

With our saptio-temporal block bootstrapping approach, impacts of environmental factors on CPB outbreaks and implications of crop rotations are assessed. Some explanatory variables, including temperature, crop rotations and soil minerals have been detected to have significant impacts. Consequently, our method offers a way to design spatial layout to minimize the risks of CPB outbreaks, given the current environmental information of a field.

Introduction

The potato industry has always been an integral part of the U.S. food system with significant economic impacts. Particularly, the state of Maine heavily relies on this industry. It generates over $300 million annual sales and provides over $112 million income to Maine residents.

However, the Maine potato industry faces continuous threats from various species of pests and diseases. Among them, Colorado Potato Beetle (CPB) is one of the leading factors to cause a large amount of losses. Consequently, scholars from different scientific backgrounds have performed numerous studies on this pest.

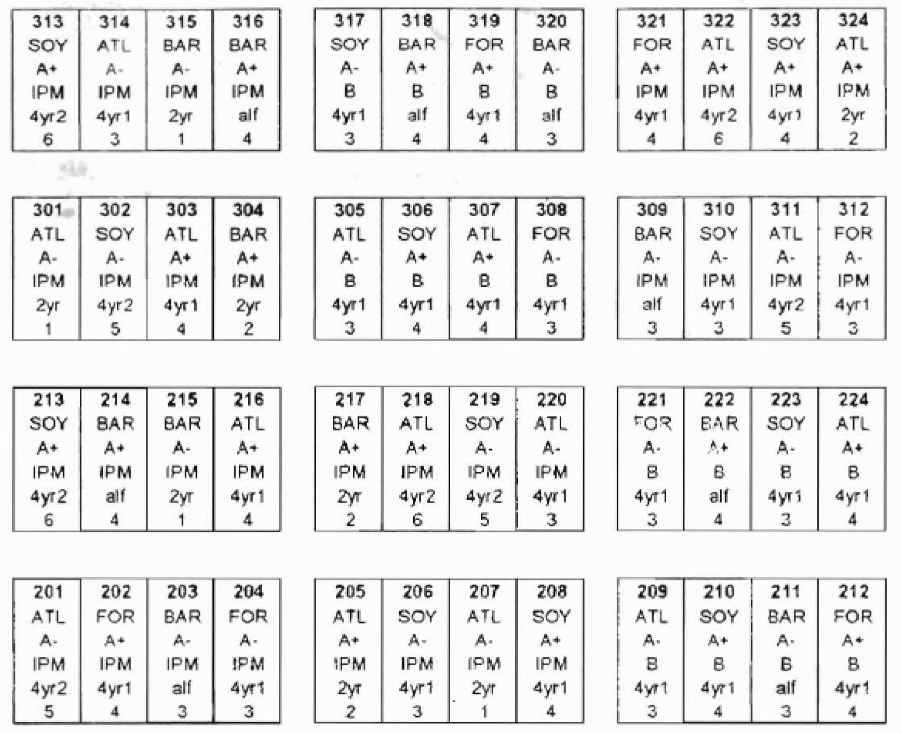
Until now, however, most of the research on CPB has been focused on its epidemiological and ecological analysis. For example, it is found that mineral balance and pesticides may significantly influence Colorado potato beetle populations. In addition, researchers also found that effective rotations may impact the CPB outbreaks and potato yields. However, the economic costs of CPB outbreaks and the spatial correlation of such risks are rarely evaluated.

Data

Our paper uses a data set from Maine Potato Ecosystem Project.

The data set spans thirteen years, describing the detailed information about soil nutrition, pest management, cultivation, rotation and pest outbreaks of several potato experimental fields in Aroostook County of Maine.

Each field consists of a large number of bordered sites with different managements and rotations. Since we found that CPB risks are spatially correlated, spatial autoregressive models are adopted. Our results suggest significant impacts by climatic and environmental factors such as temperature and mineral balance. At the same time, human practices, such as crop rotations, are found to be able to influence CPB densities significantly. Implications of these results for potato farm management are discussed.



