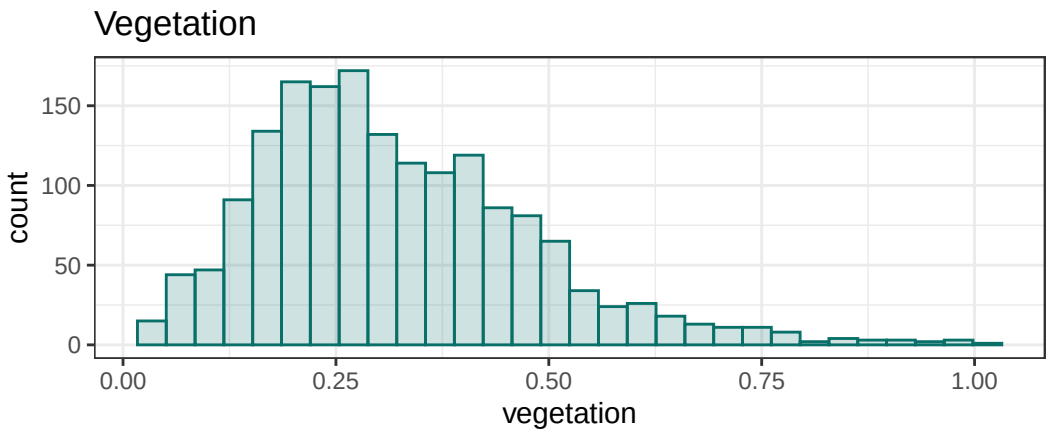
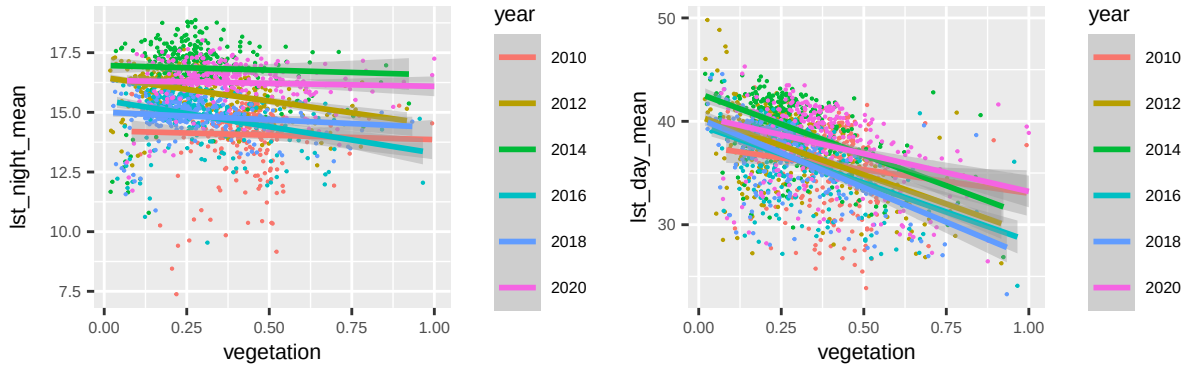
LawnProject Panel Data Analysis / Random Forest Data

