Select results

Lia Ossanna

1/16/2022

Introduction

- Presented here are the results of single-moderator and model selection analysis for the exotic and native datasets.
- All models have undergone sensitivity analysis and outliers have been removed.
- Results are summarized in the form of forest plots, and heterogeneity statistics are presented in a single table.
- Code is omitted to conserve space. See other documents for code and more details.
- Calculating the probability based on the prediction interval has been updated since the 11/2021 results document.

Summary

Summary effect

- Overall, C addition treatment significantly decreases exotic plant abundance but does not affect native plant abundance.
  - When predicting the effect of C addition on a random population, we would expect exotic plant abundance to decrease 80% of the time, and native plant abundance to increase 41% of the time.

Single moderator models

- C addition treatment has been most successful in southeast Australia (New South Wales) and the western United States, especially in the Southwest and Pacific Northwest.
- C addition treatment steadily becomes less effective over time (effect size decreases as duration since first and last C application increases).
- Sucrose alone is more effective than sawdust alone; but both had a significant effect when used alone, but not in combination.
  - However, this could be an artifact of sample size/number of comparisons. Only sucrose, sucrose AND sawdust, and sawdust have comparable `n` values (number of studies/comparisons).
- Increasing C rate decreases exotic plant abundance and increases native plant abundance.
  - Although these trends are statistically significant, practically speaking, the increase in effect likely does not compensate for the higher cost.
- The number and timing of C applications show inconsistent trends, but studies that applied C only once saw a simultaneous decrease in exotic plant abundance and increase in native plant abundance.

    - Studies that applied C 3-6 times reported the greatest decrease in exotic plant abundance; however, native plant abundance also decreased.

- C application treatment was more effective on annual exotic plants than perennial, but perennial graminoids were still significantly affected.
- In the subset of annual exotic plants, forbs decreased slightly more than graminoids, but in the overall exotic dataset, graminoids decreased more than forbs, and to a larger degree.

    - C treatment had no significant effect on perennial native plant abundance.

Model selection

- Candidate model included `region`, `dlc` (duration since last C application), `C_type`, `cratc` (C rate as categorical), `plotc` (plot size), `capt` (months applying C), and `plant_apgfs` (plant lifeform).
- `dlc`, `cratc`, `region`, `plotc`, and `plant_apgfs` were important moderators for the exotic dataset (importance value > 0.8).
- `dlc`, `cratc`, `region`, `C_type`, and `plant_apgfs` were important moderators for the native dataset (importance value > 0.8).

No moderators (summary effect)

Exotic

Model summary

```
summary(ex.mv.o)
```

```
##
## Multivariate Meta-Analysis Model (k = 486; method: REML)
##
##    logLik   Deviance        AIC        BIC       AICc
## -690.7916  1381.5831  1387.5831  1400.1355  1387.6330
##
## Variance Components:
##
##              estim    sqrt  nlvls  fixed         factor
## sigma^2.1  0.3457  0.5880     50     no         exp_ID
## sigma^2.2  0.1554  0.3942    486     no  exp_ID/obs_ID
##
## Test for Heterogeneity:
## Q(df = 485) = 1012.8128, p-val < .0001
##
## Model Results:
##
## estimate      se     zval    pval    ci.lb    ci.ub
##  -0.5768  0.1009  -5.7168  <.0001  -0.7746  -0.3791  ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- C treatment causes significant decrease in exotic plant abundance.

Prediction interval

```
predict(ex.mv.o)
```

```
##
##     pred     se   ci.lb   ci.ub   pi.lb  pi.ub
##  -0.5768 0.1009 -0.7746 -0.3791 -1.9782 0.8246
```

- The prediction interval (`pi.lb` and `pi.ub`) measures the distribution of true effects. A prediction of the effect size for any given population would fall within the prediction interval 95% of the time (Borenstein 2019, *Research Synthesis Methods*).
- The prediction interval can be used to calculate the probability the effect of a new study will be below or above a certain threshold using the left-tail cumulative t-distribution with k-1 degrees of freedom (IntHout 2016, *BMJ Open*).
  - See Supplementary Appendix Formula 2: we are finding the probability that t-value $\leq$ T, where $T = \frac{D-M}{SD_{PI}}$, and D is the threshold (0), M is the summary effect, and SD_{PI} is the standard deviation of the prediction interval.
  - I am calculating SD_{PI} from the definition of the prediction interval, $PI = Mean \pm 2SD$ (Borenstein 2019, *Research Synthesis Methods*).
  - After finding T, calculate the cumulative distribution function with $k-1$ degrees of freedom.
    * Use the calculator at https://www.danielsoper.com/statcalc/calculator.aspx?id=41 or the function `pt()`.

```
SD_PI <- abs(predict(ex.mv.o)$pi.lb - predict(ex.mv.o)$pred) / 2
t <- (0 - predict(ex.mv.o)$pred) / SD_PI
pt(t, ex.mv.o$k - 1, lower.tail = TRUE)
```

```
## [1] 0.7946017
```

- There is an 80% chance a new study/randomly selected exotic plant population will decrease in response to C addition.

I^2 statistic

```
## [1] I^2 = 56.4347952512755
```

- I^2 is a measure of relative heterogeneity. It is the proportion of variance in observed effects that is due to variance in true effects (effects in an infinitely large population with no sampling error), or, in other words, the ratio of excess dispersion to total dispersion ($\frac{V_{TRUE}}{V_{OBS}}$, expressed here as a percentage; Borenstein 2009).
- I^2 can be thought of as the inconsistency across studies; an I^2 of 0% means there is no observed variance that is actually due to true variance, and therefore no variance to explain, while an I^2 of 100% means that all the variance could be explained by something besides sampling error, such as the effect of moderators (Borenstein 2019, *Research Synthesis Methods*).

QM/QT

```
## [1] QM/QT = 0.0312595156674703
```

- QM/QT is the proportion of heterogeneity explained by the model ($\frac{Q_M}{Q_E+Q_M}$), and is "functionally equivalent" to the R^2 of a linear model (Koricheva 2013).

Native

Model summary

```r
summary(nt.mv)
```

```
##
## Multivariate Meta-Analysis Model (k = 655; method: REML)
##
##    logLik   Deviance        AIC        BIC       AICc
## -804.1182  1608.2365  1614.2365  1627.6858  1614.2734
##
## Variance Components:
##
##              estim    sqrt  nlvls  fixed         factor
## sigma^2.1   0.1155  0.3398     53     no         exp_ID
## sigma^2.2   0.0000  0.0001    655     no  exp_ID/obs_ID
##
## Test for Heterogeneity:
## Q(df = 654) = 925.7573, p-val < .0001
##
## Model Results:
##
## estimate      se     zval    pval    ci.lb   ci.ub
##  -0.0742  0.0592  -1.2543  0.2097  -0.1902  0.0417
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- C treatment does not cause a significant change in native plant abundance.

Prediction interval

```r
predict(nt.mv)
```

```
##
##     pred     se   ci.lb  ci.ub   pi.lb  pi.ub
##  -0.0742 0.0592 -0.1902 0.0417 -0.7502 0.6018
```

```r
SD_PI <- (abs(predict(nt.mv)$pi.lb) - abs(predict(nt.mv)$pred)) / 2
t <- (0 - predict(nt.mv)$pred) / SD_PI
pt(t, nt.mv$k - 1, lower.tail = TRUE)
```

```
## [1] 0.5868547
```

```r
1 - pt(t, nt.mv$k - 1, lower.tail = TRUE)
```

```
## [1] 0.4131453
```

- There is a 59% chance a new study or randomly selected population of native plants will decrease in response to C addition (or a 41% chance they will increase).