Methods

• Bootstrapping (Efron 1979)

Suppose that $\hat{\theta}_n$ is an estimate of a parameter vector θ based on a sample X= (x1, x2 …xn). An approximation to the statistical properties of $\hat{\theta}_n$ can be obtained by studying a sample of bootstrap estimators $\hat{\theta}(b)_m$, b=1, 2,….B, obtained by sampling m observations, with replacement, from X and re-computing $\hat{\theta}$ with each sample. After a total of B times, the desired sampling characteristic is computed from $\Theta = [\hat{\theta}(1)_m....\hat{\theta}(B)_m]$

For example, if it were known that the estimator were consistent and if B were reasonably large, then one might approximate the asymptotic covariance matrix of the estimator $\text{Est. Asy. Var }[\hat{\theta}] = \frac{1}{B}\sum_{b=1}^{B}(\hat{\theta}(b)_m - \hat{\theta}_n)(\hat{\theta}(b)_m - \hat{\theta}_n)'$

Basic Assumptions: Independence

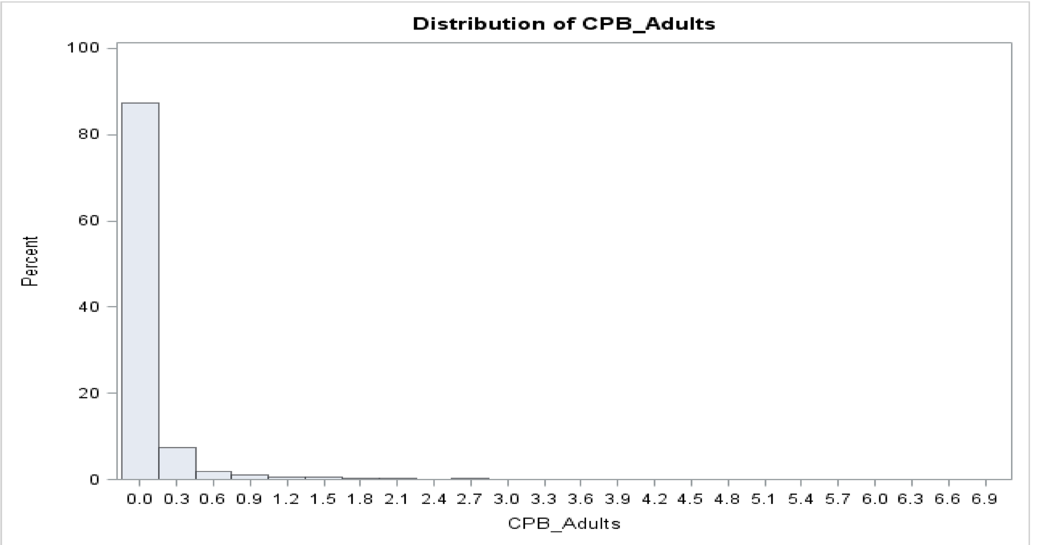
• Block Bootstrapping

Hall (1995) discussed techniques to deal with dependent data on a spatial map in the bootstrapping context. Motivated by this method, we derived a spatio-temporal block bootstrapping method in the hope to eliminate the spatio-temporal autocorrelation.

We divided all the plot-year observations into a number of blocks. In this way, we grouped the space-time records into n overlapping blocks. Each iteration, we resampled the blocks, with replacement n times.

Estimation

• Outbreaks Distribution



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• Estimation Results

Selected Independent Variable	Coefficients
Intercept	-3.36164
Two Year Rotation	-0.06119
Four Year Rotation	-0.08688
Manure	-0.06422
Integrated Pest Management	0.08152*
Mineral P	-0.00146***
Mineral MG	-0.00210
Mineral S	0.07356***
PH Value	-0.59894*

Note: Iteration=100. Single (*), double (**), and triple (***) denote significance at 0.10, 0.05, and 0.01 levels, respectively.

Conclusion

The minerals, especially P and S, positively affect CPB outbreaks significantly. The plots with higher PH value have smaller CPB risks. The Integrated Pest Management strategy is able to reduce CPB outbreaks significantly. At the same time, crops rotations are able to reduce the CPB risks as we expected. Though insignificantly, different crop rotation styles have different impacts on the CPB outbreaks in terms of magnitudes.

In general, our study provides an empirical methodology to control the risks of CPB outbreaks with an appropriate spatial management of cropping fields for potato farmers. However, such a method is not limited to the potato industry that we studied. The method developed here could be easily applied to other crops such as corn and soybean which also face various contagious hazards. Our approach may open an avenue for farmers to utilize proper spatial management methods to enhance the efficiency of their agricultural practices by effectively minimizing production risks.