

# Randomization tests on multi-factorial insect data with mixed effects

Suqin Hou, Kristina Prescott, David Andow  
Department of Entomology, University of Minnesota

## Purpose

We perform randomization tests on a nested model with mixed effects to test if Region, Region:Crop and Crop factors affect the reproductive rate of stinkbugs significantly.

## Introduction

Randomization test has been widely recognized as a useful tool while facing data with non-normal distributed errors. It is particularly useful for multivariate analysis, where distributional assumptions are even more difficult to fulfill.

We used randomization tests to establish distributions under null hypotheses for a complex, multi-level data set representing stinkbug reproductive rates by habitat over a 3-year (2009-2011) period in Georgia (See Fig. 1)

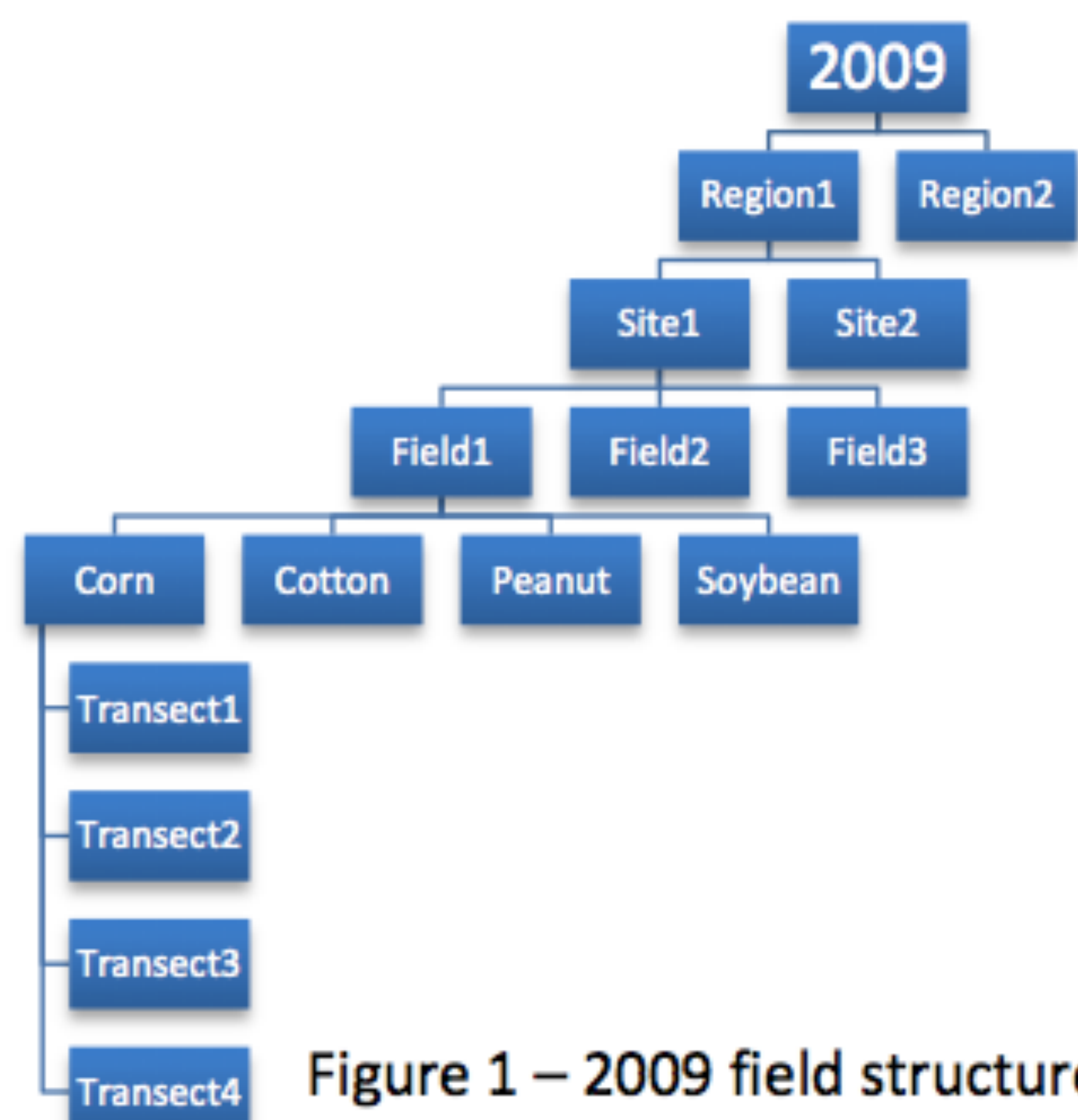


Figure 1 – 2009 field structure

## Background and Rationale

- We have calculated the stinkbug reproductive rates and constructed a linear model on the in the previous study.
- The levels we used to estimate the reproductive rates include: Year, Region, Site and Crop, where Year, Region and Crop are considered as fixed effects, and Site is considered as random effect.
- Based on the parametric test ANOVA table (see Fig. 2), our our null hypotheses (questions of interest) are: (1) there is no effect of Crop, (2) there is no effect of Region:Crop regarding the reproductive rates and (3) there is no effect of Region. Due to time limit I only focused on (1) and (2).

Analysis of Variance Table

|                  | Df | Sum Sq | Mean Sq | F value | Pr(>F)        |
|------------------|----|--------|---------|---------|---------------|
| year             | 2  | 4.469  | 2.2346  | 2.7151  | 0.072082 .    |
| region           | 1  | 5.777  | 5.7772  | 7.0195  | 0.009651 **   |
| site             | 2  | 1.215  | 0.6075  | 0.7382  | 0.481100      |
| crop             | 3  | 26.867 | 8.9556  | 10.8813 | 4.220e-06 *** |
| year:region      | 2  | 1.307  | 0.6533  | 0.7938  | 0.455524      |
| year:site        | 3  | 3.126  | 1.0420  | 1.2661  | 0.291402      |
| region:site      | 2  | 7.654  | 3.8270  | 4.6499  | 0.012187 *    |
| year:crop        | 6  | 5.473  | 0.9121  | 1.1082  | 0.364625      |
| region:crop      | 3  | 26.745 | 8.9149  | 10.8318 | 4.444e-06 *** |
| year:region:site | 3  | 0.915  | 0.3050  | 0.3706  | 0.774422      |
| year:region:crop | 5  | 9.102  | 1.8204  | 2.2118  | 0.060692 .    |
| Residuals        | 83 | 68.311 | 0.8230  |         |               |

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Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Figure 2 – Anova Table

