Soybeans are one of the most important crops and have a variety of uses as a high protein crop, oil crop and animal feed. Crop yield is highly influenced by environmental factors, such as atmospheric carbon dioxide level (CO₂) and fluctuations in temperature.

The purpose of this analysis is to investigate if there is a difference in the pattern of soybean yield (hg/ha) per country over time using annual average temperature and annual pesticide use as predictors.

Assessing Pattern of Change Over Time (1990 – 2013)

A sample of 797 records across 34 countries with 24 repeated measurements (1990 – 2013) of soybean yield (hg/ha) from the Food and Agriculture Organization and World Data Bank were used for this longitudinal analysis.

The dependent variable, soybean yield (hg/ha), is treated as a continuous variable.

Countries with multiple (>1) average annual temperatures or countries with <20 occasions were excluded.

Assessing Model Fit

A spaghetti plot for visualizing the trajectories of soybean yield for each of the 34 countries was utilized to aid in the identification of patterns in soybean yield from 1990 to 2013 and to assess overall variation in soybean yield for all countries.

After an unstructured saturated means model was generated for descriptive purposes to assess covariance structure and the pattern of soybean yield over time, the Intraclass Correlation (ICC), or the proportion of total variance attributed to between-person differences, was generated by an empty means, random intercept only model.

Fixed and random effects of time were added iteratively to a longitudinal mixed model using a bottom-up approach and assessed at each iteration for best model fit. Time was centered at the first year (1990).

SAS CODE

PROC MIXED DATA=work.soybeans SOLUTION DDFM=Satterthwaite;
CLASS country;
MODEL yield = year time temp pesticide_use / SOLUTION DDFM=Satterthwaite;
RANDOM INTERCEPT / SOLUTION DDFM=Satterthwaite;
OUTPUT COVS=corr; RUN;

DISCUSSION

Increases and fluctuation in soybean yield over time (Figure 1) serve as justification for the inclusion of fixed and random effects of time in the final model to capture the pattern of soybean yield.

The variances and covariances from the marginal V matrix from the Random Linear model appear to decrease as years pass. There is an inherent autocorrelation in that years closer together are more correlated than years further apart.

Soybean yield increased on average by 133 hg/ha per year (Table 2) from 1990 to 2013. A variance in the random linear slope was added (along with its covariance with the random intercept), resulting in a significant improvement in model fit, ~2ALL(“X”) = 5530.95, p < 0.05, indicating significant individual differences in the linear rate of increase in soybean yield across time.

There was no relationship (p=0.05) between annual pesticide use and soybean yield. There was a relationship between average annual temperature and soybean yield (p=0.0012); for every degree Celsius increase, soybean yield decreases by 452 hg/ha, while adjusting for time and temperature (Table 2).