

Evaluating agreement between measurements

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13th Expert Panel Meeting on Deposition



Gozdarski inštitut Slovenije
Slovenian Forestry Institute

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Evaluating agreement between measurements

- Agreement \neq correlation
- Perfect correlation might mean bad agreement in the case of bias
- Searching for agreement is searching for bias
- Fixed, proportional bias
- No agreed statistics, different approaches
- Numerical variables – regression, repeated measures, difference analysis
- Categorical variables – Kappa statistics



I. REGRESSION

MAIN APPROACHES when dealing with numerical variables

Model I

Gold standard (exact values) of old method -> OLS regression (1)

*rarely suitable

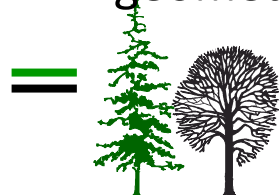
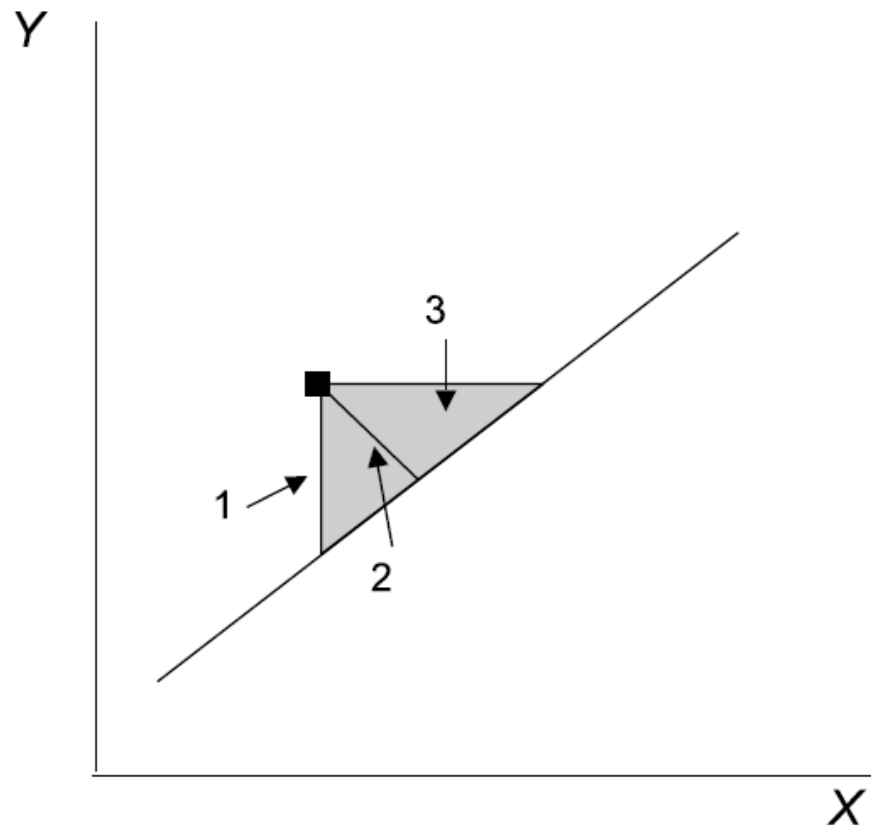
Model II

No gold standard; both methods erroneous (bivariate normal distribution; both variables random)

-> major axis regression

(Deming regression) (2) or

-> geometric mean regression (3)

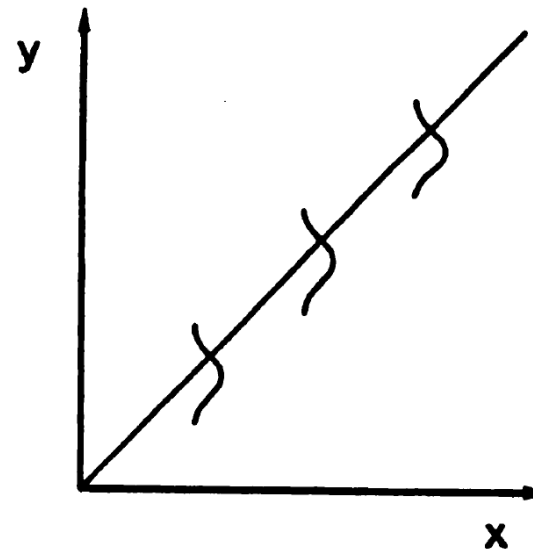


MAIN APPROACHES when dealing with numerical variables

Model I

Gold standard (exact values) of old method -> OLS regression (1)

*rarely suitable



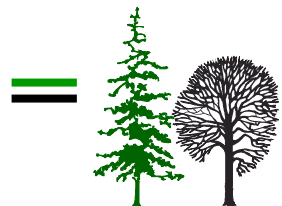
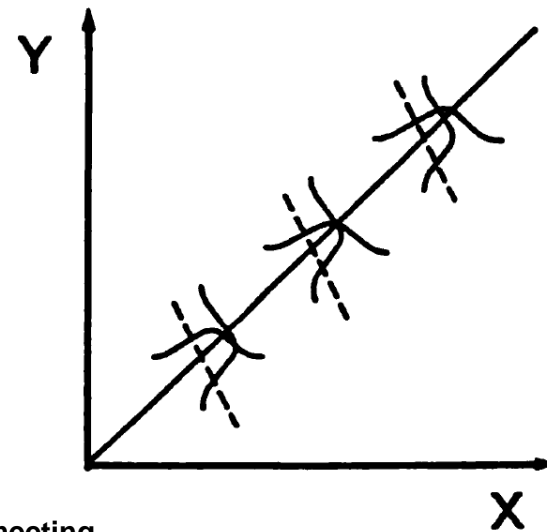
Model II

No gold standard; both methods erroneous (bivariate normal distribution; both variables random)

-> major axis regression

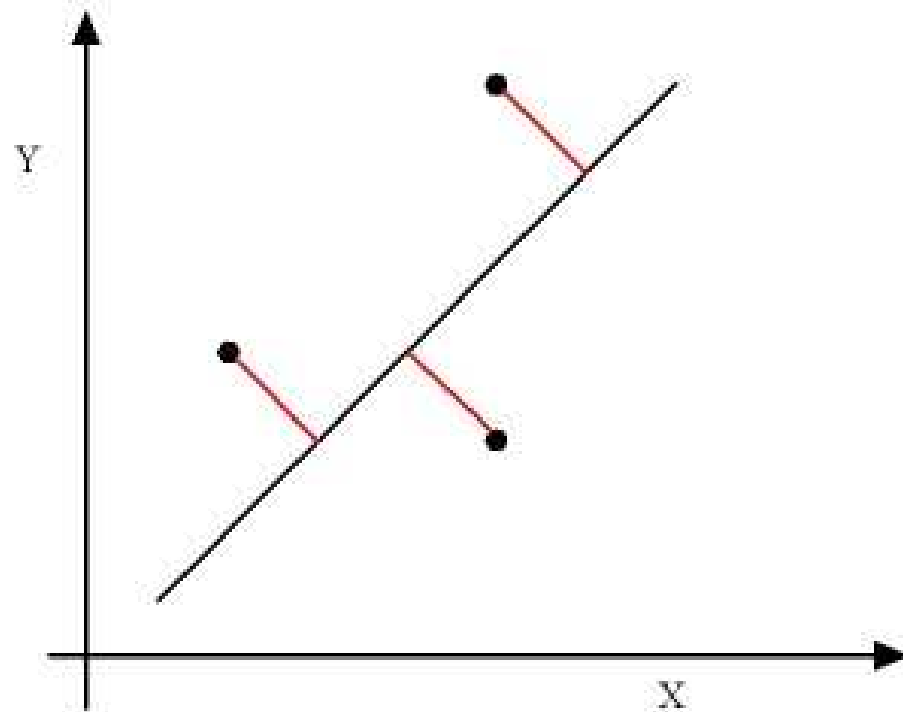
(Deming regression) (2) or

-> geometric mean regression (3)



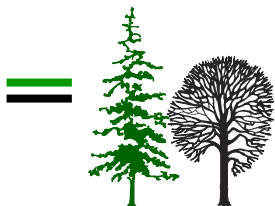
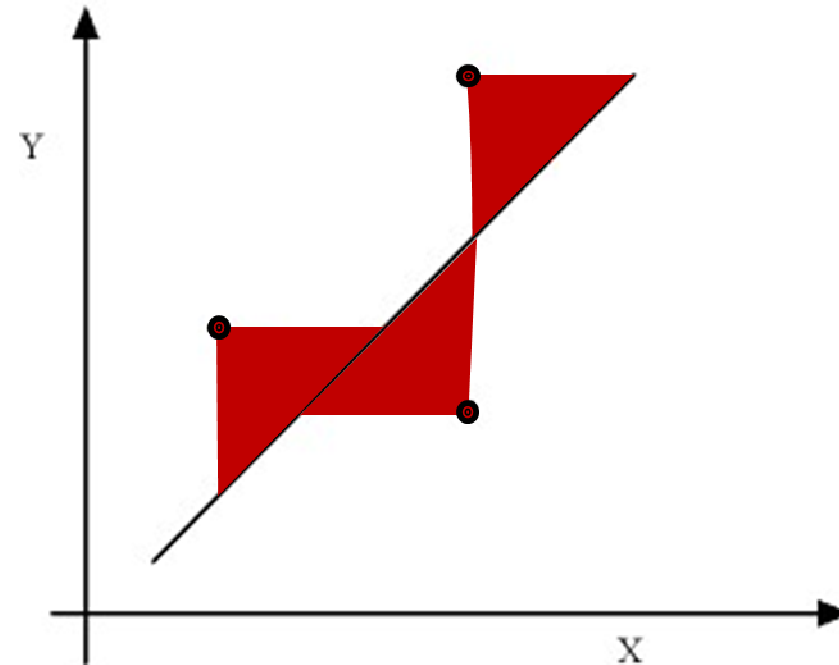
**Deming regression or
Orthogonal linear regression or
Major axis regression**

- Equivalent to first axis of PCA
- Minimizing the perpendicular distances between points and regression line