## Methods

- I examined the three ways of doing the randomization tests – unrestricted permutation of raw data, permute residuals under reduced model, and permute residuals under full model. By comparing powers of permutations tests by Anderson et al (2008), I used permutation of residuals under the full model since for our data (errors are distributed between lognormal and super-exponential), powers of each permutation test seem to be very similar. Also it is generally agreed by scholars that permuting residuals is more efficient than permuting the raw data. The next step is to permute residuals under the reduced model.
- For testing the effects of Crop and Region:Crop: First I regressed the responses on all parameters and get original residuals; Then I permuted the residuals and get a new set of responses by adding up new residuals and fitted values; Next, I regressed the new responses on all parameters, and obtained a new F value for the parameter of interest. Then I repeated this procedure by n times. The formula is:

$$p\text{-value} = P(F^{TB*} \geq F) = \frac{\text{number of } F^{TB*} \geq F}{n!}$$

- For testing the effects of Region: though we can perform the same procedure as above, it is actually more complicated than above since the expected mean square error (EMS)'s degree of freedom is too low. We will focus on this part later.

## Results

- P-values for Crop and Region:Crop effects with respect to different number of permutations:

| Number of permutations (n) | P-value for crop | P value for region:crop |
|----------------------------|------------------|-------------------------|
| 10000                      | 0.353            | 0.1166                  |
| 20000                      | 0.34005          | 0.1113                  |
| 30000                      | 0.34388333       | 0.1114                  |
| 40000                      | 0.34805          | 0.111725                |
| 50000                      | 0.3429           | 0.1118                  |

## Discussion

- Since all p-values are significantly higher than 0.05, Crop and Region:Crop effects don't significantly affect the reproductive rates of stinkbugs.
- Scholars tend to think permuting residuals under reduced model has to test the significant terms, thus my next step is to permute residuals under reduced model to see does it make any difference.
- This approach could be possibly well applied to other ecological data since they tend to have multi-level structures with mixed effects and non-normal error distributions.

## Literature Cited

- Anderson, M.J & ter Braak, C.J.F. 2003. Permutation tests for multi-factorial analysis of variance. *Journal of Statistical Computation Simulation* 73: 85-113
- Andow, D, A, D.M.Olson, J.R. Ruberson et al (2008). *Mechanisms for stink bug outbreaks associated with Bt cotton. Poster presented in 2008.*
- Storm, C. (2012). *Permutation Procedure of Anova, Regression and PCA.* University of Pretoria. Pretoria.