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| **Biostokastikum** | 2013-06-14 |

**Exercise: Agricultural field experiment with spatial correlation**

Bayisa (2010) discussed statistical analyses of a bread wheat experiment. Table 1 includes the data. In this experiment, 20 varieties were investigated in four replicates (i.e. blocks).

Fit a randomized complete block (RCB) model and compare this model with alternative mixed models that accounts for spatial correlation between plots.

Is the difference between varieties 1 and 3 significant (with or without adjustment for multiple comparisons)? Which is the top performing variety?

#### Table 1. Data from bread wheat experiment (Bayisa, 2010)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variety | Replicate | Northing | Easting | Yield (kg/plot) |
| 1 | 1 | 2.5 | 1.2 | 1.19223 |
| 2 | 1 | 2.5 | 2.8 | 1.25214 |
| 3 | 1 | 2.5 | 4.4 | 1.10406 |
| 4 | 1 | 2.5 | 6 | 1.24683 |
| 5 | 1 | 2.5 | 7.6 | 1.1163 |
| 6 | 1 | 2.5 | 9.2 | 1.31448 |
| 7 | 1 | 2.5 | 10.8 | 1.38618 |
| 8 | 1 | 2.5 | 12.4 | 0.96372 |
| 9 | 1 | 2.5 | 14 | 1.05519 |
| 10 | 1 | 2.5 | 15.6 | 0.93897 |
| 11 | 1 | 2.5 | 17.2 | 1.24407 |
| 12 | 1 | 2.5 | 18.8 | 1.08006 |
| 13 | 1 | 2.5 | 20.4 | 0.87837 |
| 14 | 1 | 2.5 | 22 | 0.95181 |
| 15 | 1 | 2.5 | 23.6 | 1.12923 |
| 16 | 1 | 2.5 | 25.2 | 1.19439 |
| 17 | 1 | 2.5 | 26.8 | 1.37079 |
| 18 | 1 | 2.5 | 28.4 | 1.11795 |
| 19 | 1 | 2.5 | 30 | 1.06083 |
| 20 | 1 | 2.5 | 31.6 | 0.5982 |
| 17 | 2 | 6 | 1.2 | 0.96315 |
| 18 | 2 | 6 | 2.8 | 1.22655 |
| 2 | 2 | 6 | 4.4 | 1.33428 |
| 1 | 2 | 6 | 6 | 1.21092 |
| 11 | 2 | 6 | 7.6 | 0.9933 |
| 20 | 2 | 6 | 9.2 | 0.834 |
| 15 | 2 | 6 | 10.8 | 1.16139 |
| 10 | 2 | 6 | 12.4 | 0.96909 |
| 6 | 2 | 6 | 14 | 1.26492 |
| 13 | 2 | 6 | 15.6 | 1.26306 |
| 3 | 2 | 6 | 17.2 | 1.19709 |
| 9 | 2 | 6 | 18.8 | 1.00335 |
| 7 | 2 | 6 | 20.4 | 1.16799 |
| 14 | 2 | 6 | 22 | 1.11702 |
| 4 | 2 | 6 | 23.6 | 1.45665 |
| 16 | 2 | 6 | 25.2 | 1.24578 |
| 8 | 2 | 6 | 26.8 | 1.1958 |
| 19 | 2 | 6 | 28.4 | 1.40355 |
| 12 | 2 | 6 | 30 | 1.15674 |
| 5 | 2 | 6 | 31.6 | 1.18893 |
| 7 | 3 | 9.5 | 1.2 | 1.50873 |
| 18 | 3 | 9.5 | 2.8 | 1.30551 |
| 20 | 3 | 9.5 | 4.4 | 0.96009 |
| 17 | 3 | 9.5 | 6 | 1.19313 |
| 13 | 3 | 9.5 | 7.6 | 1.24824 |
| 5 | 3 | 9.5 | 9.2 | 1.27143 |
| 12 | 3 | 9.5 | 10.8 | 1.2984 |
| 8 | 3 | 9.5 | 12.4 | 1.28733 |
| 10 | 3 | 9.5 | 14 | 1.28445 |
| 2 | 3 | 9.5 | 15.6 | 1.42425 |
| 6 | 3 | 9.5 | 17.2 | 1.46925 |
| 19 | 3 | 9.5 | 18.8 | 1.62126 |
| 16 | 3 | 9.5 | 20.4 | 1.53294 |
| 14 | 3 | 9.5 | 22 | 1.39626 |
| 9 | 3 | 9.5 | 23.6 | 1.43559 |
| 3 | 3 | 9.5 | 25.2 | 1.27431 |
| 15 | 3 | 9.5 | 26.8 | 1.14534 |
| 11 | 3 | 9.5 | 28.4 | 1.158 |
| 1 | 3 | 9.5 | 30 | 1.44753 |
| 4 | 3 | 9.5 | 31.6 | 0.86952 |
| 8 | 4 | 13 | 1.2 | 1.12695 |
| 11 | 4 | 13 | 2.8 | 1.27158 |
| 6 | 4 | 13 | 4.4 | 1.43334 |
| 20 | 4 | 13 | 6 | 1.13727 |
| 14 | 4 | 13 | 7.6 | 1.28595 |
| 3 | 4 | 13 | 9.2 | 1.27863 |
| 5 | 4 | 13 | 10.8 | 1.47174 |
| 10 | 4 | 13 | 12.4 | 1.41009 |
| 1 | 4 | 13 | 14 | 1.50213 |
| 12 | 4 | 13 | 15.6 | 1.32705 |
| 7 | 4 | 13 | 17.2 | 1.24656 |
| 19 | 4 | 13 | 18.8 | 1.38981 |
| 17 | 4 | 13 | 20.4 | 1.40769 |
| 9 | 4 | 13 | 22 | 1.36182 |
| 13 | 4 | 13 | 23.6 | 1.45791 |
| 4 | 4 | 13 | 25.2 | 1.18266 |
| 16 | 4 | 13 | 26.8 | 1.19025 |
| 15 | 4 | 13 | 28.4 | 1.26933 |
| 18 | 4 | 13 | 30 | 1.30791 |
| 2 | 4 | 13 | 31.6 | 1.45482 |