I^2 statistic

```
## [1] I^2 = 20.5377724218779
```

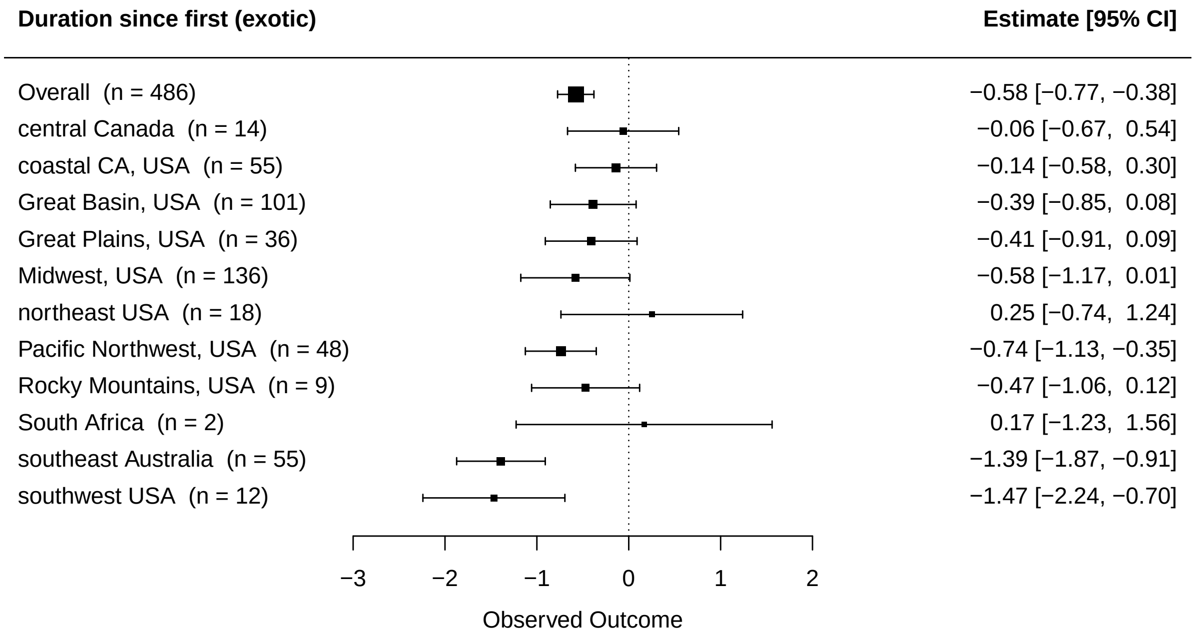
- A low I^2 indicates most of the variance is due to randomness and cannot be explained with moderators. Therefore, the following native single moderator models should be interpreted with caution.

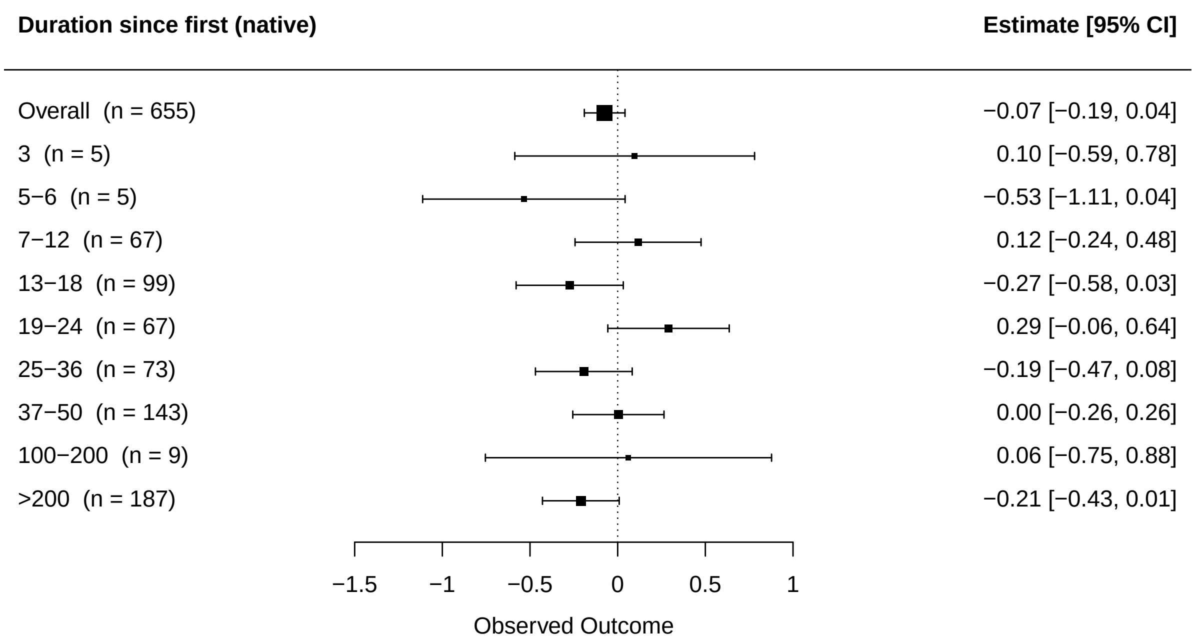
QM/QT

```
## [1] QM/QT = 0.00169661166339359
```

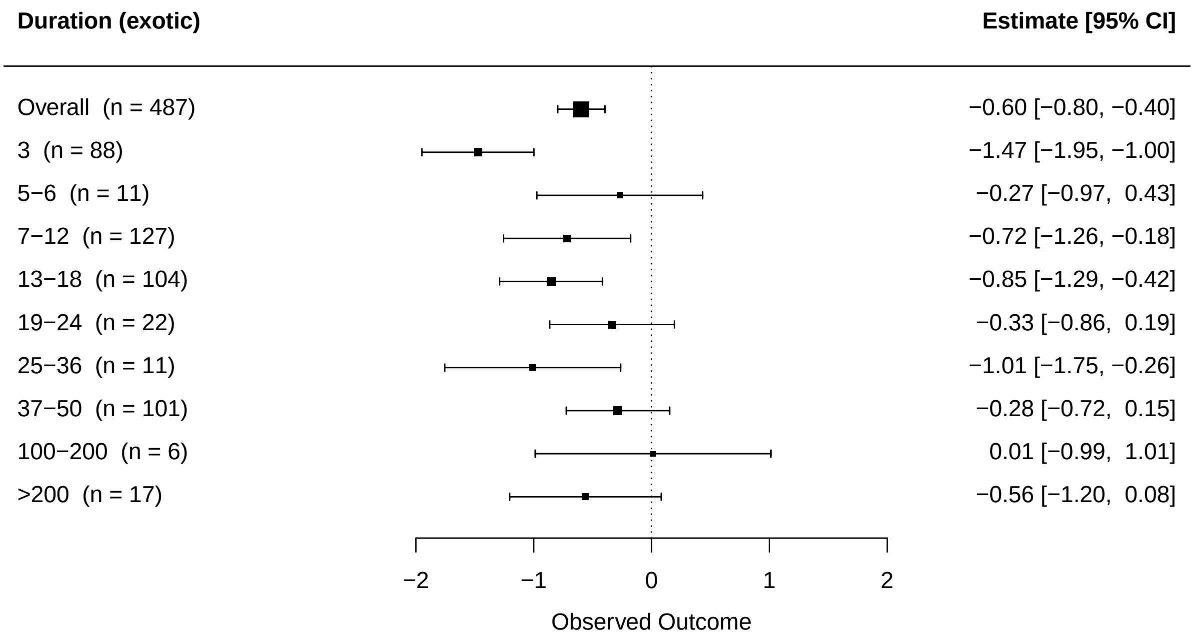
Single moderator models

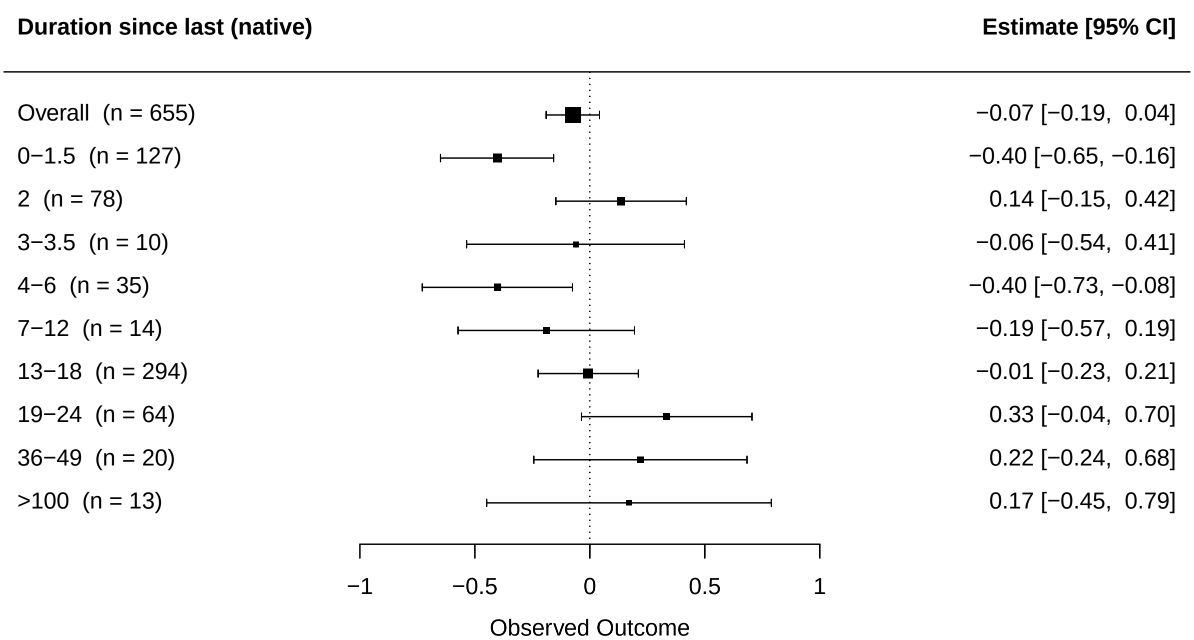
Duration since first C app (`dfc`)