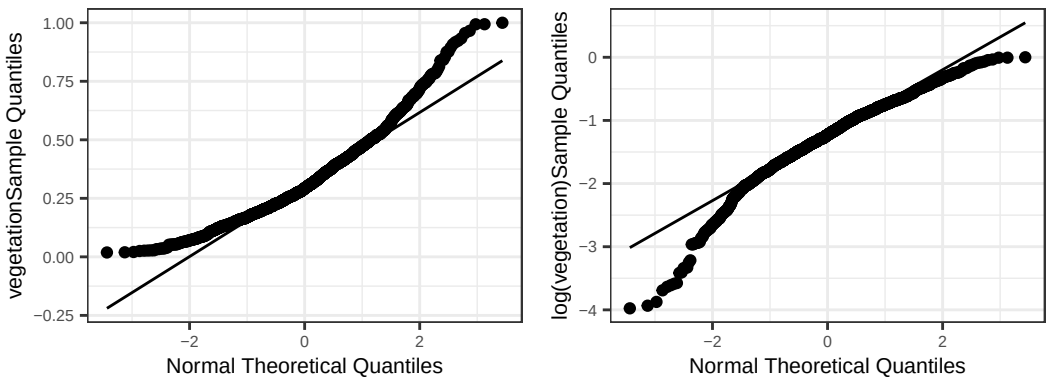
LawnProject Team

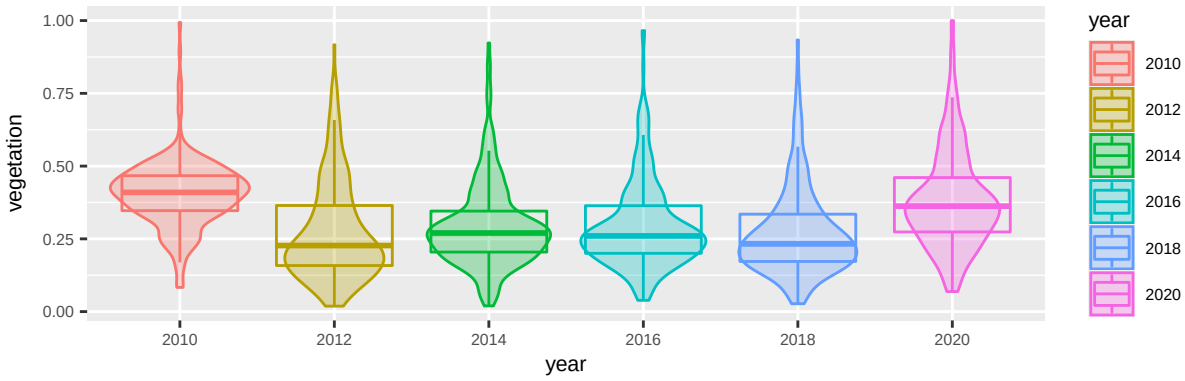
Intro

Aggregate Vegetation Area (Trees + Lawn)