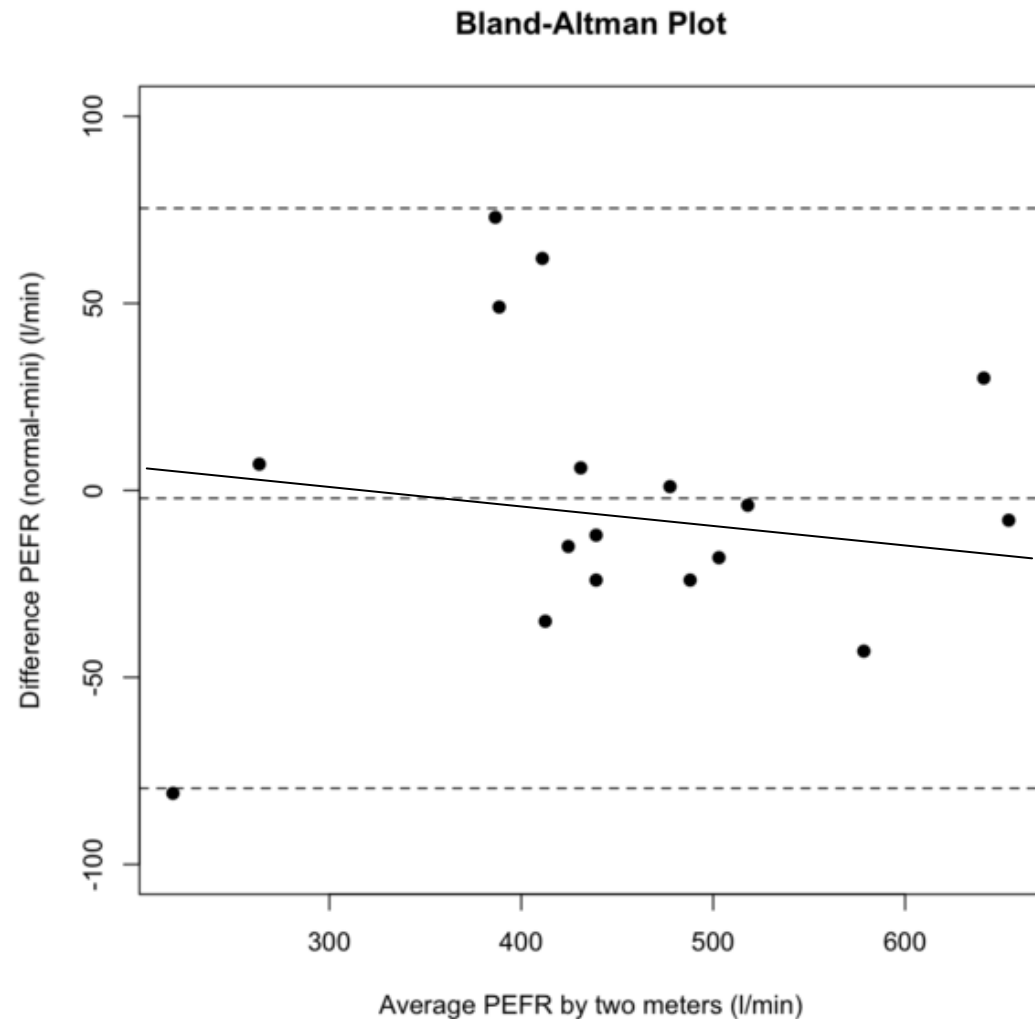
Geometric mean regression or
Ordinary least product regression
Reduced major axis regression

- Slope is calculated as the geometric mean of the slope of X regressed to Y and the slope of Y regressed to X
- Minimizing the area of the triangle between regression line and x and y distances between regression line and points

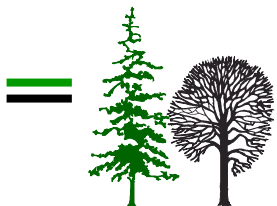
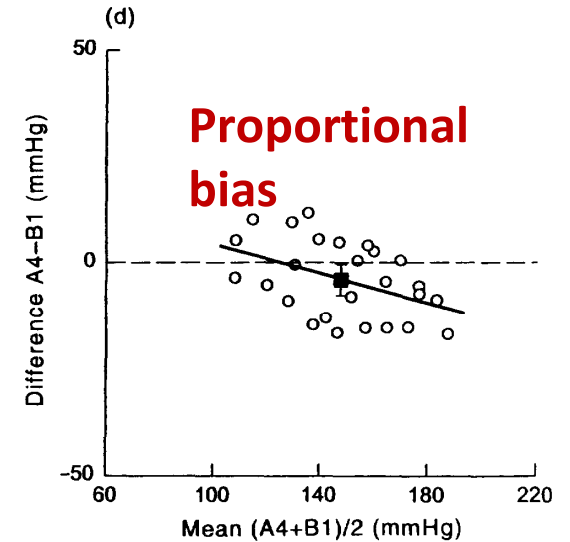
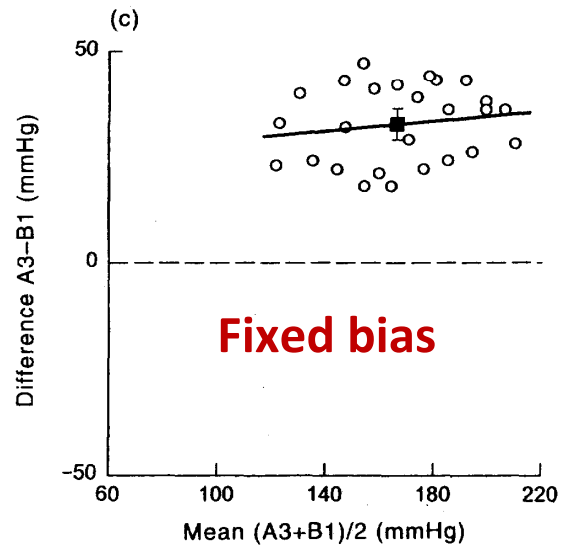
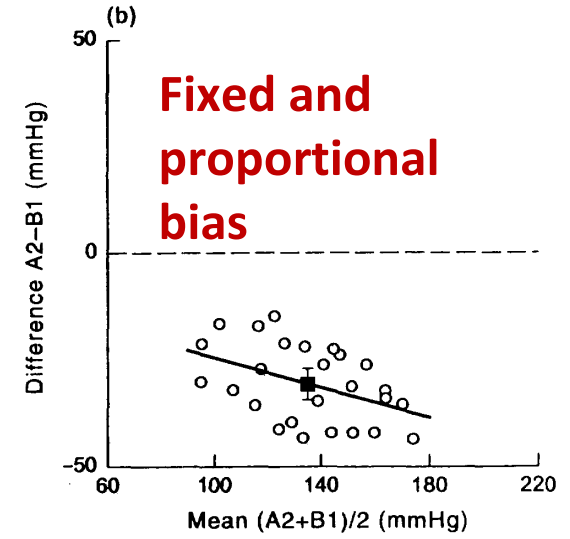
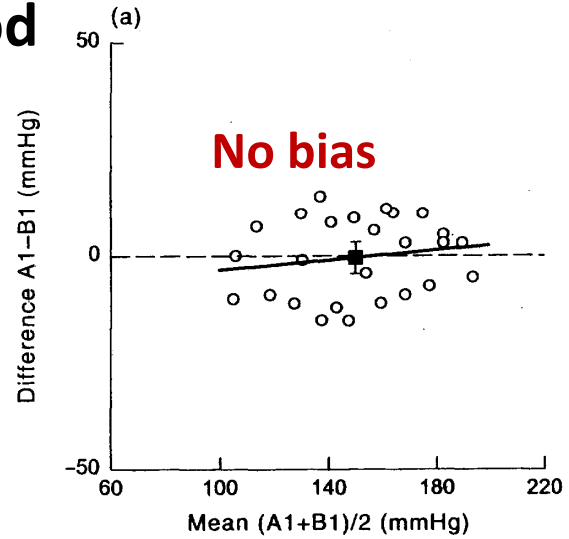


Altman – Bland method

- Plot of difference between measurements vs. the mean of two measurements
- 95% confidence bounds for the difference
- Regression line of differences on means suggests the proportional bias (testing if significantly different from slope=0)
- Paired t-test for testing for fixed bias
- In the case of proportional bias the fixed bias overdiagnosed

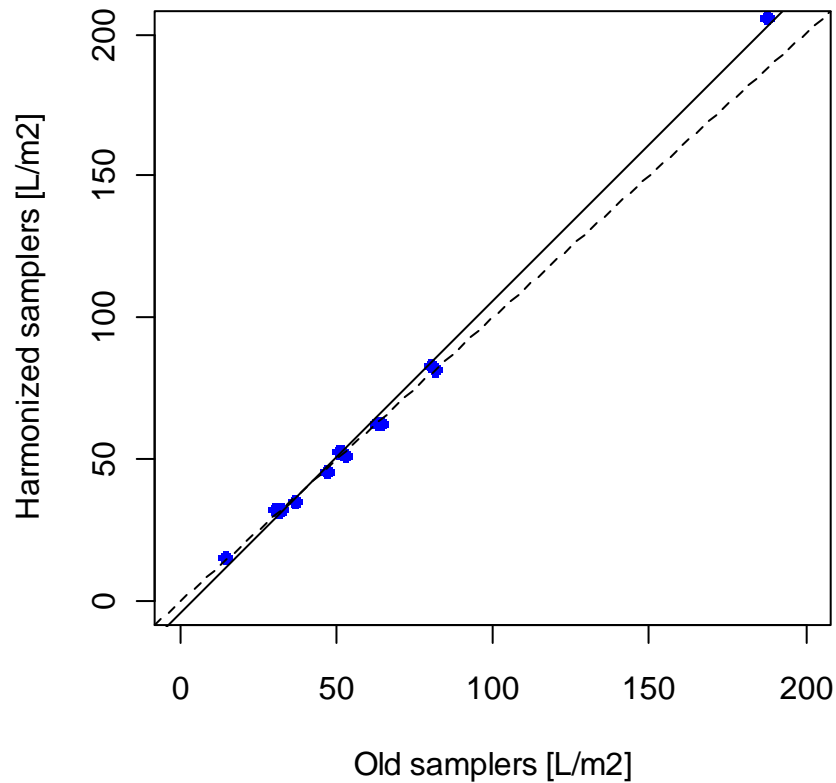


Altman – Bland method



QUANTITIES - Analysis of samplers in the open-field

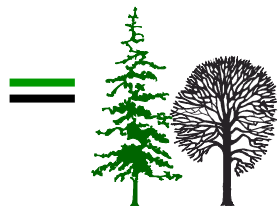
OLS regression - WRONG!!