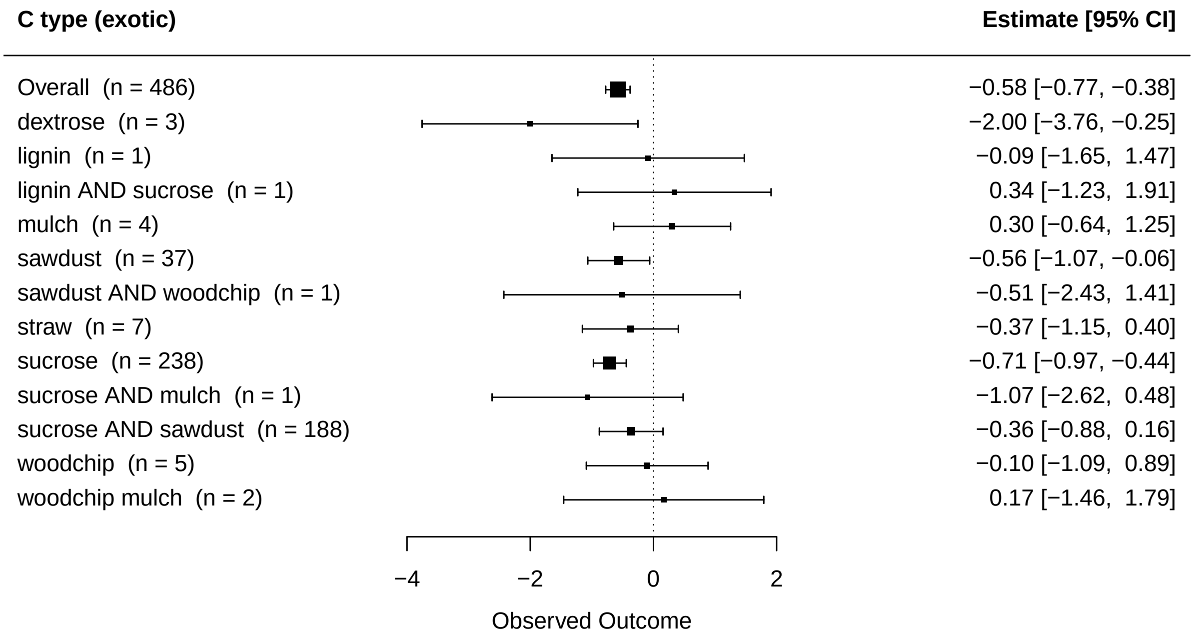


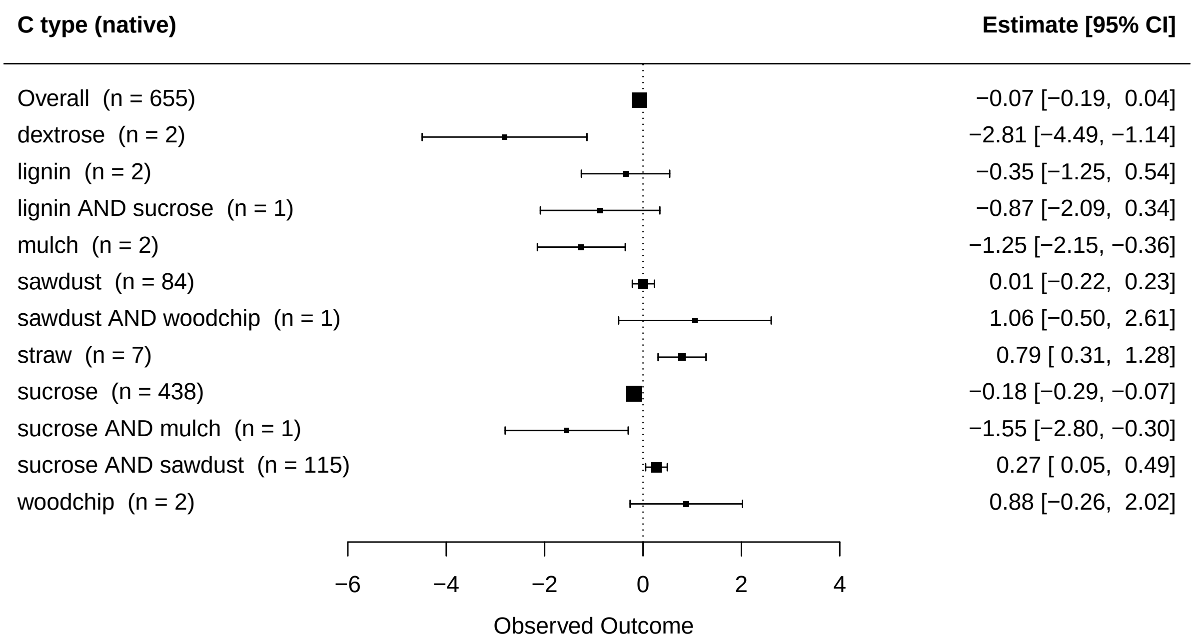
Duration since last C app (`dlc`)



