Empirical models for assessing predictor variables

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```
library(data.table)
library(lme4)
```

```
pdat <- fread('../ALFAM2-data/data/ALFAM2_plot.csv')
```

Subset

```
s1 <- pdat[meas.tech2 == 'micro met' & man.source %in% c('cat', 'pig'), ]
```

Models

```
m1 <- lmer(log10(e.rel.final) ~ (man.dm + man.ph + man.source +
                                 air.temp.24 + wind.24 + app.rate) *
                                app.method + (1 | inst),
           data = s1)
```

```
## Warning in eval(predvars, data, env): NaNs produced
## Warning in eval(predvars, data, env): NaNs produced
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```

```
## fixed-effect model matrix is rank deficient so dropping 8 columns / coefficients
```

```
summary(m1)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: log10(e.rel.final) ~ (man.dm + man.ph + man.source + air.temp.24 +
##     wind.24 + app.rate) * app.method + (1 | inst)
##    Data: s1
##
## REML criterion at convergence: 393.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -4.6563 -0.5085  0.0442  0.6218  5.6727
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  inst     (Intercept) 0.04414  0.2101
##  Residual             0.07838  0.2800
## Number of obs: 712, groups:  inst, 17
##
## Fixed effects:
##                               Estimate Std. Error t value
## (Intercept)                 -1.280e+00  3.105e-01  -4.123
## man.dm                      -5.628e-03  4.647e-03  -1.211
## man.ph                       1.027e-01  4.104e-02   2.504
```

```
## man.sourcepig                -4.142e-01  5.670e-02  -7.305
## air.temp.24                   9.978e-03  4.063e-03   2.456
## wind.24                       3.284e-02  1.606e-02   2.045
## app.rate                     -3.173e-03  1.286e-03  -2.466
## app.methodbss                -5.687e+01  1.134e+02  -0.501
## app.methodbsth               -1.141e+00  4.821e-01  -2.366
## app.methodcs                 -8.332e+01  2.973e+02  -0.280
## app.methodos                 -2.352e+00  7.492e-01  -3.140
## app.methodpi                 -1.768e+01  9.697e+00  -1.824
## app.methodts                 -2.273e+00  5.155e-01  -4.409
## man.dm:app.methodbss          9.987e+00  1.921e+01   0.520
## man.dm:app.methodbsth         4.655e-02  1.738e-02   2.678
## man.dm:app.methodcs           2.707e+00  6.692e+00   0.405
## man.dm:app.methodos           4.439e-02  1.554e-02   2.857
## man.dm:app.methodpi          -2.757e-02  1.430e-01  -0.193
## man.dm:app.methodts           5.114e-02  1.430e-02   3.577
## man.ph:app.methodbsth         1.126e-01  5.854e-02   1.923
## man.ph:app.methodcs           1.067e+01  3.851e+01   0.277
## man.ph:app.methodos           9.450e-02  9.224e-02   1.025
## man.ph:app.methodpi           2.040e+00  1.157e+00   1.764
## man.ph:app.methodts           1.817e-01  6.895e-02   2.635
## man.sourcepig:app.methodbsth  1.788e-01  8.208e-02   2.178
## man.sourcepig:app.methodos    3.971e-01  9.142e-02   4.343
## man.sourcepig:app.methodts    2.352e-01  1.142e-01   2.060
## air.temp.24:app.methodbss     4.173e-02  2.290e-01   0.182
## air.temp.24:app.methodbsth   -1.178e-02  6.691e-03  -1.760
## air.temp.24:app.methodcs     -4.100e-01  1.249e+00  -0.328
## air.temp.24:app.methodos      9.783e-03  6.219e-03   1.573
## air.temp.24:app.methodts      4.941e-03  6.481e-03   0.762
## wind.24:app.methodbss         5.966e-01  1.332e+00   0.448
## wind.24:app.methodbsth       -2.773e-02  1.912e-02  -1.450
## wind.24:app.methodcs         -5.559e-01  1.510e+00  -0.368
## wind.24:app.methodos          3.401e-02  2.575e-02   1.321
## wind.24:app.methodts          2.615e-02  2.212e-02   1.182
## app.rate:app.methodbss       -4.726e-03  6.437e-02  -0.073
## app.rate:app.methodbsth       5.699e-04  3.071e-03   0.186
## app.rate:app.methodos         1.512e-02  3.106e-03   4.869
## app.rate:app.methodts         2.769e-03  2.569e-03   1.078

##
## Correlation matrix not shown by default, as p = 41 > 12.
## Use print(x, correlation=TRUE)  or
##     vcov(x)        if you need it

## fit warnings:
## fixed-effect model matrix is rank deficient so dropping 8 columns / coefficients
```

```
m2 <- lmer(log10(e.rel.final) ~ (man.dm + man.ph + man.tan + man.source +
                                 air.temp.24 + wind.24 + app.rate) *
                                app.method + (1 | inst),
           data = s1)
```

```