Intercept Slope
-4.103606 1.102232

2.5%-Intercept 97.5%-Intercept
-6.828269 -1.378942

2.5%-Slope 97.5%-Slope
1.063909 1.140555



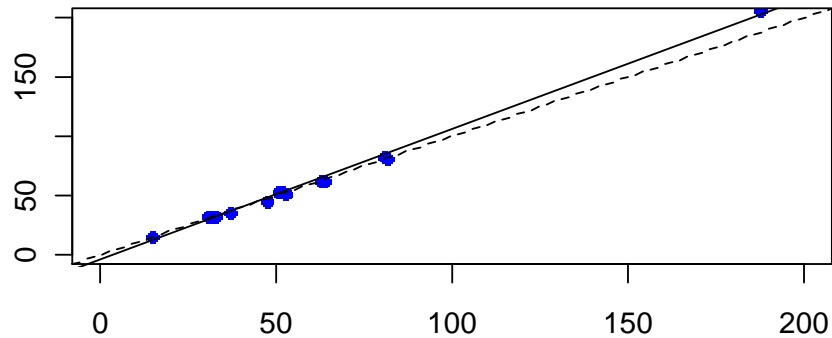
QUANTITIES

Analysis of samplers in the open-field

Geometric mean regression

Harmonized samplers [L/m²]

With outlier



Intercept Slope
-4.202339 1.103915

2.5%-Intercept 97.5%-Intercept
-6.489856 -1.992856

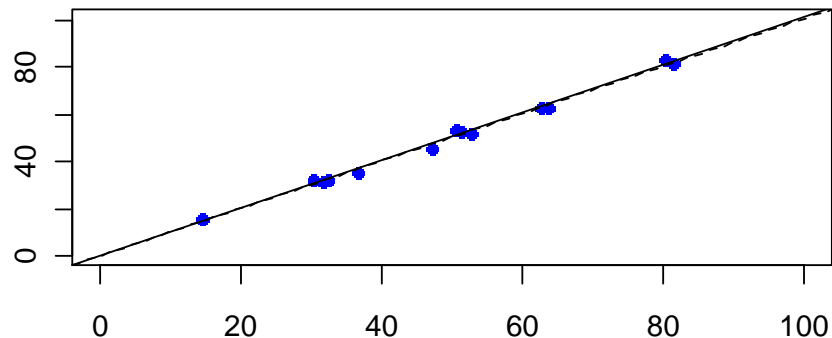
2.5%-Slope 97.5%-Slope
1.066256 1.142903

Old samplers [L/m²]

- significantly different from 1:1 line,
- significantly different from zero intercept

Harmonized samplers [L/m²]

Outlier removed



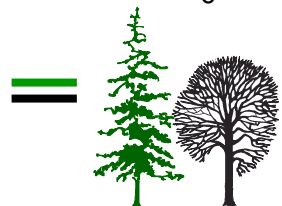
Intercept Slope
0.5378916 1.001634

2.5%-Intercept 97.5%-Intercept
-1.877944 2.953727

2.5%-Slope 97.5%-Slope
0.9555184 1.047749

Old samplers [L/m²]

- **No significant difference from 1:1 line**



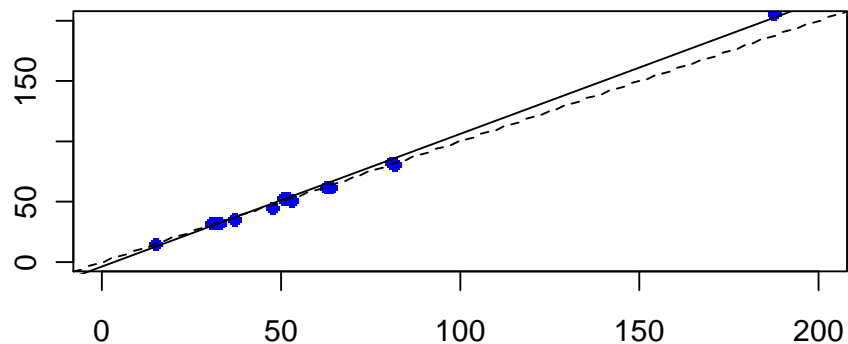
QUANTITIES

Analysis of samplers in the open-field

Deming regression

Harmonized samplers [L/m²]

With outlier



Intercept Slope
-4.212084 1.104081

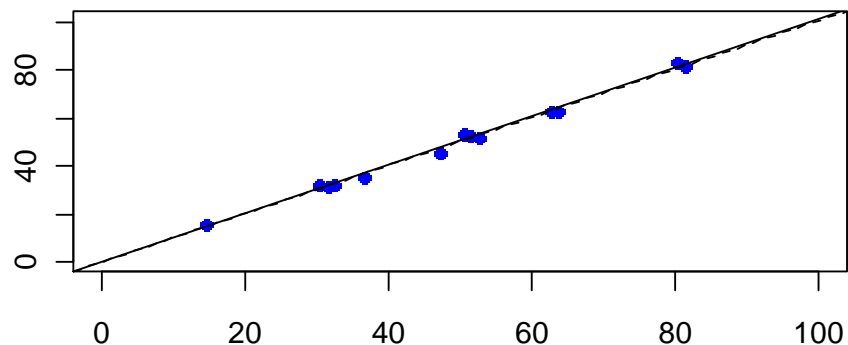
2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
-6.508562 -2.001700 1.066407 1.143222

- Significantly different from 1:1 line,
- significantly different from zero intercept

Old samplers [L/m²]

Harmonized samplers [L/m²]

Outlier removed



Intercept Slope
0.4199842 1.004051

2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
-1.888718 2.624348 0.958857 1.051384

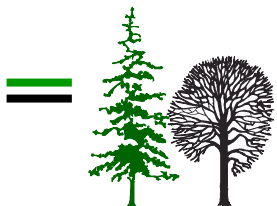
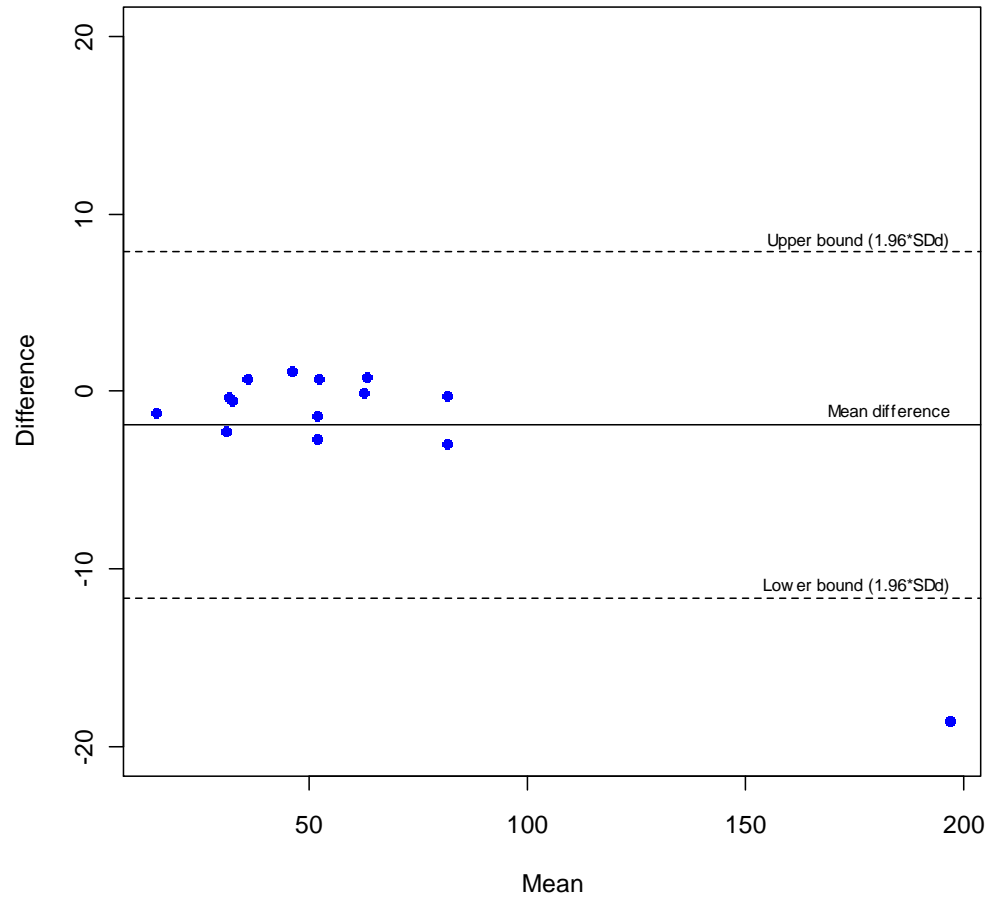
- **No significant difference from 1:1 line**

Old samplers [L/m²]



Analysis of samplers in the open-field

Altman-Bland plot



Paired t-test to test for fixed bias

$t = 1.4294$, $df = 13$, $p\text{-value} = 0.1765$

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval:

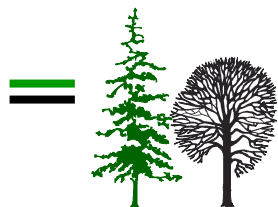
-0.9688455 4.7579082

sample estimates:

mean of the differences

1.894531

Fixed bias not significant!



Analysis of samplers in the open-field

Repeated measures ANOVA

H0: No difference between samplers along time

```
mary(aov(kol_Lm2 ~ opis*zap + Error(oznvz),  
RMAOV_prosto))
```

Error: oznvz

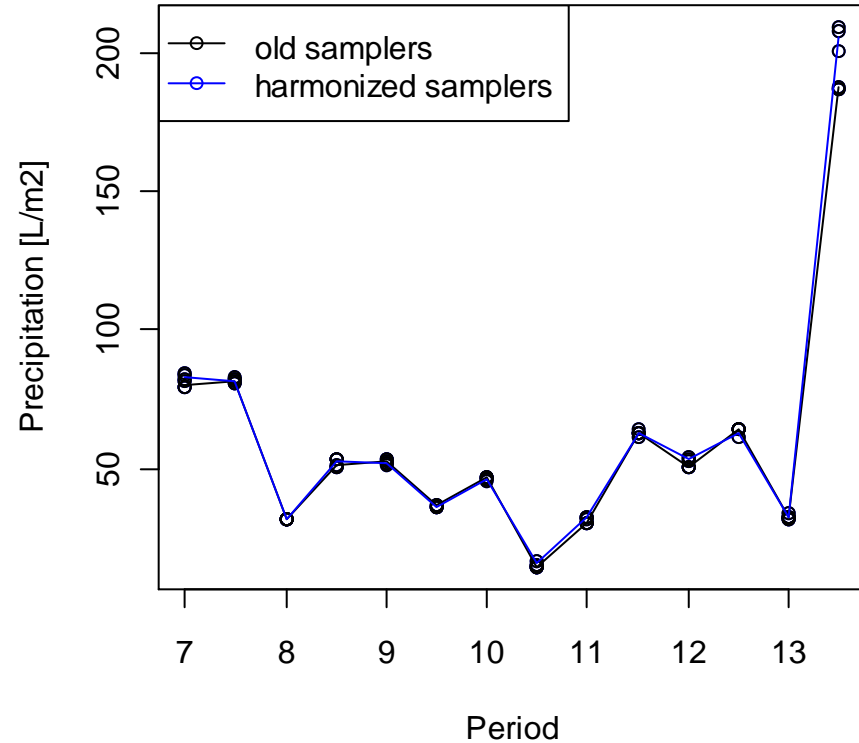
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Type	1	75.374	75.374	15.665	0.01671 *
Residuals	4	19.247	4.812		

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

Error: Within

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Period	1	10180	10179.7	5.5244	0.02135 *
Type:Period	1	79	79.1	0.0429	0.83639
Residuals	76	140044	1842.7		

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



Significant effect
caused by outlier !!