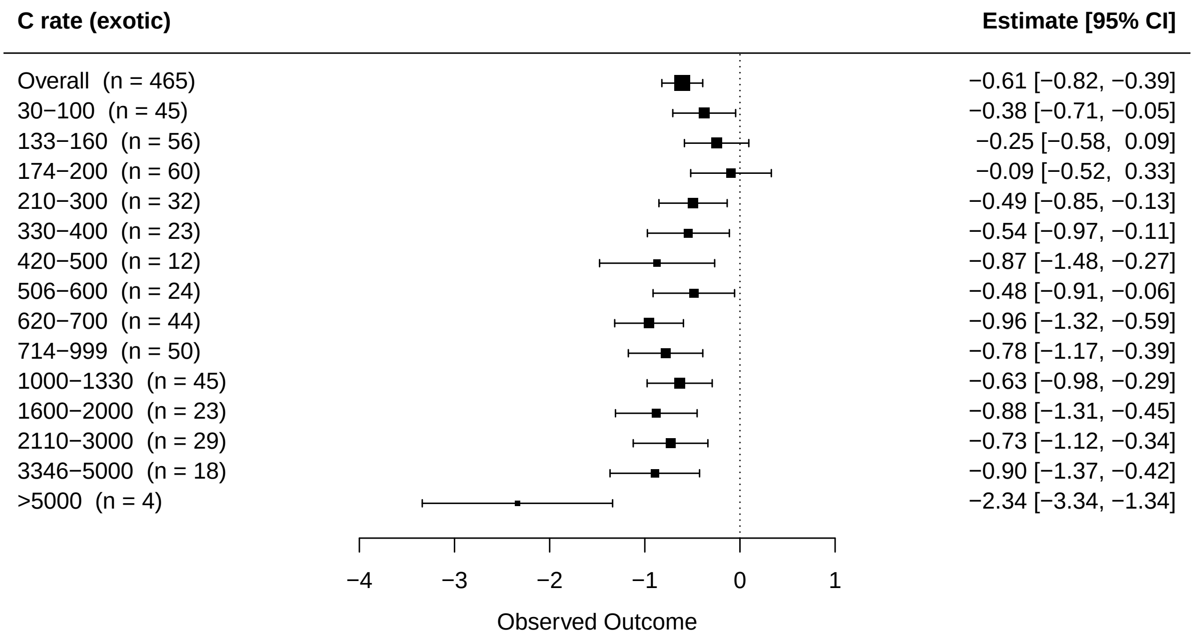


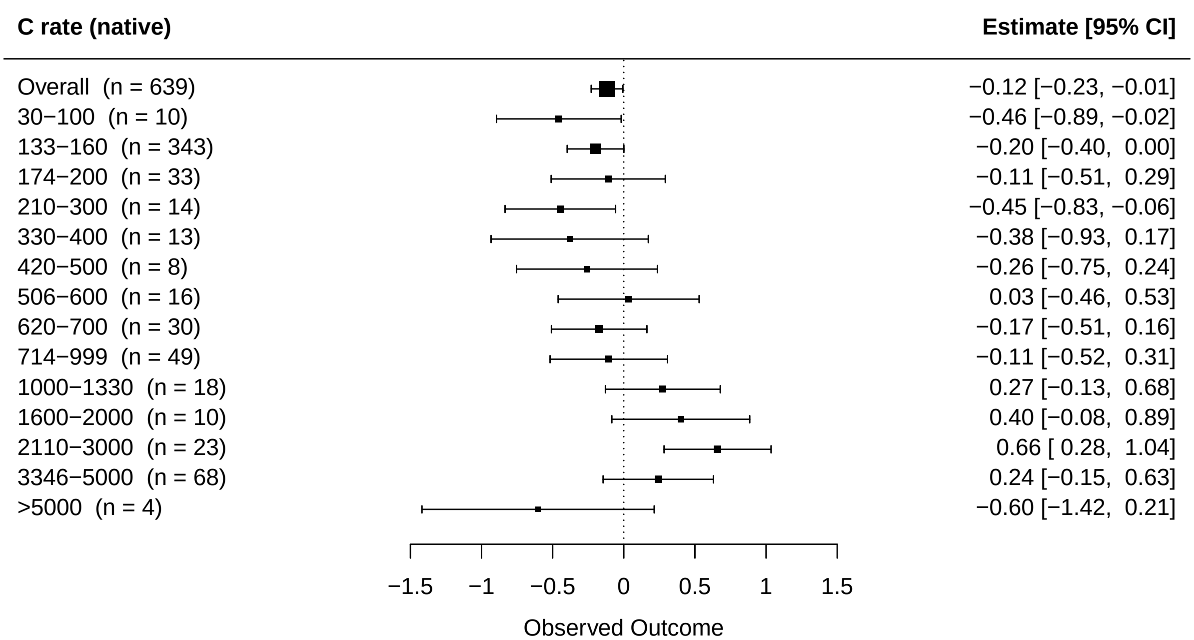
C type


C type (exotic)
Estimate [95% CI]
Overall (n = 486)
dextrose (n = 3)
lignin (n = 1)
lignin AND sucrose (n = 1)
mulch (n = 4)
sawdust (n = 37)
sawdust AND woodchip (n = 1)
straw (n = 7)
sucrose (n = 238)
sucrose AND mulch (n = 1)
sucrose AND sawdust (n = 188)
woodchip (n = 5)
woodchip mulch (n = 2)
−0.58 [−0.77, −0.38]
−2.00 [−3.76, −0.25]
−0.09 [−1.65, 1.47]
0.34 [−1.23, 1.91]
0.30 [−0.64, 1.25]
−0.56 [−1.07, −0.06]
−0.51 [−2.43, 1.41]
−0.37 [−1.15, 0.40]
−0.71 [−0.97, −0.44]
−1.07 [−2.62, 0.48]
−0.36 [−0.88, 0.16]
−0.10 [−1.09, 0.89]
0.17 [−1.46, 1.79]
−4
−2
0
2
Observed Outcome

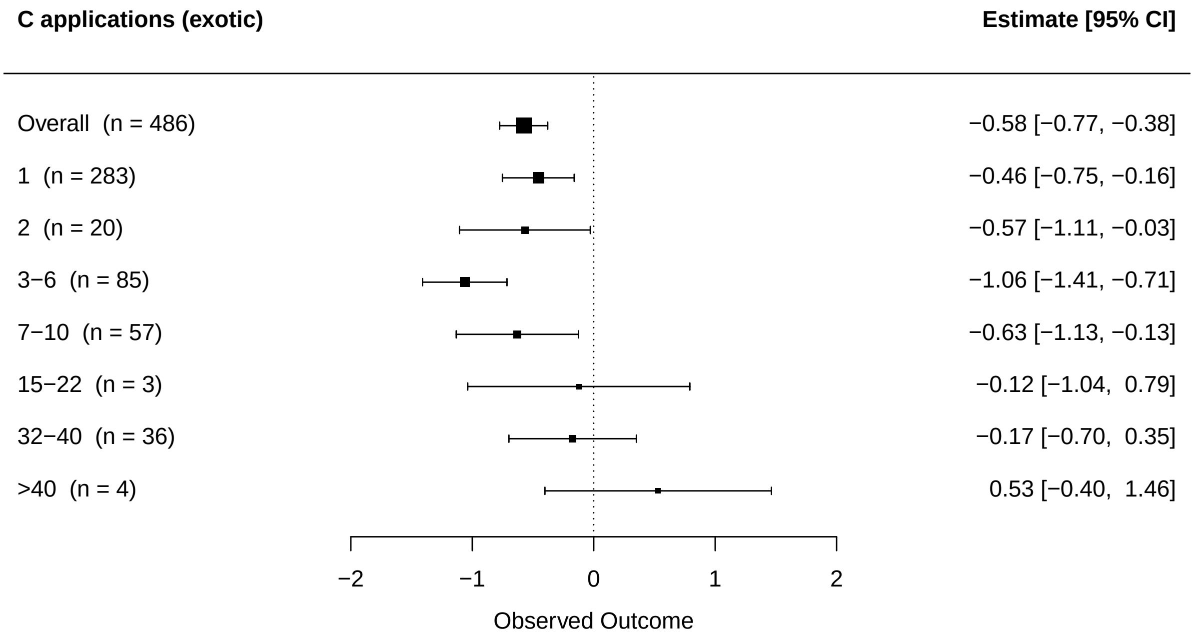

C type (native)
Estimate [95% CI]
Overall (n = 655)
dextrose (n = 2)
lignin (n = 2)
lignin AND sucrose (n = 1)
mulch (n = 2)
sawdust (n = 84)
sawdust AND woodchip (n = 1)
straw (n = 7)
sucrose (n = 438)
sucrose AND mulch (n = 1)
sucrose AND sawdust (n = 115)
woodchip (n = 2)
−0.07 [−0.19, 0.04]
−2.81 [−4.49, −1.14]
−0.35 [−1.25, 0.54]
−0.87 [−2.09, 0.34]
−1.25 [−2.15, −0.36]
0.01 [−0.22, 0.23]
1.06 [−0.50, 2.61]
0.79 [0.31, 1.28]
−0.18 [−0.29, −0.07]
−1.55 [−2.80, −0.30]
0.27 [0.05, 0.49]
0.88 [−0.26, 2.02]
−6
−4
−2
0
2
4
Observed Outcome

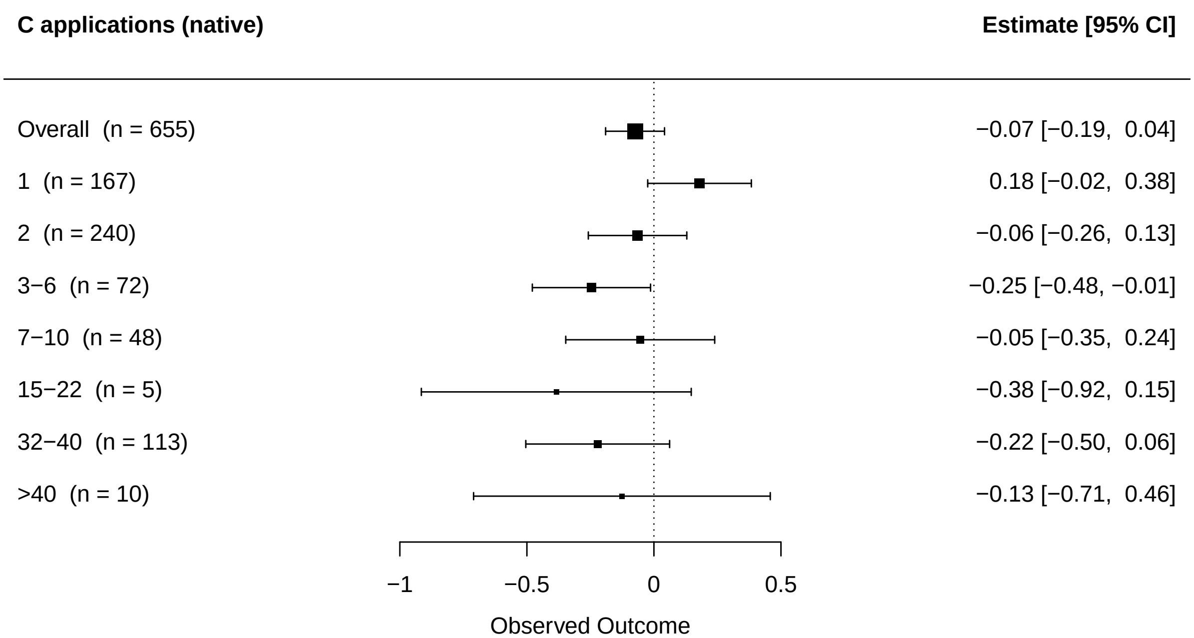
C rate (`cratc`)


C rate (exotic)
Estimate [95% CI]
Overall (n = 465) −0.61 [−0.82, −0.39]
30−100 (n = 45) −0.38 [−0.71, −0.05]
133−160 (n = 56) −0.25 [−0.58, 0.09]
174−200 (n = 60) −0.09 [−0.52, 0.33]
210−300 (n = 32) −0.49 [−0.85, −0.13]
330−400 (n = 23) −0.54 [−0.97, −0.11]
420−500 (n = 12) −0.87 [−1.48, −0.27]
506−600 (n = 24) −0.48 [−0.91, −0.06]
620−700 (n = 44) −0.96 [−1.32, −0.59]
714−999 (n = 50) −0.78 [−1.17, −0.39]
1000−1330 (n = 45) −0.63 [−0.98, −0.29]
1600−2000 (n = 23) −0.88 [−1.31, −0.45]
2110−3000 (n = 29) −0.73 [−1.12, −0.34]
3346−5000 (n = 18) −0.90 [−1.37, −0.42]
>5000 (n = 4) −2.34 [−3.34, −1.34]
−4 −3 −2 −1 0 1
Observed Outcome