## Warning in eval(predvars, data, env): NaNs produced
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## Warning in eval(predvars, data, env): NaNs produced
```

```
## fixed-effect model matrix is rank deficient so dropping 11 columns / coefficients
```

```
summary(m2)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: log10(e.rel.final) ~ (man.dm + man.ph + man.tan + man.source +
##     air.temp.24 + wind.24 + app.rate) * app.method + (1 | inst)
##    Data: s1
##
## REML criterion at convergence: 385.1
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -4.5609 -0.5109  0.0437  0.6252  5.6601
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  inst     (Intercept) 0.04861  0.2205
##  Residual             0.07605  0.2758
## Number of obs: 712, groups:  inst, 17
##
## Fixed effects:
##                                Estimate Std. Error t value
## (Intercept)                  -1.474e+00  3.191e-01  -4.620
## man.dm                       -6.683e-03  4.624e-03  -1.445
## man.ph                        1.140e-01  4.089e-02   2.787
## man.tan                       7.392e-02  3.167e-02   2.334
## man.sourcepig                -5.805e-01  8.943e-02  -6.491
## air.temp.24                   1.003e-02  4.021e-03   2.493
## wind.24                       2.953e-02  1.589e-02   1.858
## app.rate                     -2.629e-03  1.306e-03  -2.012
## app.methodbss                -5.764e+01  1.117e+02  -0.516
## app.methodbsth               -1.181e+00  4.854e-01  -2.433
## app.methodcs                 -8.929e+01  3.082e+02  -0.290
## app.methodos                 -1.975e+00  7.454e-01  -2.649
## app.methodpi                 -1.937e+01  9.583e+00  -2.021
## app.methodts                 -2.044e+00  5.242e-01  -3.900
## man.dm:app.methodbss          1.013e+01  1.892e+01   0.535
## man.dm:app.methodbsth         6.425e-02  2.046e-02   3.140
## man.dm:app.methodcs           1.437e+00  3.529e+00   0.407
## man.dm:app.methodos           1.066e-01  2.146e-02   4.966
## man.dm:app.methodpi          -3.506e-02  1.409e-01  -0.249
## man.dm:app.methodts           6.036e-02  1.999e-02   3.019
## man.ph:app.methodbsth         1.340e-01  5.962e-02   2.247
## man.ph:app.methodcs           1.071e+01  3.804e+01   0.281
## man.ph:app.methodos           6.727e-02  9.116e-02   0.738
## man.ph:app.methodpi           2.247e+00  1.143e+00   1.965
## man.ph:app.methodts           1.718e-01  6.952e-02   2.471
## man.tan:app.methodbsth       -1.519e-01  5.859e-02  -2.592
## man.tan:app.methodcs          1.248e+00  3.561e+00   0.351
## man.tan:app.methodos         -3.395e-01  7.599e-02  -4.468
## man.tan:app.methodts         -1.160e-01  8.548e-02  -1.357
## man.sourcepig:app.methodbsth  4.858e-01  1.416e-01   3.430
## man.sourcepig:app.methodos    1.260e+00  2.135e-01   5.901
## man.sourcepig:app.methodts    5.393e-01  2.856e-01   1.888
```

```
## air.temp.24:app.methodbss     4.168e-02  2.256e-01   0.185
## air.temp.24:app.methodbsth   -1.259e-02  6.632e-03  -1.898
## air.temp.24:app.methodcs     -1.437e-01  5.521e-01  -0.260
## air.temp.24:app.methodos      1.412e-02  6.211e-03   2.273
## air.temp.24:app.methodts      5.407e-03  6.407e-03   0.844
## wind.24:app.methodbss         5.999e-01  1.312e+00   0.457
## wind.24:app.methodbsth       -2.326e-02  1.900e-02  -1.224
## wind.24:app.methodos          1.283e-02  2.614e-02   0.491
## wind.24:app.methodts          3.077e-02  2.187e-02   1.407
## app.rate:app.methodbss       -5.270e-03  6.340e-02  -0.083
## app.rate:app.methodbsth       7.155e-04  3.037e-03   0.236
## app.rate:app.methodos         1.470e-02  3.103e-03   4.737
## app.rate:app.methodts         1.630e-03  2.669e-03   0.611

##
## Correlation matrix not shown by default, as p = 45 > 12.
## Use print(x, correlation=TRUE)  or
##     vcov(x)        if you need it

## fit warnings:
## fixed-effect model matrix is rank deficient so dropping 11 columns / coefficients
```

```
anova(m1, m2, test = 'Chisq')
```

```
## refitting model(s) with ML (instead of REML)

## Data: s1
## Models:
## m1: log10(e.rel.final) ~ (man.dm + man.ph + man.source + air.temp.24 + wind.24 + app.rate) * app.meth
## m2: log10(e.rel.final) ~ (man.dm + man.ph + man.tan + man.source + air.temp.24 + wind.24 + app.rate)
##    npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## m1   43 290.66 487.09 -102.33   204.66
## m2   47 274.68 489.38  -90.34   180.68 23.979  4  8.064e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

With crops.