Analysis of samplers in the open-field

RM ANOVA with outlier removed

```
mary(aov(kol_lm2 ~ opis*zap + Error(oznvz),  
RMAOV_prosto2))
```

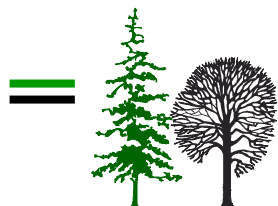
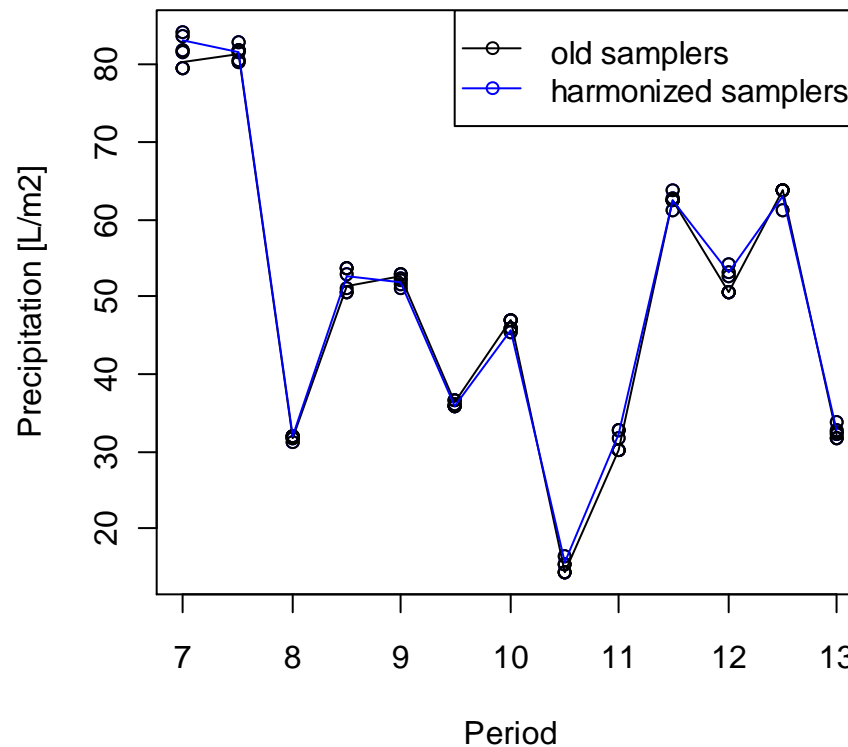
Error: oznvz

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Type	1	7.4371	7.4371	3.8592	0.1209
Residuals	4	7.7085	1.9271		

Error: Within

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Period	1	3752.4	3752.4	10.555	0.001781 **
Type:Period 1		0.4	0.4	0.001	0.974537
Residuals	70	24885.4	355.5		

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

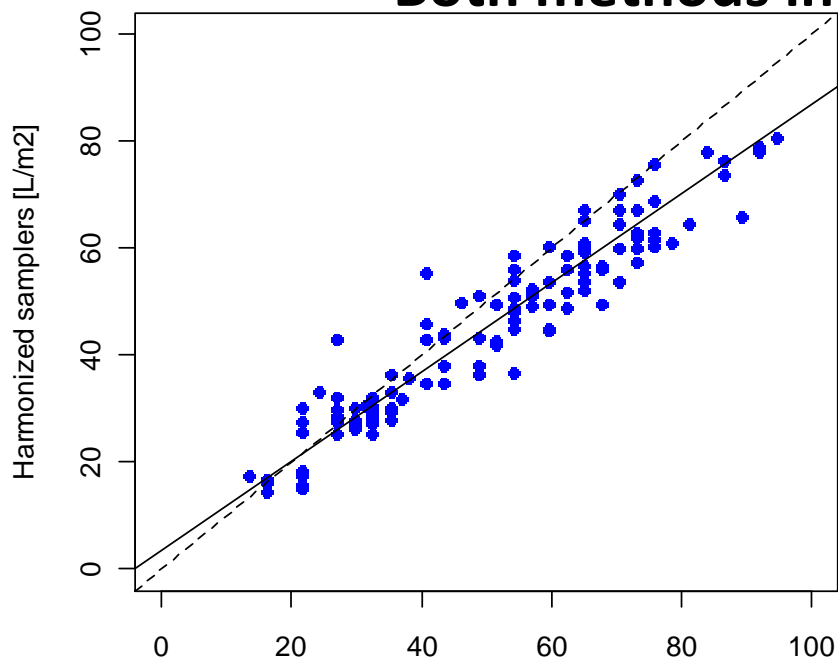


Analysis of samplers in the forest stand

Geom. mean regr.

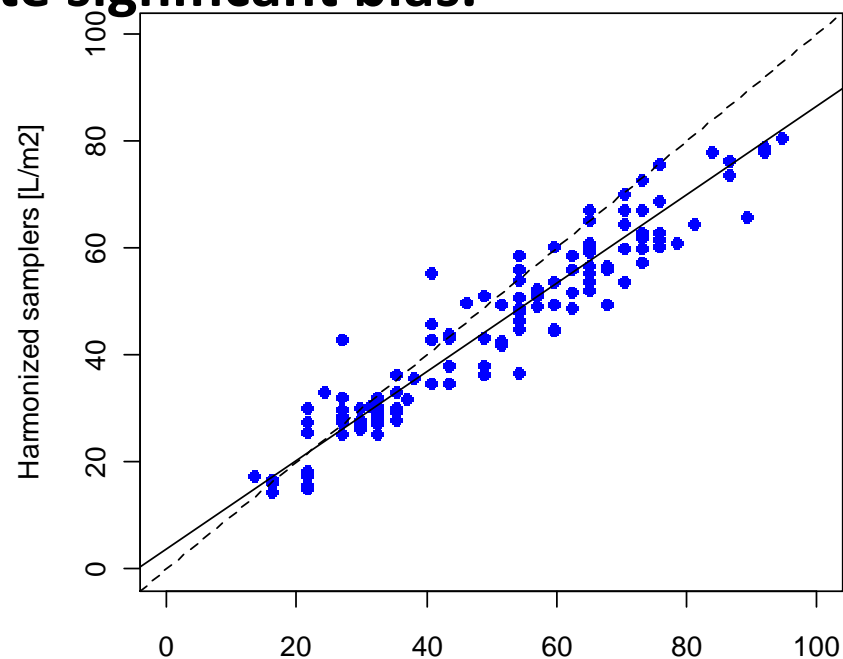
Deming regr.

Both methods indicate significant bias.



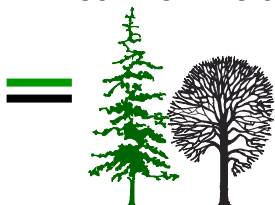
Intercept	Slope	Old samplers [L/m ²]
3.538215	0.8356791	

95% CI Intercept	95% CI Slope
1.304775 5.657065	0.7928033 0.8808737



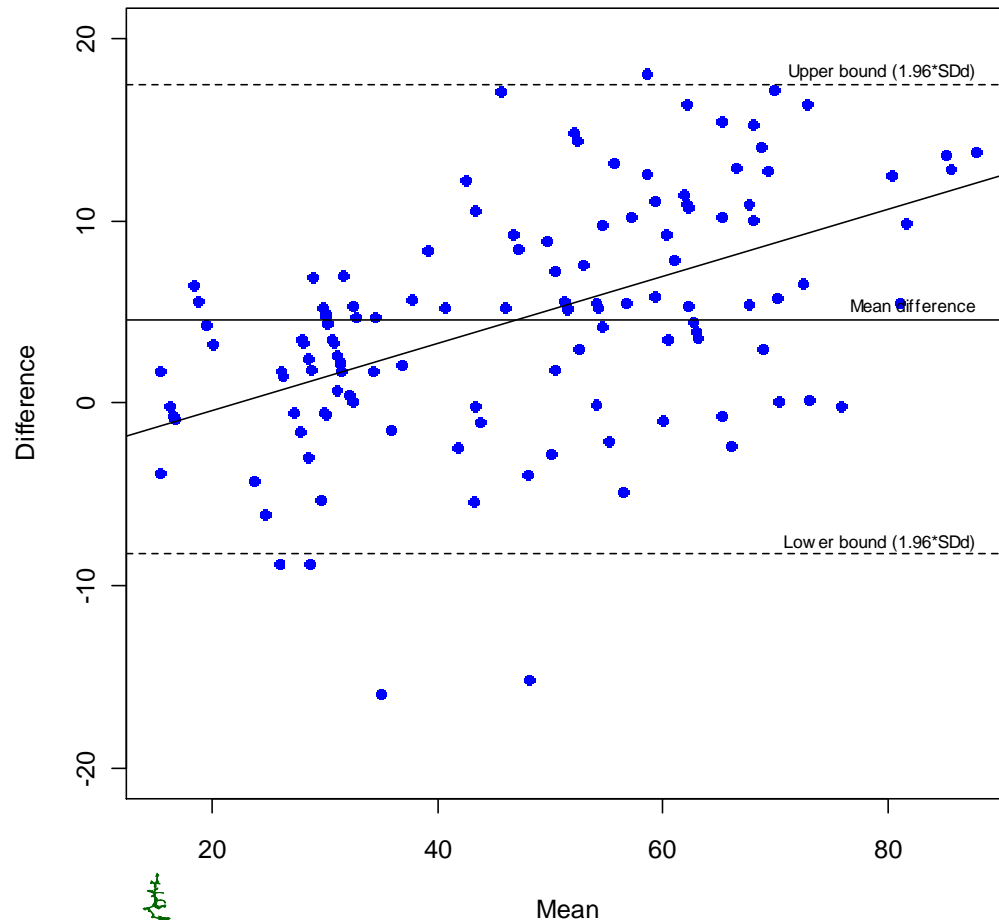
Intercept	Slope	Old samplers [L/m ²]
3.893847	0.8284827	