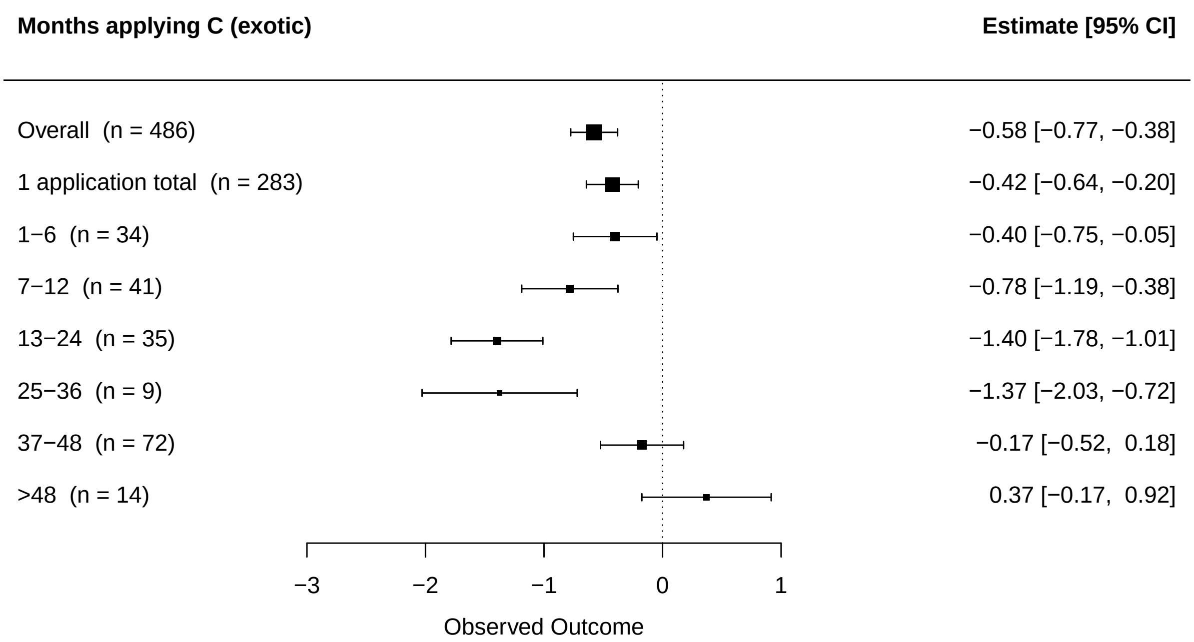

C rate (native)
Estimate [95% CI]
Overall (n = 639) −0.12 [−0.23, −0.01]
30−100 (n = 10) −0.46 [−0.89, −0.02]
133−160 (n = 343) −0.20 [−0.40, 0.00]
174−200 (n = 33) −0.11 [−0.51, 0.29]
210−300 (n = 14) −0.45 [−0.83, −0.06]
330−400 (n = 13) −0.38 [−0.93, 0.17]
420−500 (n = 8) −0.26 [−0.75, 0.24]
506−600 (n = 16) 0.03 [−0.46, 0.53]
620−700 (n = 30) −0.17 [−0.51, 0.16]
714−999 (n = 49) −0.11 [−0.52, 0.31]
1000−1330 (n = 18) 0.27 [−0.13, 0.68]
1600−2000 (n = 10) 0.40 [−0.08, 0.89]
2110−3000 (n = 23) 0.66 [0.28, 1.04]
3346−5000 (n = 68) 0.24 [−0.15, 0.63]
>5000 (n = 4) −0.60 [−1.42, 0.21]
−1.5 −1 −0.5 0 0.5 1 1.5
Observed Outcome