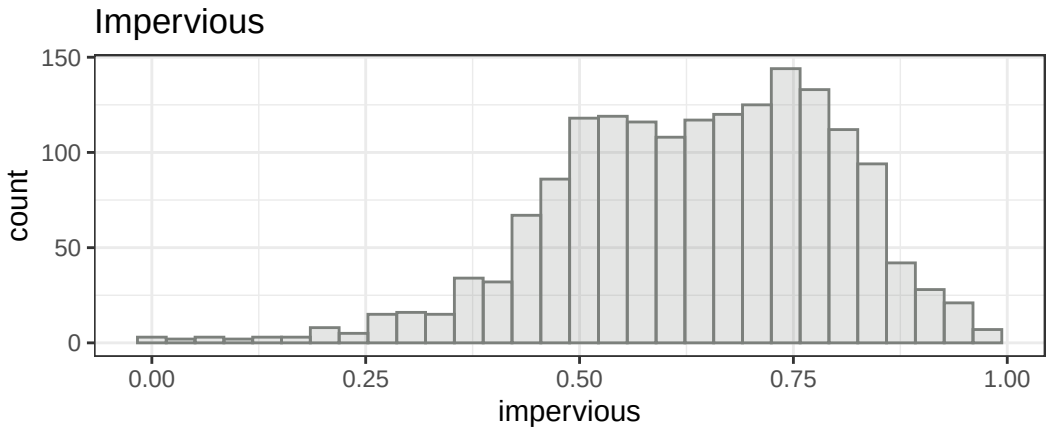


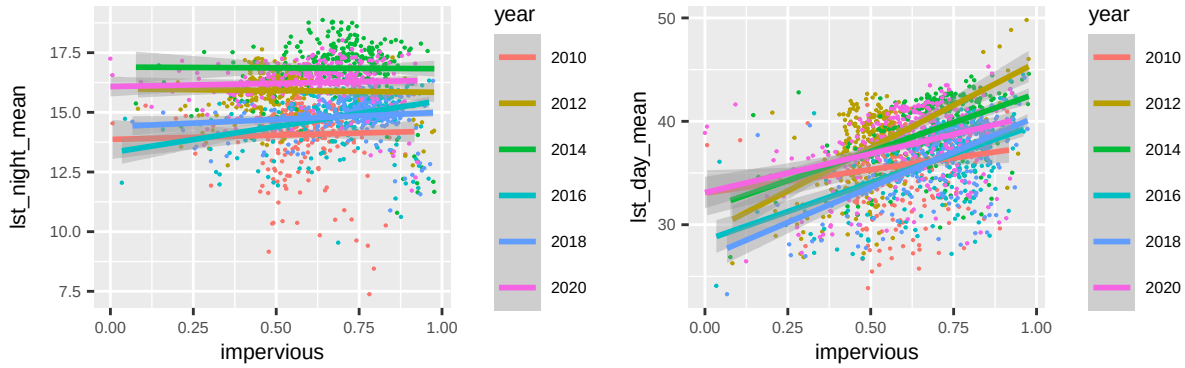


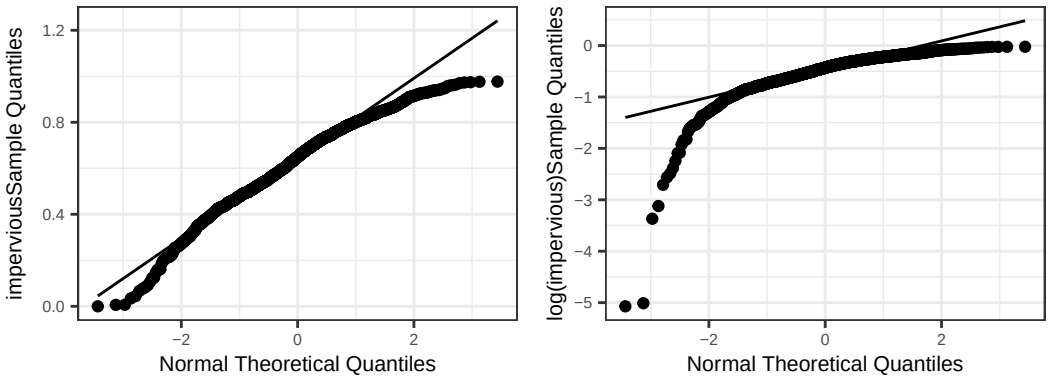


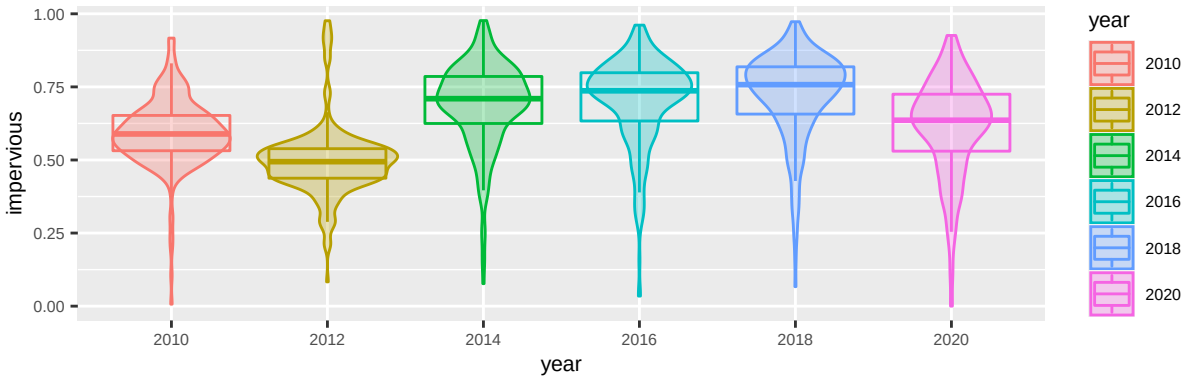
Google Earth: Random Forest Model

Aggregate Impervious Area (Soil + Turf + Impervious)