## Reference

Bayisa, D. (2010). *Application of Spatial Mixed Model in Agricultural Field Experiment.* Master thesis. Department of Statistics, Addis Ababa University.

## Solution in SAS (Agricultural field experiment with spatial correlation)

With fixed effects of varieties and random effects of blocks, the randomized complete block model can be fitted through

**proc** **mixed** data = BreadWheat ; title "RCB" ;

class Replicate Variety ;

model Yield = Variety / ddfm = kr ;

random Replicate ;

lsmeans Variety / pdiff ;

\*lsmeans Variety / pdiff adjust = Tukey

adjdfe = row ;

ods output lsmeans = RCBLSMeans ;

**run** ; title ;

According to the RCB analysis, variety 6 is top performing.

According to the Akaike information criterion (AIC), a model with exponential covariance structure and no effects of replicates gives a better fit:

**proc** **mixed** data = BreadWheat ; title "Two dimensions, exp" ;

class Replicate Variety ;

model Yield = Variety / ddfm = kr ;

repeated / type = sp(exp)(Northing Easting)

subject = Intercept ;

lsmeans Variety / pdiff ;

\*lsmeans Variety /pdiff adjust = Tukey

adjdfe = row ;

ods output diffs = SpatialDiffs

lsmeans = SpatialLSMeans ;

**run** ; title ;

With this spatial model, the best variety is variety 1.

Table 2 presents a comparison of the two models, with regard to the test of the difference between Varieties 1 and 3.

#### Table 2. Results using SAS. Comparison of two models with regard to AIC and the estimate of the difference between varieties 1 and 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | AIC  (smaller is better) | Estimate | Std. error | P-value | |
| No adjust. | Tukey |
| RCB model | -28.0 | 0.1247 | 0.0978 | 0.2076 | 0.9990 |
| Spatial model | -34.0 | 0.2317 | 0.0869 | 0.0103 | 0.4746 |

## Solution in R (Agricultural field experiment with spatial correlation)

With fixed effects of varieties and random effects of blocks, the randomized complete block model can be fitted through

library(nlme)

library(multcomp)

BreadWheat$Variety <- factor(BreadWheat$Variety)

BreadWheat$Replicate <- factor(BreadWheat$Replicate)

RCB <- lme(Yield ~ Variety,

random = ~ 1 | Replicate, data = BreadWheat)

summary(RCB)

summary(glht(RCB, linfct = mcp(Variety = "Tukey")))

According to the RCB analysis, variety 6 is top performing.

According to the Akaike information criterion (AIC), a model with exponential covariance gives a better fit:

SpatialModel <- lme(Yield ~ Variety,

random = ~ 1 | Replicate, data = BreadWheat,

corr = corExp(form = ~ Easting + Northing))

summary(SpatialModel)

anova(SpatialModel)

summary(glht(SpatialModel,

linfct = mcp(Variety = "Tukey")))

With this spatial model, the best variety is variety 1.

Table 3 presents a comparison of the two models, with regard to the test of the difference between Varieties 1 and 3.

#### Table 3. Results using R. Comparison of two models with regard to AIC and the estimate of the difference between varieties 1 and 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | AIC  (smaller is better) | Estimate | Std. error | P-value | |
| No adjust. | Tukey |
| RCB model | 12.0 | 0.1247 | 0.0978 | 0.2076 | 0.9994 |
| Spatial model | 7.8 | 0.2041 | 0.0889 | 0.0253 | 0.7313 |