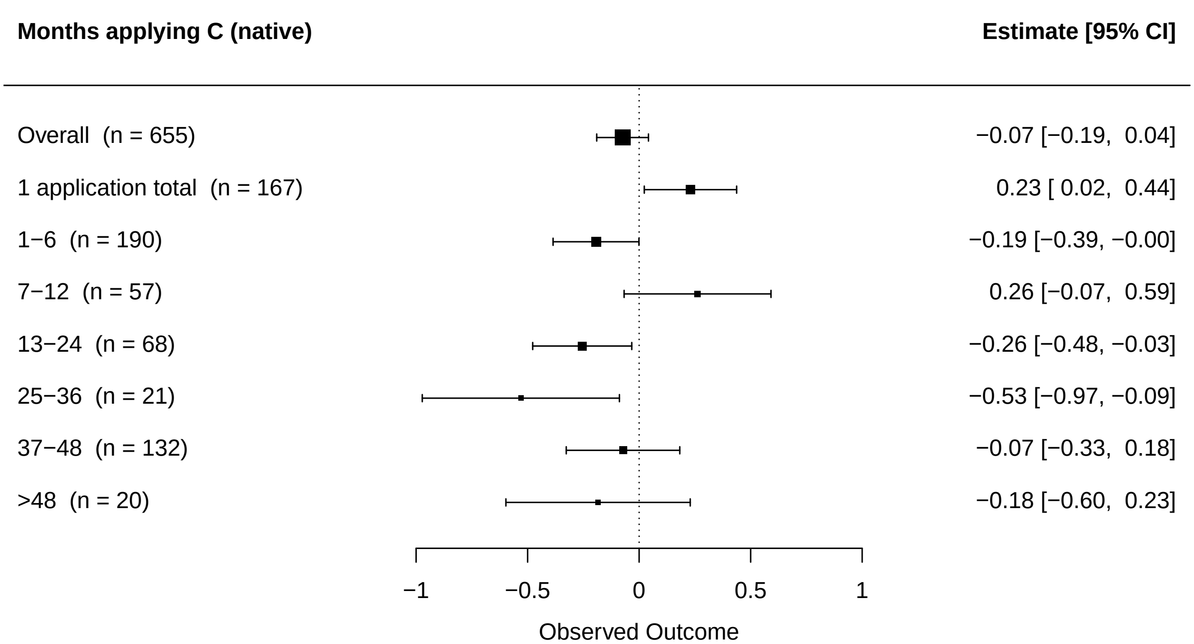
Total C applications



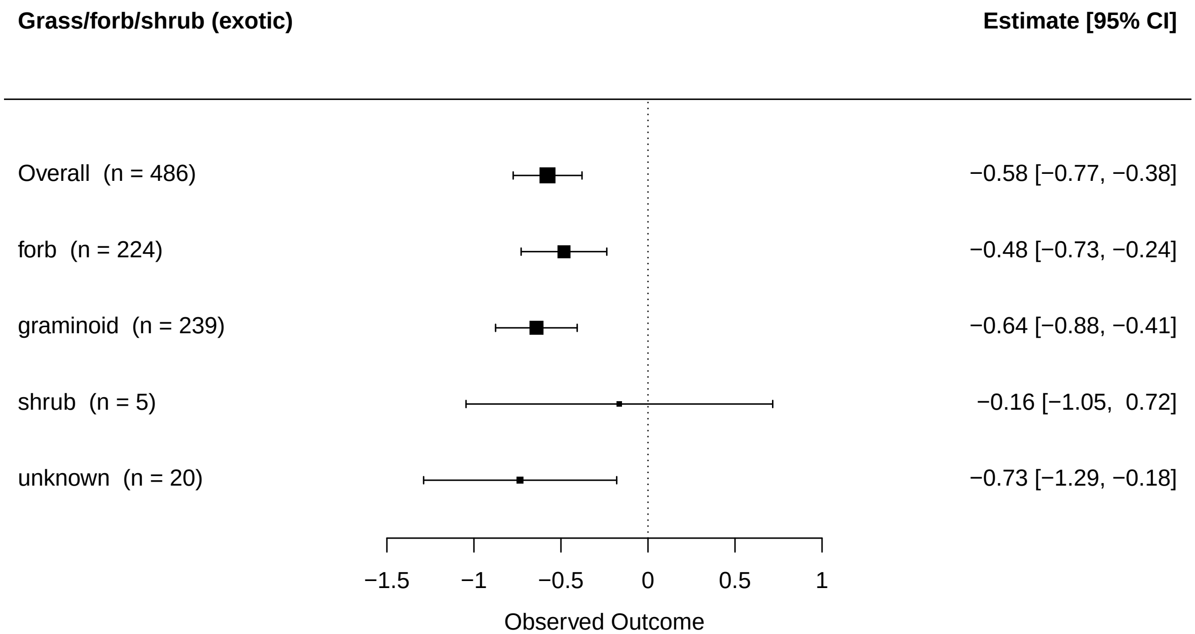


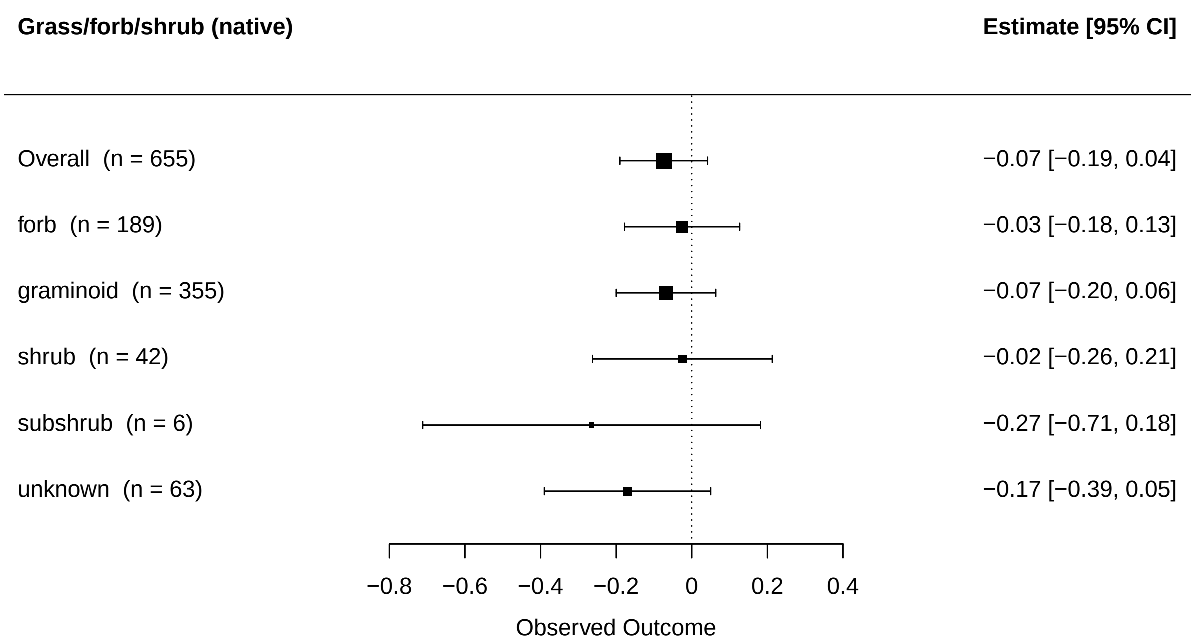
Months applying C (capt)