```
s1[is.na(crop.z), crop.z := 0]
s1[crop == 'bare soil', crop := 'none']
s1[, crop := relevel(factor(crop), ref = 'none')]
m3 <- lmer(log10(e.rel.final) ~ (man.dm + man.ph + man.tan + man.source +
                                 air.temp.24 + wind.24 + app.rate + crop + crop.z) *
                                app.method + (1 | inst),
           data = s1)
```

```
## Warning in eval(predvars, data, env): NaNs produced
## Warning in eval(predvars, data, env): NaNs produced
## Warning in eval(predvars, data, env): NaNs produced

## fixed-effect model matrix is rank deficient so dropping 43 columns / coefficients
```

```
summary(m3)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: log10(e.rel.final) ~ (man.dm + man.ph + man.tan + man.source +
##     air.temp.24 + wind.24 + app.rate + crop + crop.z) * app.method +
##     (1 | inst)
##    Data: s1
```

```
##
## REML criterion at convergence: 388.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -4.6501 -0.5058  0.0747  0.6100  4.8765
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  inst     (Intercept) 0.05689  0.2385
##  Residual             0.07098  0.2664
## Number of obs: 712, groups:  inst, 17
##
## Fixed effects:
##                                Estimate Std. Error t value
## (Intercept)                  -1.771e+00  3.537e-01  -5.006
## man.dm                       -1.555e-03  5.041e-03  -0.309
## man.ph                        1.142e-01  4.207e-02   2.716
## man.tan                       6.910e-02  3.197e-02   2.162
## man.sourcepig                -4.213e-01  1.095e-01  -3.847
## air.temp.24                   1.060e-02  4.085e-03   2.595
## wind.24                       4.076e-02  1.602e-02   2.545
## app.rate                     -1.157e-03  1.436e-03  -0.805
## cropcereal                   -2.189e-01  3.452e-01  -0.634
## cropgrass                     2.332e-01  1.064e-01   2.192
## cropother                    -1.168e-02  1.526e-01  -0.077
## croprapeseed                 -4.458e-01  3.446e-01  -1.294
## cropstubble                   5.991e-02  1.031e-01   0.581
## cropwheat                     4.471e-01  2.069e-01   2.161
## crop.z                        3.881e-04  6.387e-03   0.061
## app.methodbss                -5.743e+01  1.080e+02  -0.532
## app.methodbsth               -7.492e-01  5.548e-01  -1.350
## app.methodcs                 -1.071e+02  2.988e+02  -0.358
## app.methodos                 -6.976e-01  8.046e-01  -0.867
## app.methodpi                 -2.663e+01  9.682e+00  -2.750
## app.methodts                 -1.884e+00  5.282e-01  -3.566
## man.dm:app.methodbss          1.011e+01  1.828e+01   0.553
## man.dm:app.methodbsth         6.507e-02  2.261e-02   2.878
## man.dm:app.methodcs           1.497e+00  3.412e+00   0.439
## man.dm:app.methodos           8.754e-02  2.243e-02   3.903
## man.dm:app.methodpi          -2.060e-02  1.365e-01  -0.151
## man.dm:app.methodts           5.799e-02  2.034e-02   2.852
## man.ph:app.methodbsth         1.570e-01  6.124e-02   2.563
## man.ph:app.methodcs           1.297e+01  3.689e+01   0.352
## man.ph:app.methodos          -5.303e-02  9.430e-02  -0.562
## man.ph:app.methodpi           3.107e+00  1.154e+00   2.692
## man.ph:app.methodts           1.615e-01  7.084e-02   2.280
## man.tan:app.methodbsth       -1.733e-01  6.071e-02  -2.855
## man.tan:app.methodcs          1.398e+00  3.445e+00   0.406
## man.tan:app.methodos         -3.501e-01  7.678e-02  -4.560
## man.tan:app.methodts         -7.052e-02  8.526e-02  -0.827
## man.sourcepig:app.methodbsth  2.699e-01  1.634e-01   1.651
## man.sourcepig:app.methodos    1.115e+00  2.847e-01   3.917
## man.sourcepig:app.methodts    7.587e-02  3.221e-01   0.236
```