95% CI Intercept	95% CI Slope
1.578369 6.107417	0.7836902 0.8753374



Analysis of samplers in the forest stand

Altman-Bland plot



CI for slope [0.1297489 0.2367586]
Indicating significant proportional bias

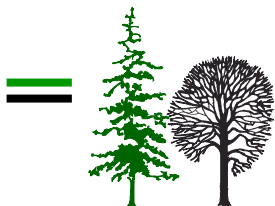
Paired t-test

p-value = 7.19e-13

95 percent confidence interval:
[-5.719317 -3.445182]

mean of the differences
-4.58225

Indicating significant fixed bias



Analysis of samplers in the forest stand

Repeated measures ANOVA

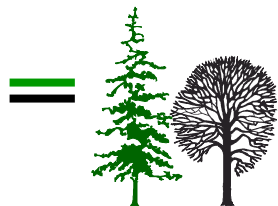
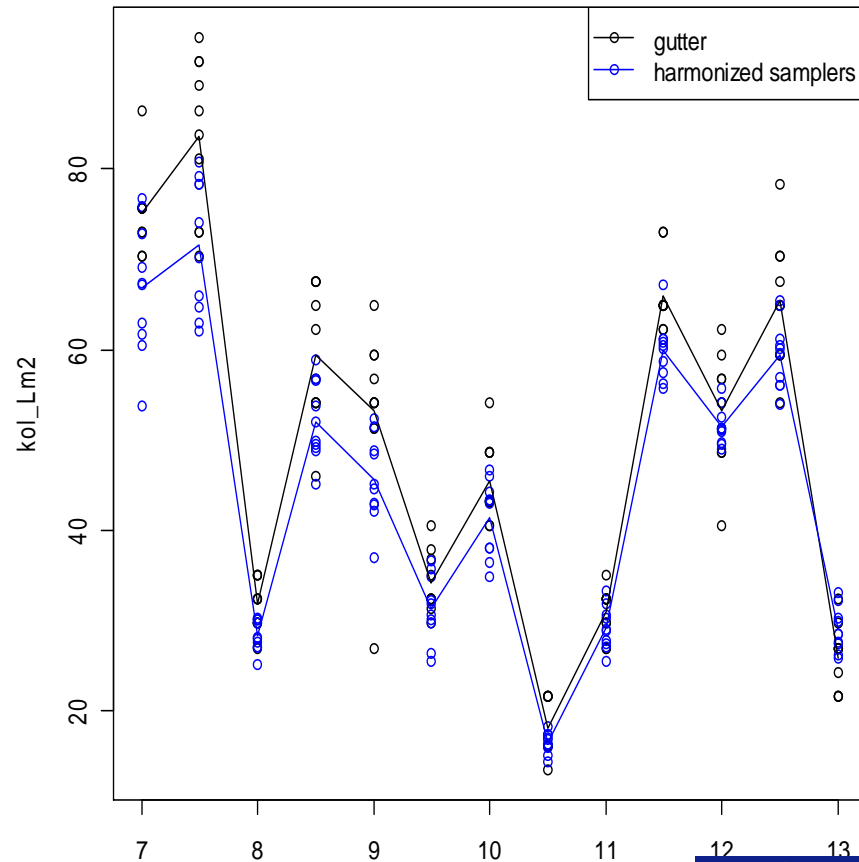
Error: vzorec

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
opis	1	1364.8	1364.81	13.158	0.001926 **
Residuals	18	1867.0	103.72		

Error: Within

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
zap	1	8608	8608.0	25.9368	7.176e-07 ***
opis:zap	1	412	412.0	1.2414	0.2663
Residuals	238	78988	331.9		

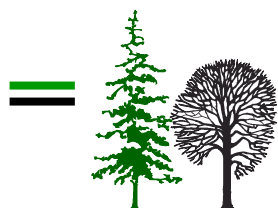
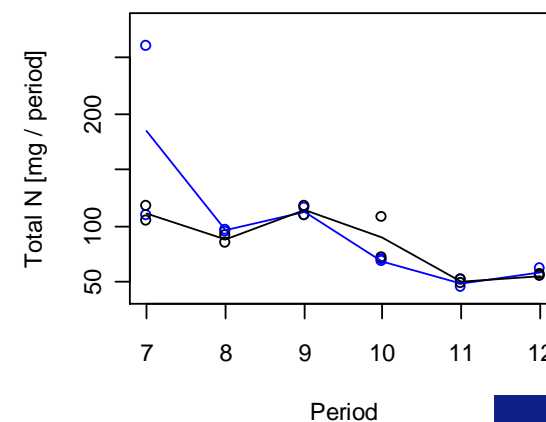
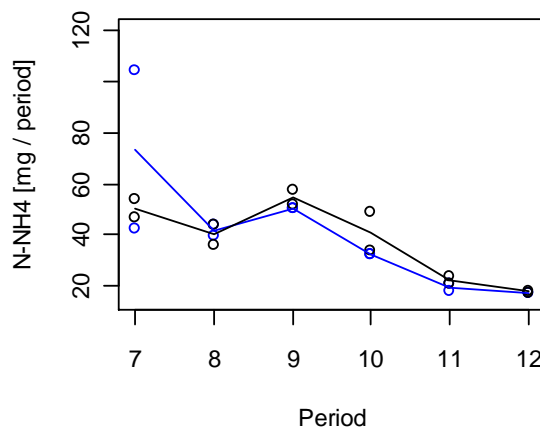
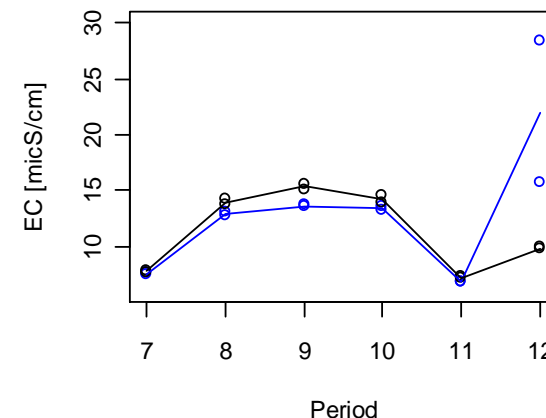
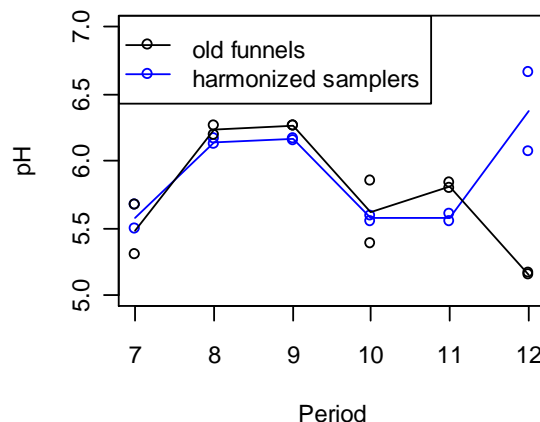
Significant difference between samplers – but: take into account the required accuracy !!!



CHEMISTRY (some examples)

Analysis of samplers in the open-field

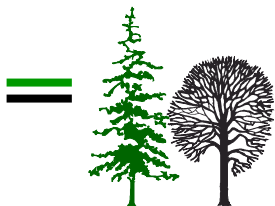
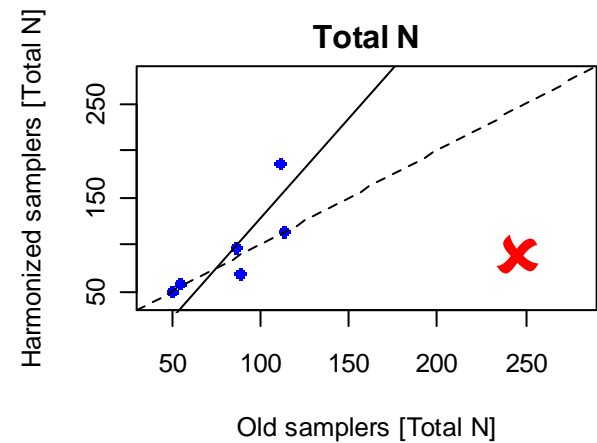
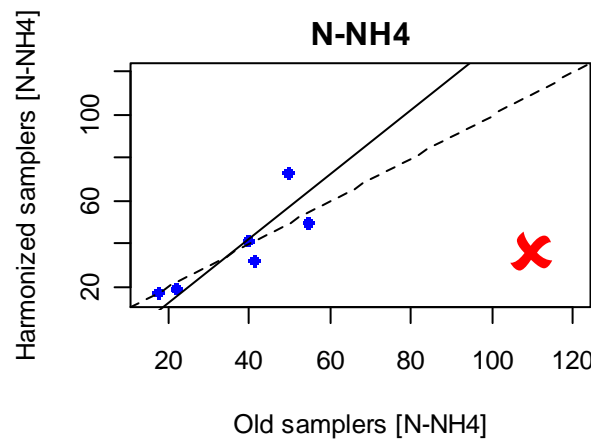
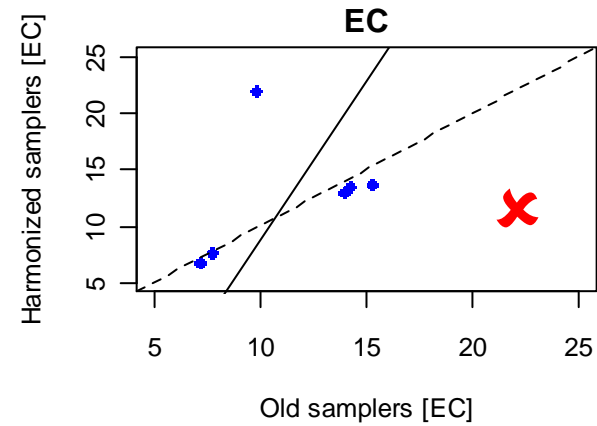
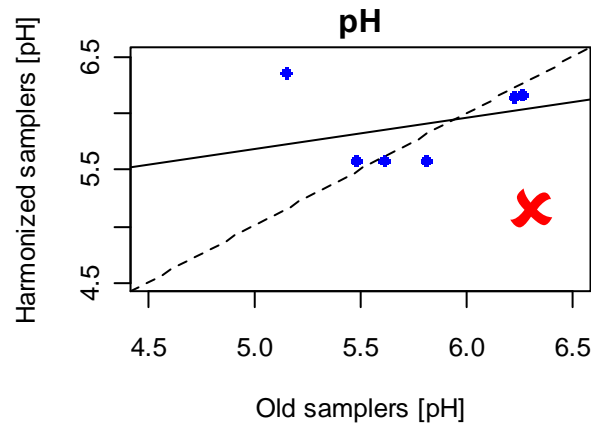
- Expressed as depositions (mg) per period
- Problem with chemistry regarding statistics: much smaller number of data points to compare