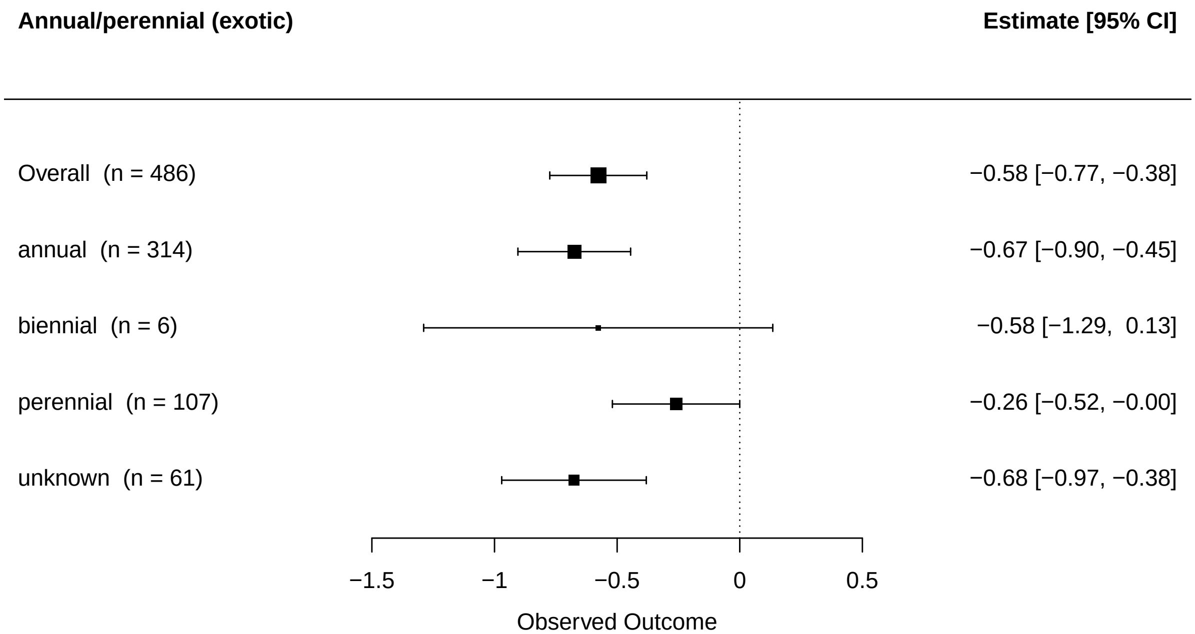


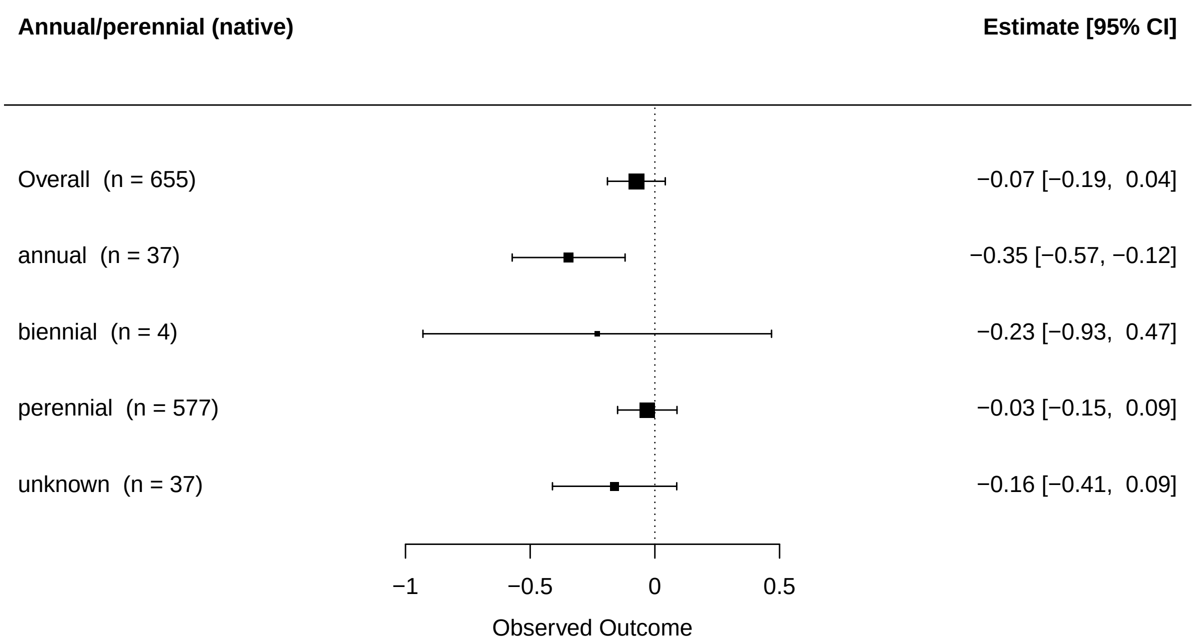
Grass/forb/shrub



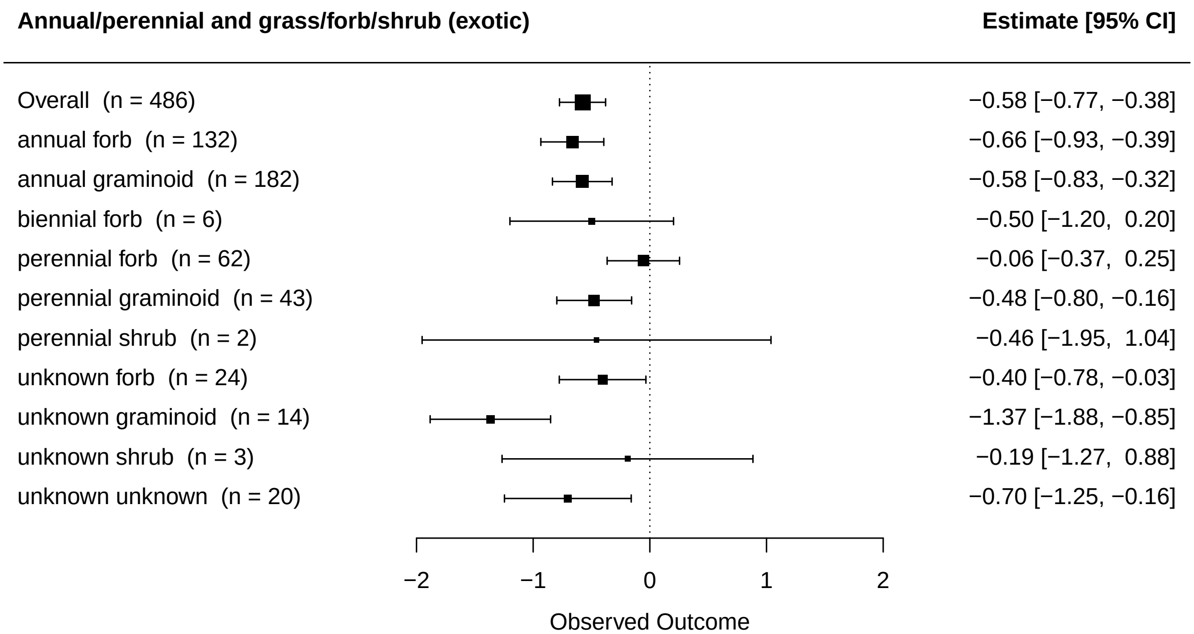


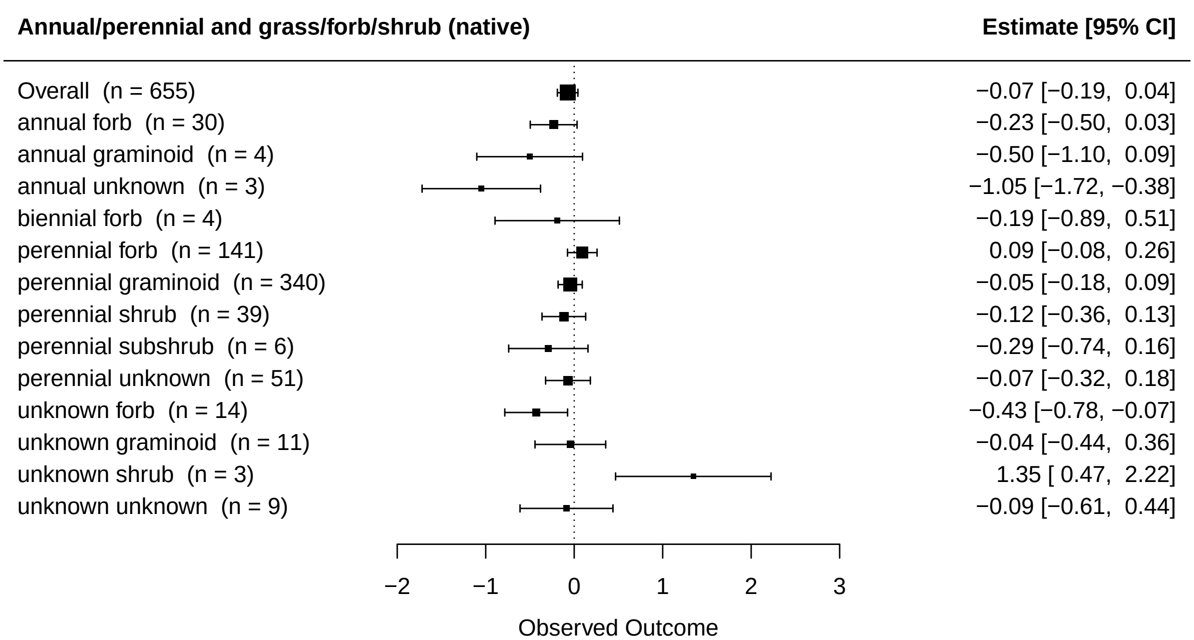
Annual/perennial



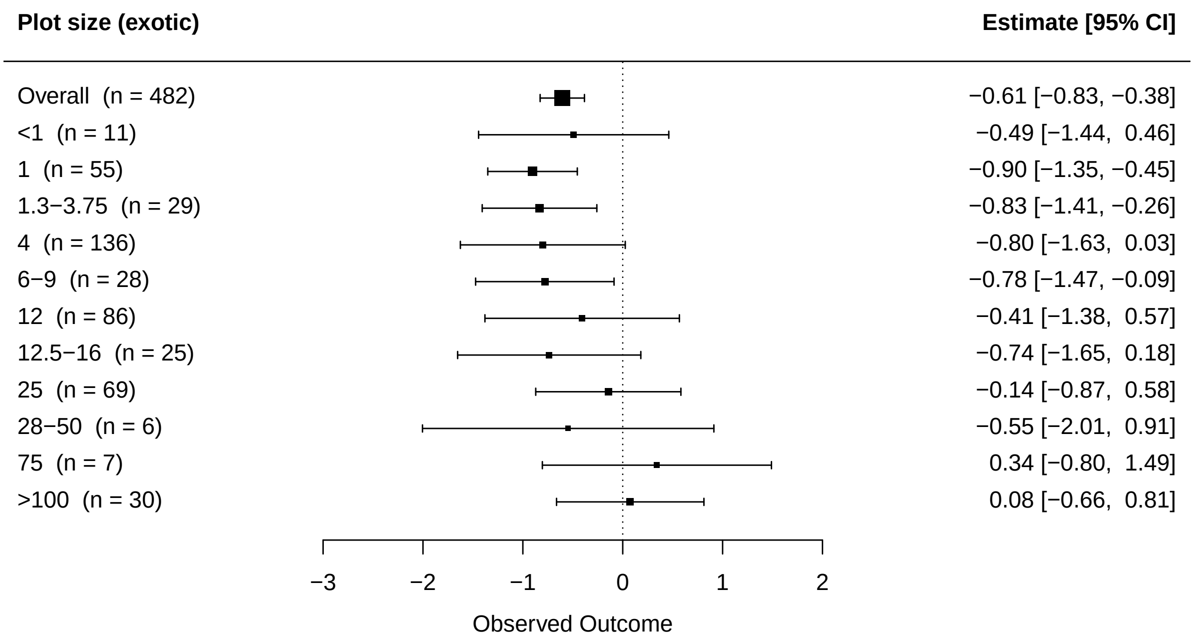


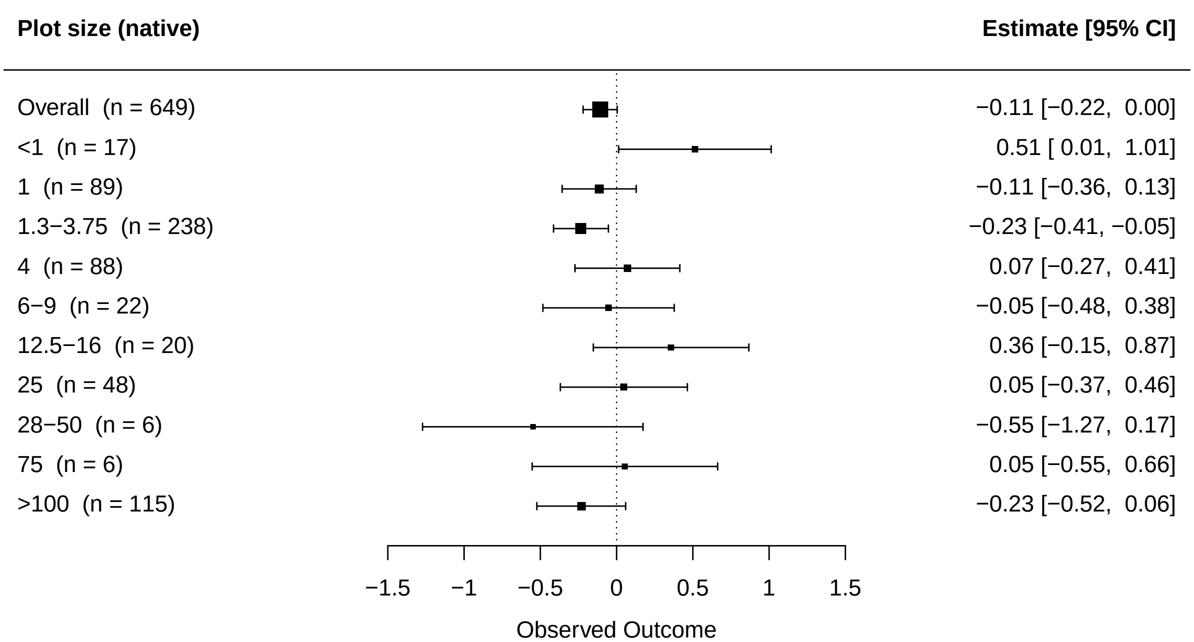
Annual/perennial and grass/forb/shrub



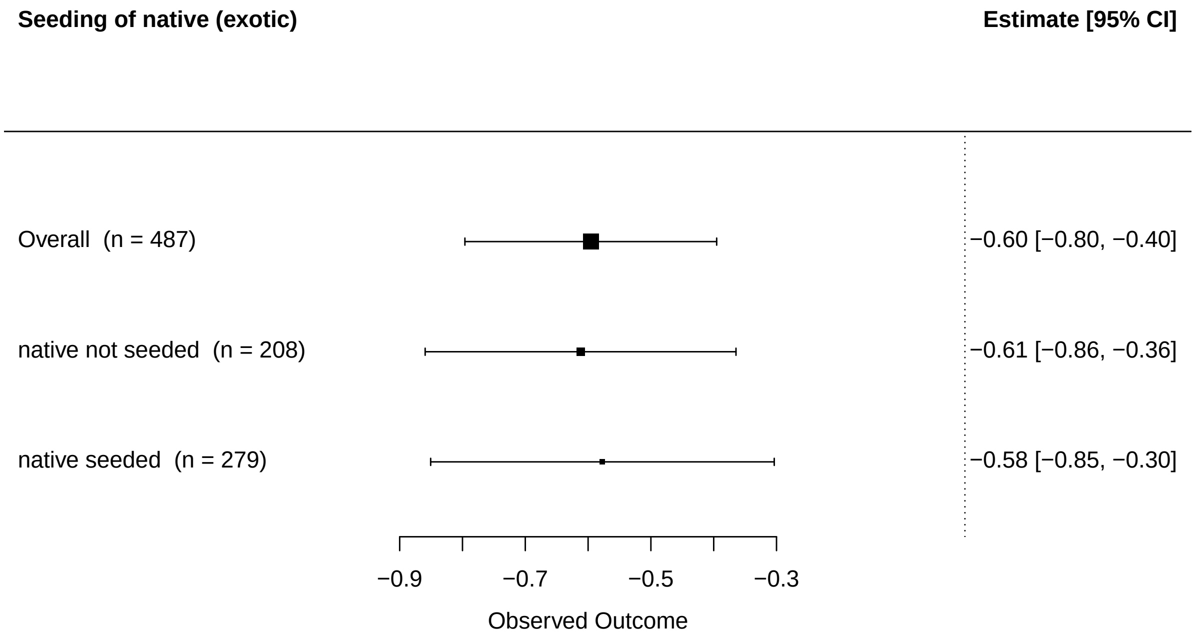


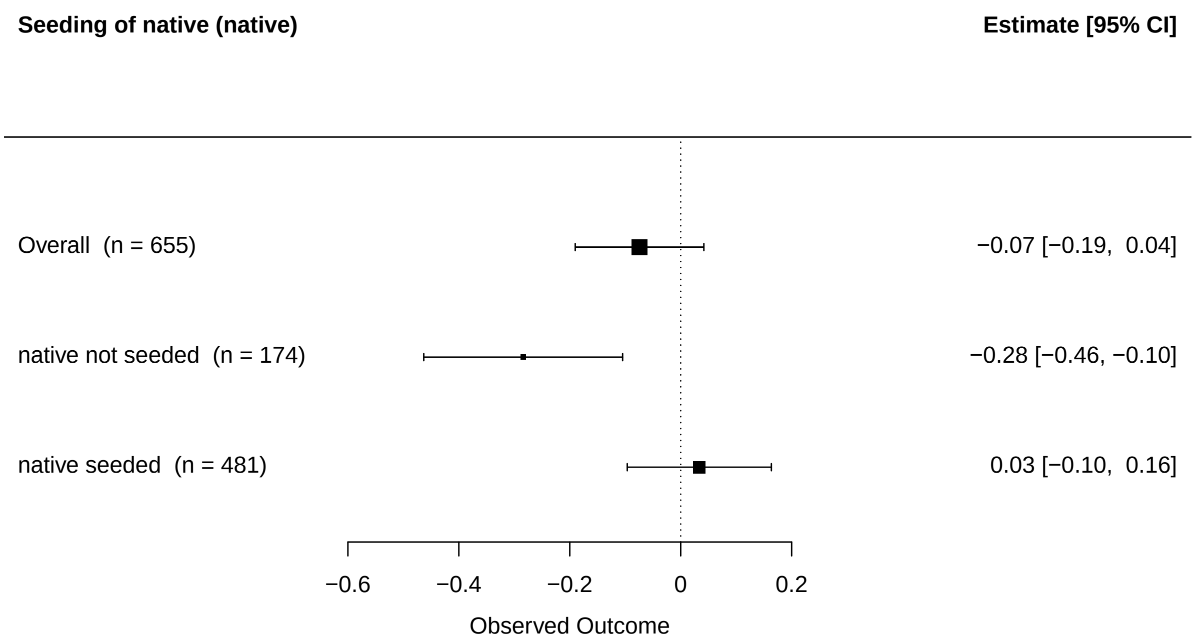
Plot size


Plot size (exotic)
Estimate [95% CI]
Overall (n = 482)
<1 (n = 11)
1 (n = 55)
1.3−3.75 (n = 29)
4 (n = 136)
6−9 (n = 28)
12 (n = 86)
12.5−16 (n = 25)
25 (n = 69)
28−50 (n = 6)
75 (n = 7)
>100 (n = 30)
−0.61 [−0.83, −0.38]
−0.49 [−1.44, 0.46]
−0.90 [−1.35, −0.45]
−0.83 [−1.41, −0.26]
−0.80 [−1.63, 0.03]
−0.78 [−1.47, −0.09]
−0.41 [−1.38, 0.57]
−0.74 [−1.65, 0.18]
−0.14 [−0.87, 0.58]
−0.55 [−2.01, 0.91]
0.34 [−0.80, 1.49]
0.08 [−0.66, 0.81]
−3
−2
−1
0
1
2
Observed Outcome


Plot size (native)
Estimate [95% CI]
Overall (n = 649)
<1 (n = 17)
1 (n = 89)
1.3−3.75 (n = 238)
4 (n = 88)
6−9 (n = 22)
12.5−16 (n = 20)
25 (n = 48)
28−50 (n = 6)
75 (n = 6)
>100 (n = 115)
−0.11 [−0.22, 0.00]
0.51 [0.01, 1.01]
−0.11 [−0.36, 0.13]
−0.23 [−0.41, −0.05]
0.07 [−0.27, 0.41]
−0.05 [−0.48, 0.38]
0.36 [−0.15, 0.87]
0.05 [−0.37, 0.46]
−0.55 [−1.27, 0.17]
0.05 [−0.55, 0.66]
−0.23 [−0.52, 0.06]
−1.5
−1
−0.5
0
0.5
1
1.5
Observed Outcome

Seeding of native





Heterogeneity stats

Model	QE	QE_df	QE_p	QM	QM_df	QM_p	QM_QT
Summary							
Exotic	1013.0	485	0.0e+00	32.680	1	0.0000000	0.031260
Native	925.8	654	0.0e+00	1.573	1	0.2097000	0.001697
Region							
Exotic	871.4	485	0.0e+00	71.990	11	0.0000000	0.076320
Native	841.8	654	3.0e-07	32.480	10	0.0003331	0.037150
Duration since first C app							
Exotic	959.4	486	0.0e+00	60.610	9	0.0000000	0.059420