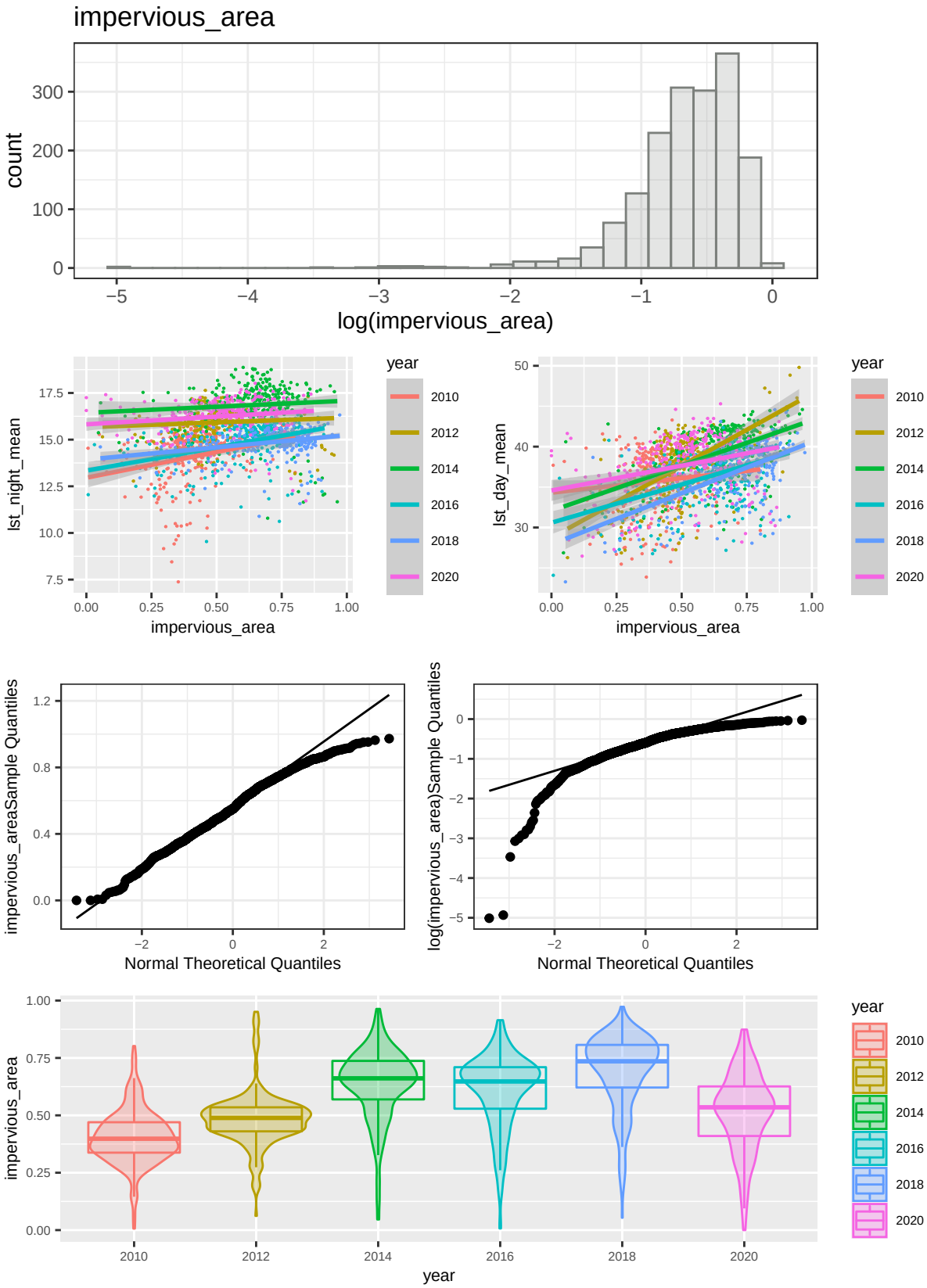






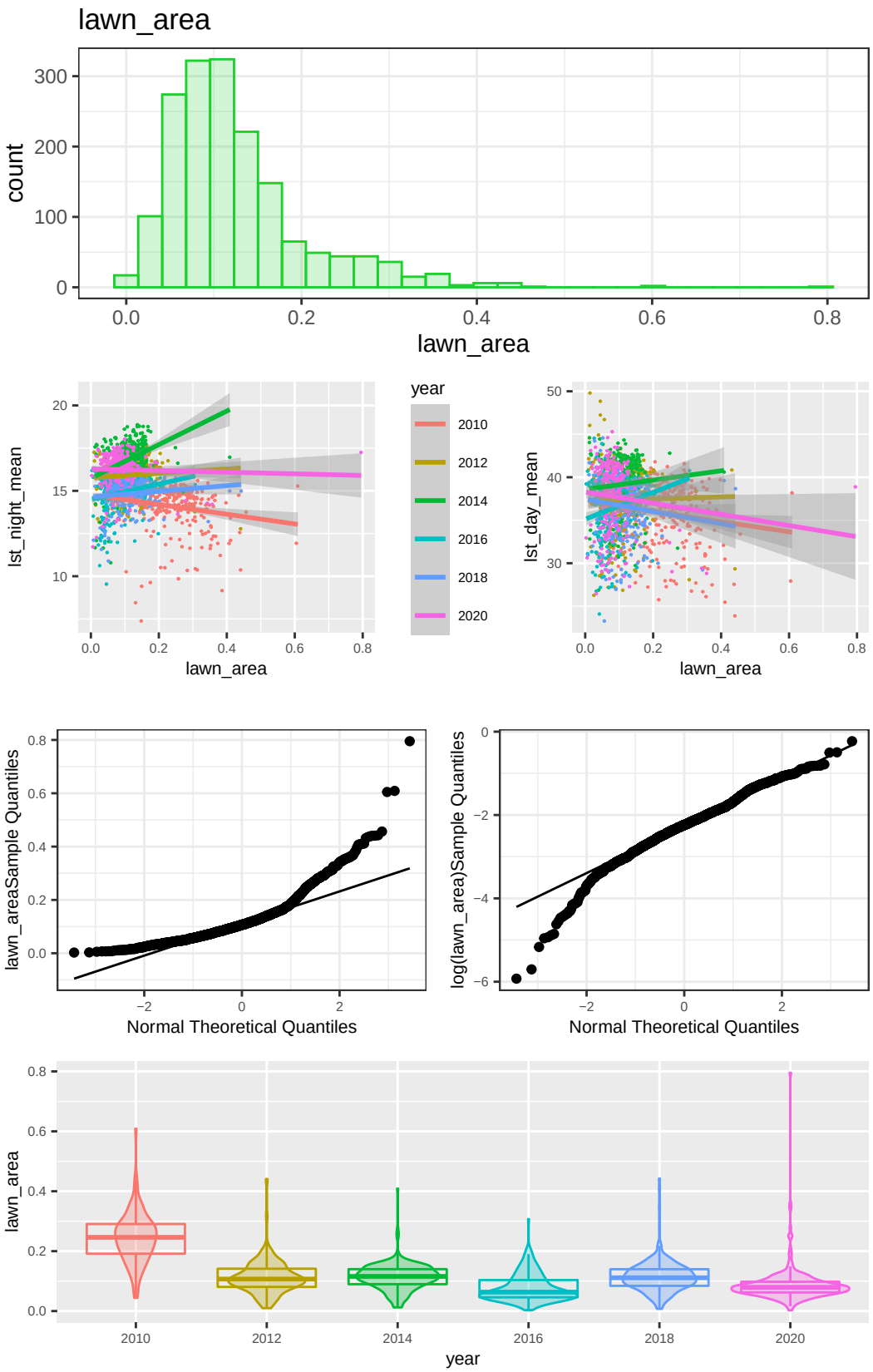