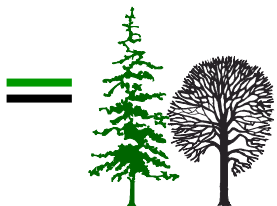
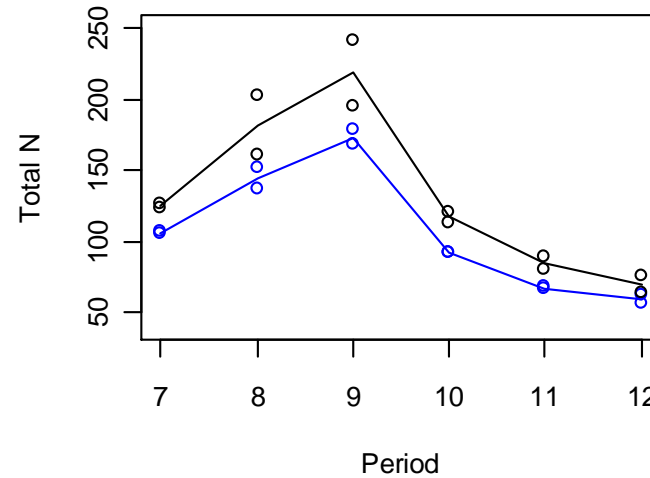
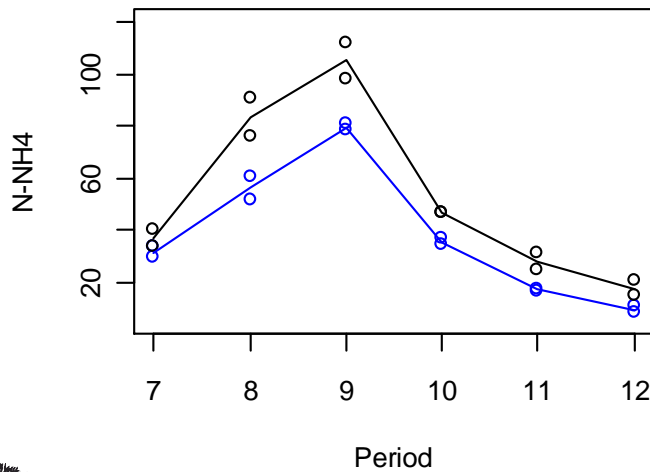
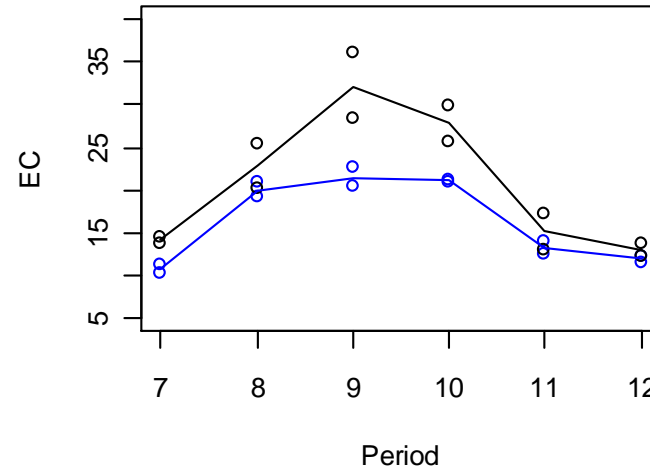
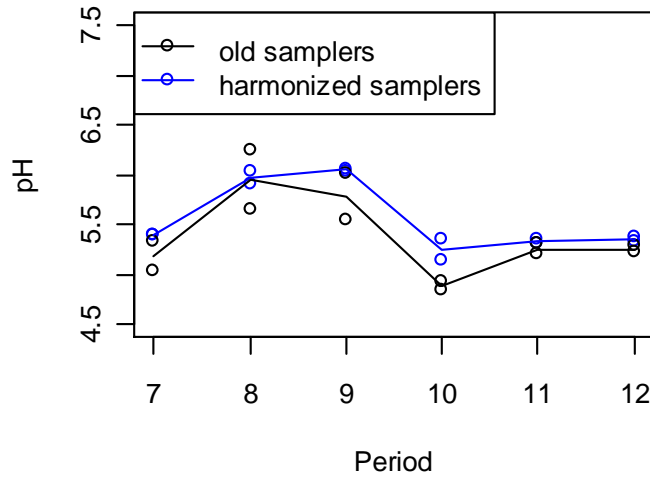
CHEMISTRY

Analysis of samplers in the open-field

DEMING REGRESSION

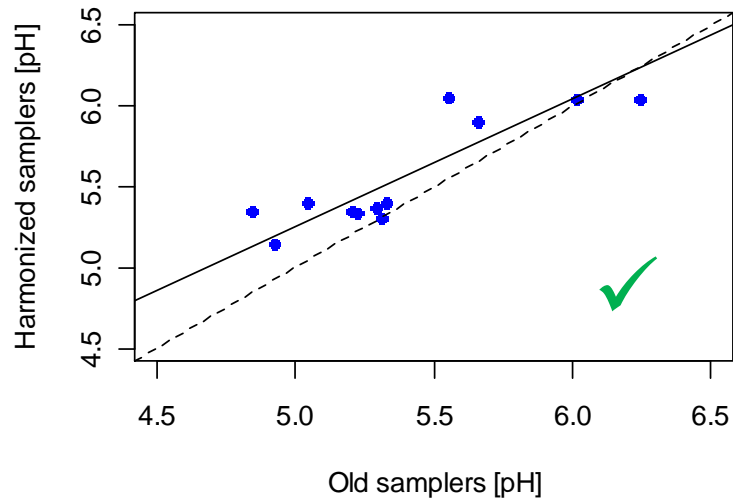


Analysis of samplers in the forest stand



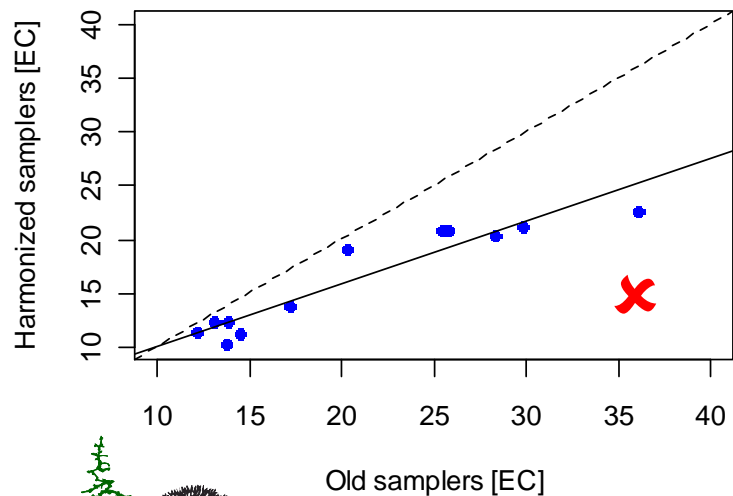
Analysis of samplers in the forest stand

DEMING REGRESSION



Intercept Slope
1.300643 0.7910893

2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
-0.7817887 2.813613 0.5100858 1.1778589



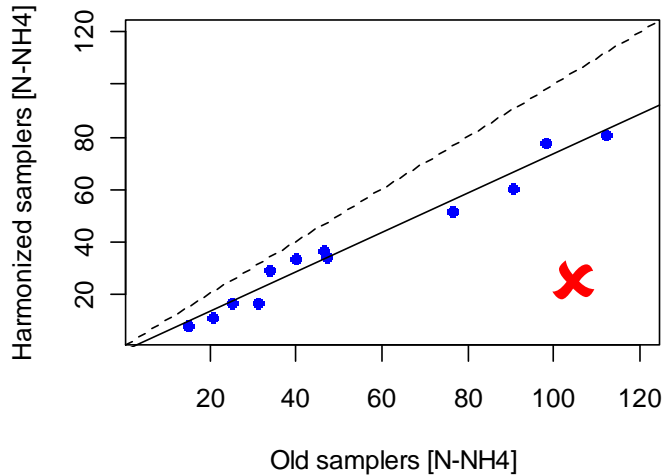
Intercept Slope
4.319620 0.5806441

2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
1.0233754 7.217532 0.4414998 0.7389144



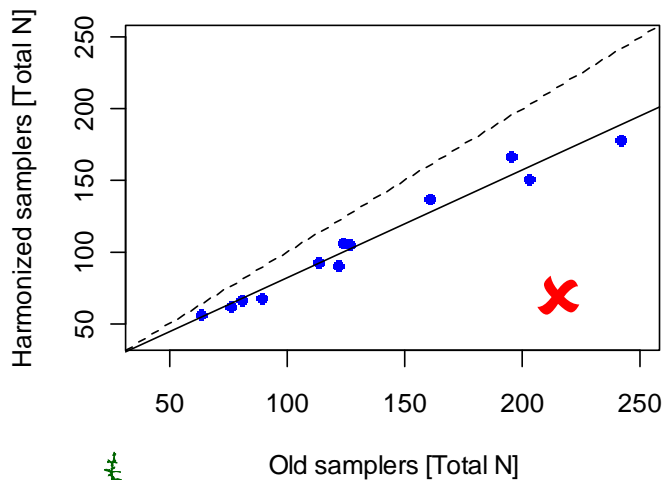
Analysis of samplers in the forest stand

DEMING REGRESSION



Intercept Slope
 -1.582219 0.7524007

2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
 -6.579364 2.999204 0.6658195 0.8468383