Native	884.8	654	0.0e+00	13.620	9	0.1364000	0.015160
Duration since last C app							
Exotic	954.6	487	0.0e+00	64.110	9	0.0000000	0.062940
Native	883.2	654	0.0e+00	23.030	9	0.0061220	0.025420
C type							
Exotic	948.4	487	0.0e+00	42.870	12	0.0000238	0.043240
Native	814.0	654	5.6e-06	56.400	11	0.0000000	0.064800
C rate							
Exotic	879.8	464	0.0e+00	72.930	14	0.0000000	0.076540
Native	799.4	638	2.6e-06	41.870	14	0.0001297	0.049770
Total C applications							
Exotic	956.7	487	0.0e+00	49.720	7	0.0000000	0.049400
Native	875.6	654	0.0e+00	12.450	7	0.0867700	0.014020
Months applying C							
Exotic	890.9	487	0.0e+00	98.500	7	0.0000000	0.099550
Native	866.5	654	0.0e+00	19.860	7	0.0058790	0.022410
Grass/forb/shrub							
Exotic	1003.0	487	0.0e+00	48.880	4	0.0000000	0.046450
Native	909.1	654	0.0e+00	10.630	4	0.0310600	0.011560
Annual/perennial							
Exotic	1034.0	487	0.0e+00	33.070	4	0.0000012	0.030980
Native	918.8	654	0.0e+00	4.090	5	0.5365000	0.004432
Annual/perennial and grass/forb/shrub							
Exotic	973.9	487	0.0e+00	68.770	10	0.0000000	0.065950
Native	881.2	654	0.0e+00	37.230	13	0.0003817	0.040530
Plot size							
Exotic	937.3	481	0.0e+00	37.840	11	0.0000833	0.038800
Native	824.1	648	9.0e-07	18.570	10	0.0461400	0.022030
Seeding of native							
Exotic	1005.0	486	0.0e+00	33.420	2	0.0000001	0.032190
Native	894.7	654	0.0e+00	10.240	2	0.0059620	0.011320

Model selection

Exotic

```
##                                             model     aicc   weights
## 1 yi ~ 1 + dlc + plotc + region + plant_apgfs 1286.618 0.9369876
```

- The top model has a weight of 94%.

Native

```
##                                                      model     aicc   weights
## 1 yi ~ 1 + dlc + cratc + region + C_type + plant_apgfs 1503.092 0.9702438
```

- The top model has a weight of 97%.