```
## air.temp.24:app.methodbss     4.111e-02  2.180e-01   0.189
## air.temp.24:app.methodbsth   -8.863e-03  7.712e-03  -1.149
## air.temp.24:app.methodcs     -1.714e-01  5.351e-01  -0.320
## air.temp.24:app.methodos      1.784e-02  6.269e-03   2.846
## air.temp.24:app.methodts      2.386e-03  6.389e-03   0.373
## wind.24:app.methodbss         5.887e-01  1.268e+00   0.464
## wind.24:app.methodbsth       -3.877e-02  1.940e-02  -1.999
## wind.24:app.methodos         -9.360e-03  2.625e-02  -0.357
## wind.24:app.methodts          1.622e-02  2.177e-02   0.745
## app.rate:app.methodbss       -6.742e-03  6.126e-02  -0.110
## app.rate:app.methodbsth      -4.226e-03  3.269e-03  -1.293
## app.rate:app.methodos         1.299e-02  3.295e-03   3.942
## app.rate:app.methodts         1.984e-03  3.170e-03   0.626
## cropcereal:app.methodbsth     1.643e-01  3.889e-01   0.422
## cropgrass:app.methodbsth     -5.095e-01  1.592e-01  -3.200
## cropother:app.methodbsth     -7.547e-02  1.966e-01  -0.384
## cropstubble:app.methodbsth   -5.422e-02  1.806e-01  -0.300
## cropcereal:app.methodos       7.027e-01  4.454e-01   1.578
## cropgrass:app.methodos        4.040e-02  2.174e-01   0.186
## cropwheat:app.methodos       -1.325e-01  2.460e-01  -0.539
## crop.z:app.methodbsth        -4.674e-03  6.838e-03  -0.683
## crop.z:app.methodos          -3.330e-02  1.148e-02  -2.899
## crop.z:app.methodts          -9.512e-03  8.270e-03  -1.150

##
## Correlation matrix not shown by default, as p = 62 > 12.
## Use print(x, correlation=TRUE)  or
##     vcov(x)        if you need it

## fit warnings:
## fixed-effect model matrix is rank deficient so dropping 43 columns / coefficients
```

```
anova(m2, m3, test = 'Chisq')
```

```
## refitting model(s) with ML (instead of REML)

## Data: s1
## Models:
## m2: log10(e.rel.final) ~ (man.dm + man.ph + man.tan + man.source + air.temp.24 + wind.24 + app.rate)
## m3: log10(e.rel.final) ~ (man.dm + man.ph + man.tan + man.source + air.temp.24 + wind.24 + app.rate +
##    npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## m2   47 274.68 489.38 -90.340   180.68
## m3   64 244.48 536.83 -58.239   116.48 64.202 17  2.095e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```