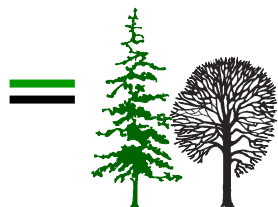
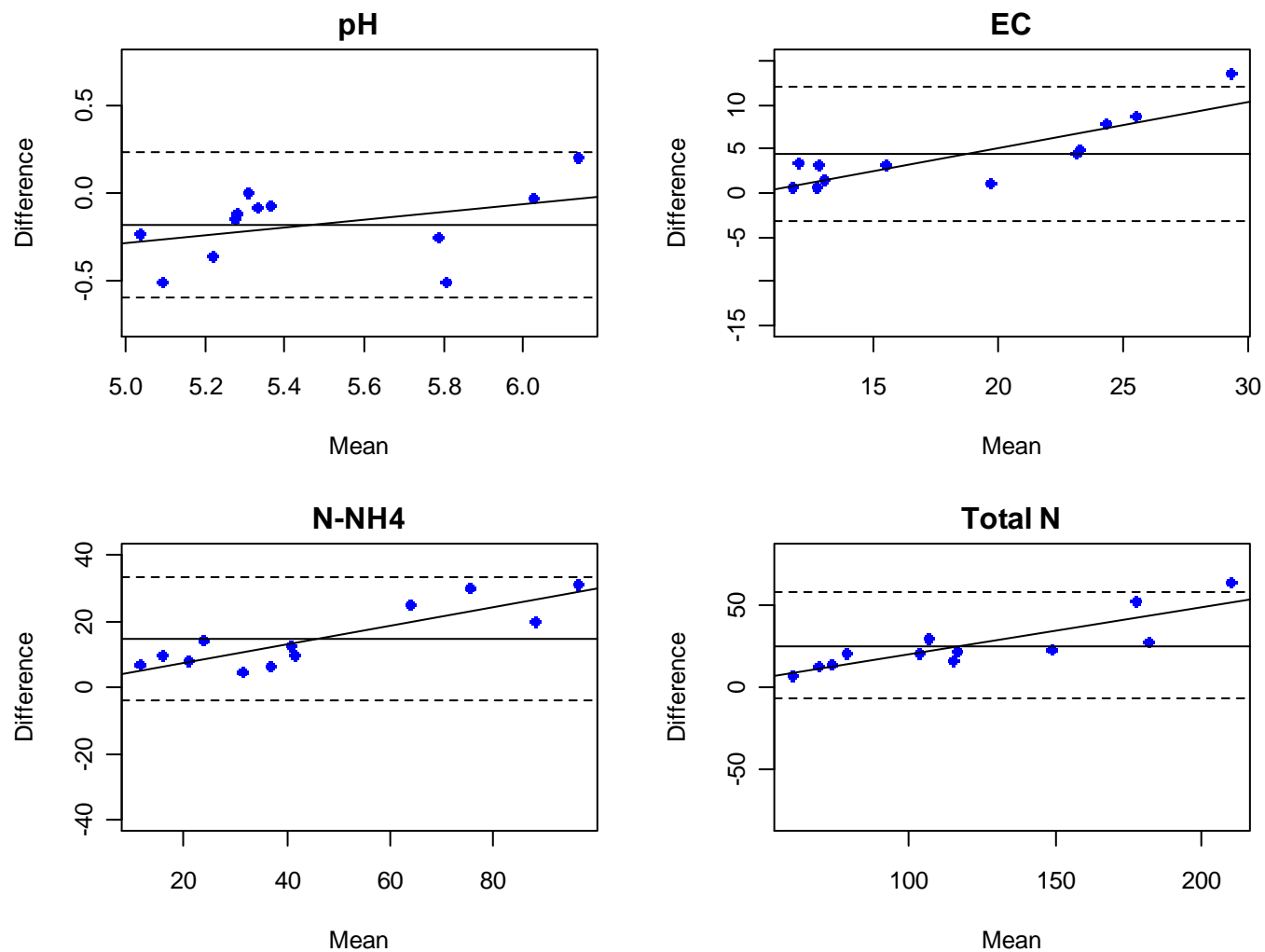
Intercept Slope
 7.839864 0.7494198

2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
 -5.103421 19.67611 0.6603067 0.8468675



Analysis of samplers in the forest stand

ALTMAN-BLAND PLOT



Model II regression in R environment

Call: lmodel2(formula = h.pH ~ g.pH, data = sestoj)

n = 12 r = 0.8677992 r-square = 0.7530754
Parametric P-values: 2-tailed = 0.0002536588 1-tailed = 0.0001268294
Angle between the two OLS regression lines = 7.933972 degrees

Regression results

	Method	Intercept	Slope	Angle (degrees)
1	OLS	1.749154	0.7077875	35.29038
2	MA	1.300643	0.7910893	38.34714
3	SMA	1.168608	0.8156121	39.20110

Confidence intervals

	Method	2.5%-Intercept	97.5%-Intercept	2.5%-Slope	97.5%-Slope
1	OLS	0.2073410	3.290967	0.4222205	0.9933546
2	MA	-0.7817887	2.813613	0.5100858	1.1778589
3	SMA	-0.6303197	2.444762	0.5785925	1.1497266



Still to do in the near future

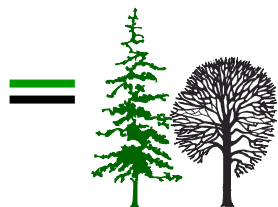
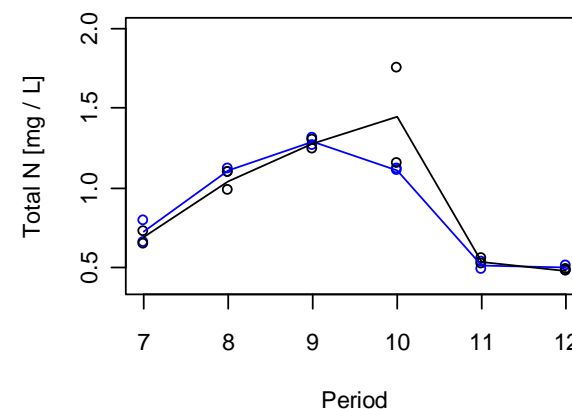
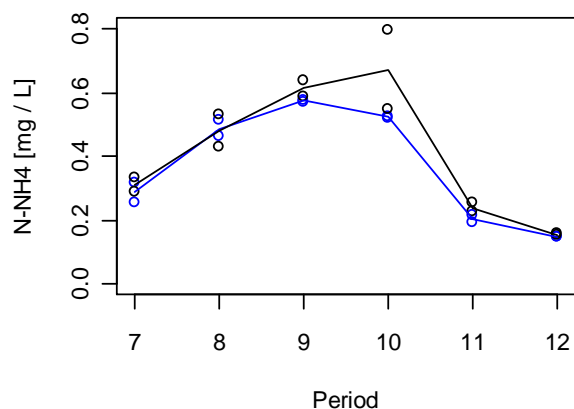
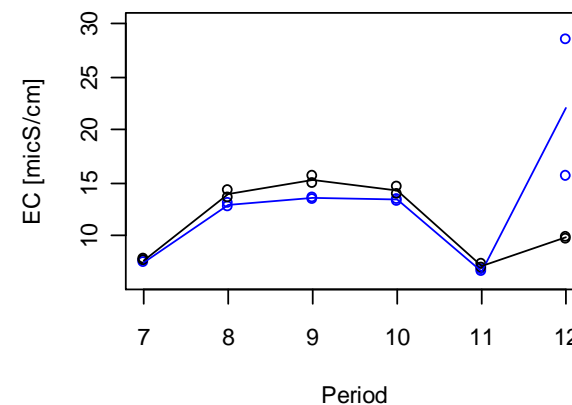
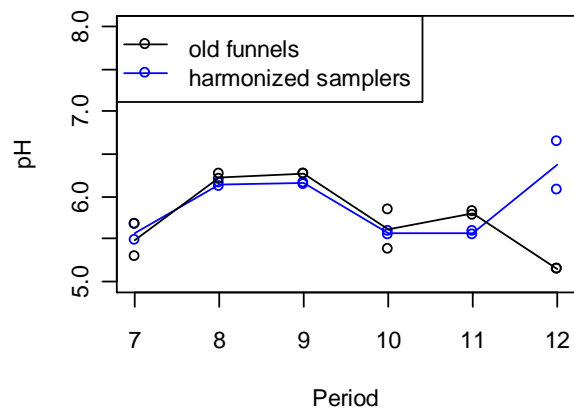
- Testing some additional methods – e.g. time series analysis combined with RM ANOVA
- Performing more elaborate comparison data analysis approaches – only possible with larger dataset
- Tentatively: develop general R package for methods comparison studies



CHEMISTRY (some examples)

Analysis of samplers in the open-field

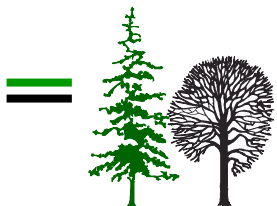
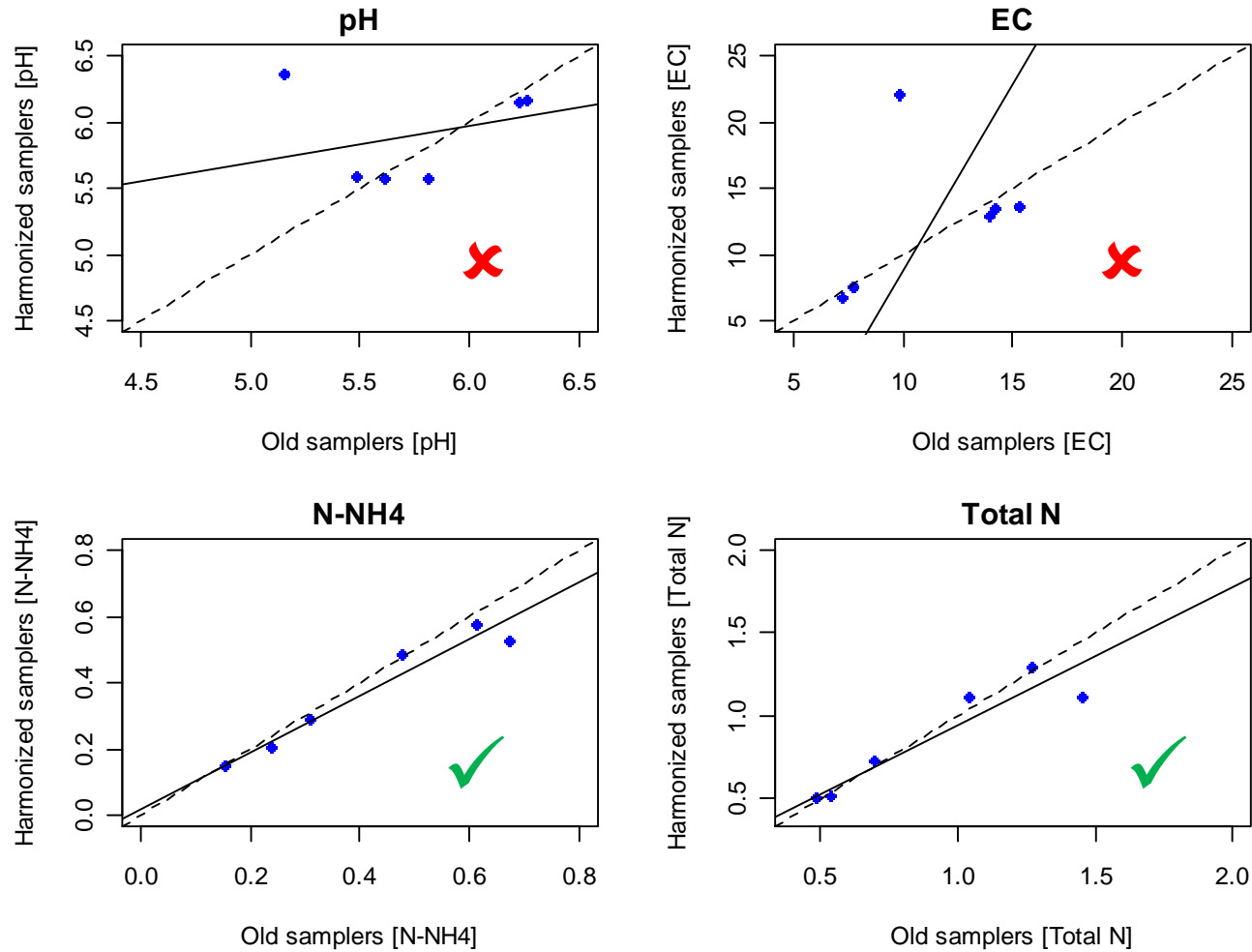
- Expressed as depositions (mg) per period
- Problem with chemistry regarding statistics: much smaller number of data points to compare



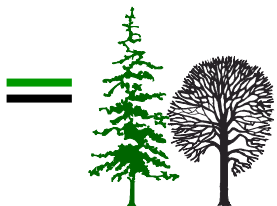
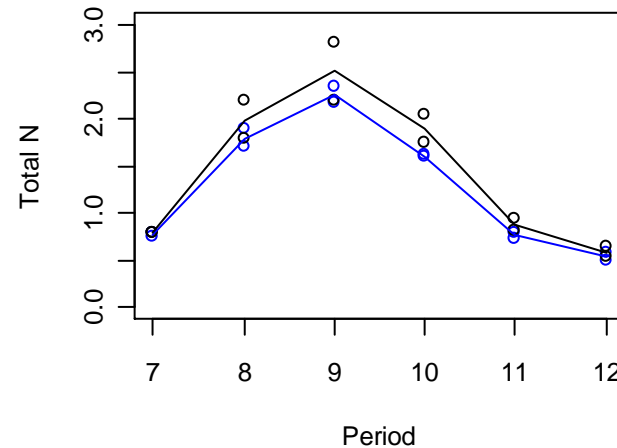
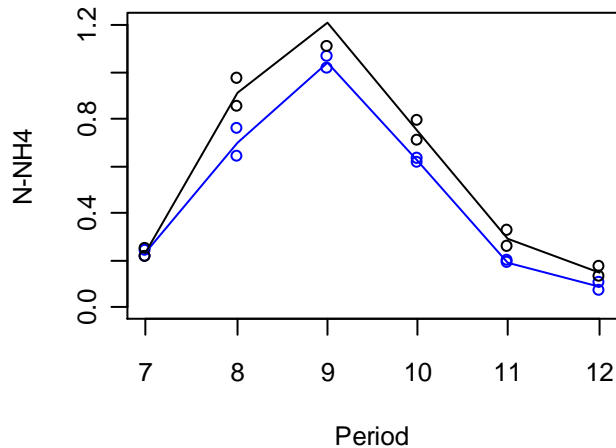
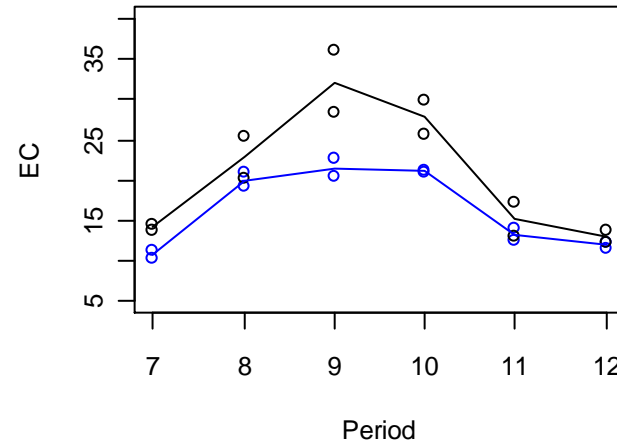
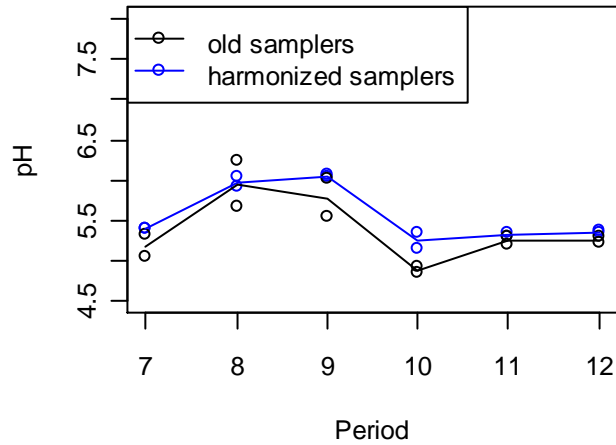
CHEMISTRY

Analysis of samplers in the open-field

DEMING REGRESSION

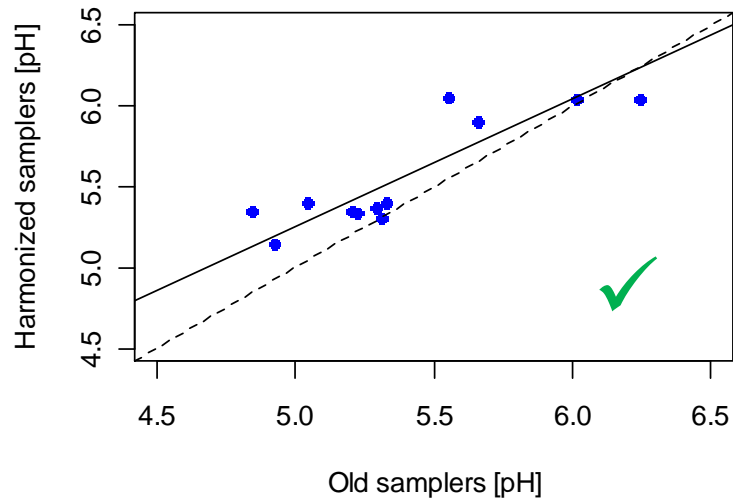


Analysis of samplers in the forest stand



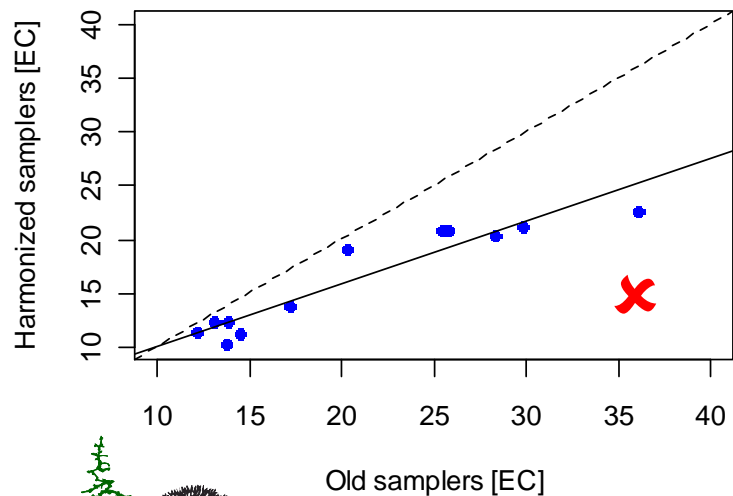
Analysis of samplers in the forest stand

DEMING REGRESSION



Intercept Slope
 1.300643 0.7910893

2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
 -0.7817887 2.813613 0.5100858 1.1778589



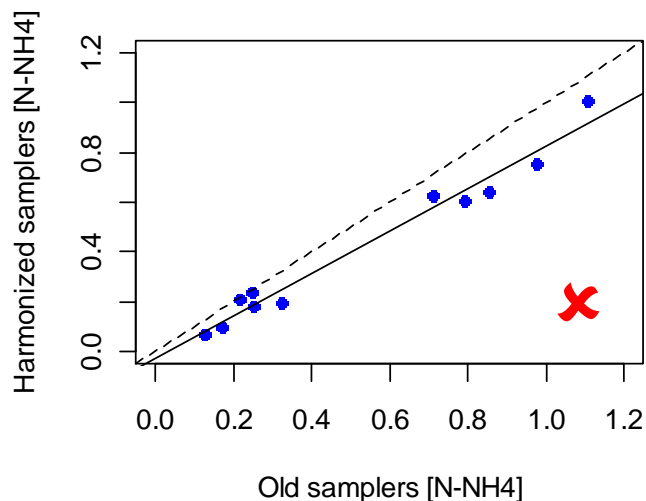
Intercept Slope
 4.319620 0.5806441

2.5%-Intercept 97.5%-Intercept 2.5%-Slope 97.5%-Slope
 1.0233754 7.217532 0.4414998 0.7389144



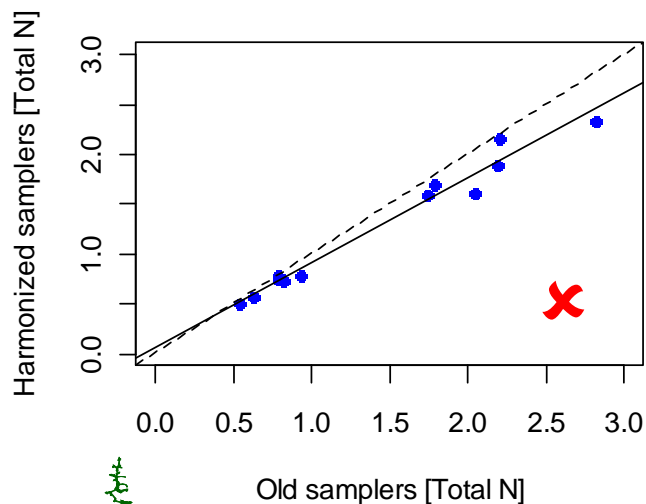
Analysis of samplers in the forest stand

DEMING REGRESSION



Intercept	Slope
-0.02489365	0.8498672

2.5%-Intercept	97.5%-Intercept	2.5%-Slope	97.5%-Slope
-0.07896684	0.02469089	0.7657558	0.9415929



Intercept	Slope
0.05546983	0.8561844

2.5%-Intercept	97.5%-Intercept	2.5%-Slope	97.5%-Slope
-0.09554261	0.1922983	0.7611242	0.9610987



Analysis of samplers in the forest stand

ALTMAN-BLAND PLOT