Google Earth: Random Forest Model

Impervious Area



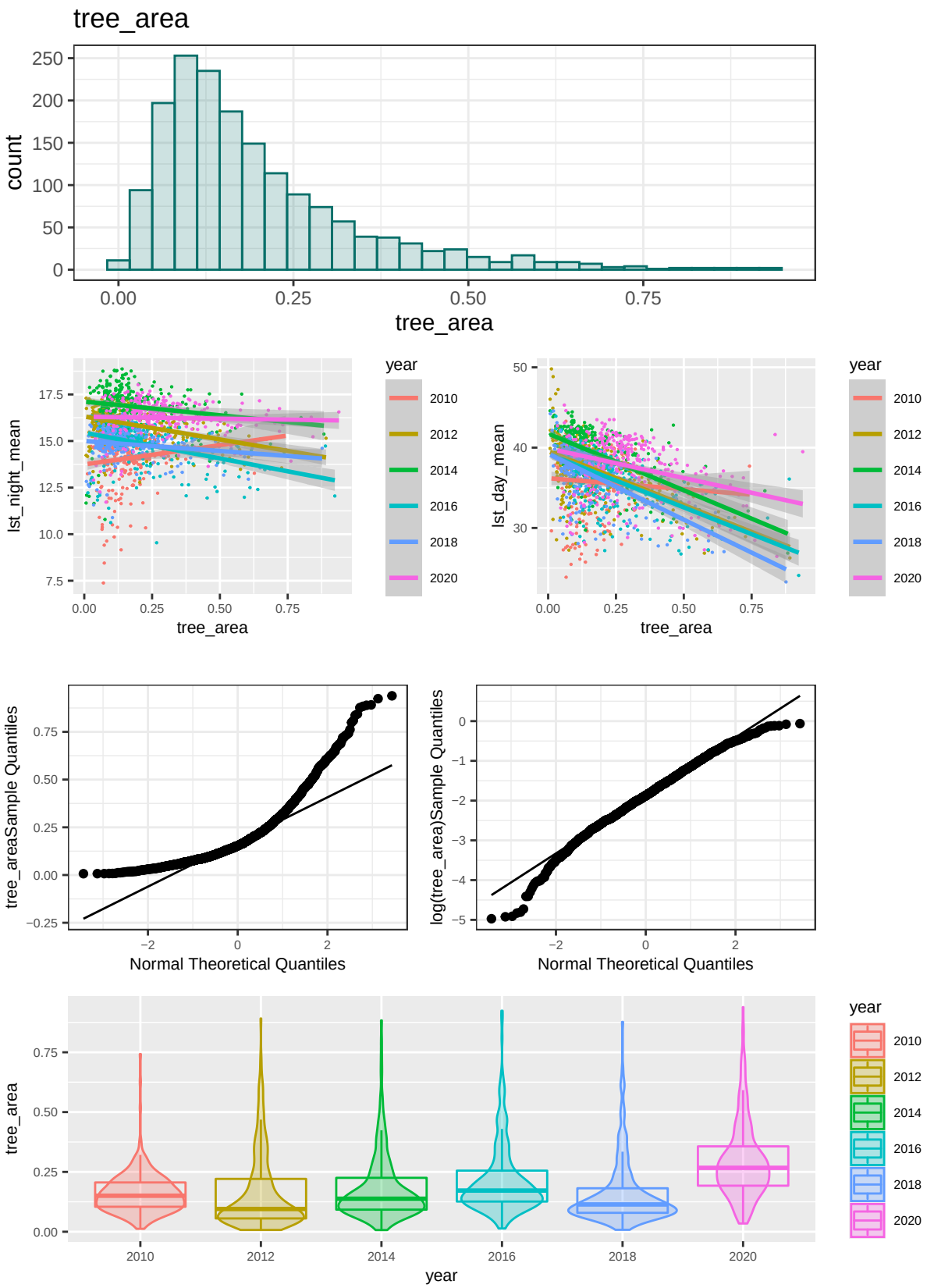
Google Earth: Random Forest Model

Lawn Area



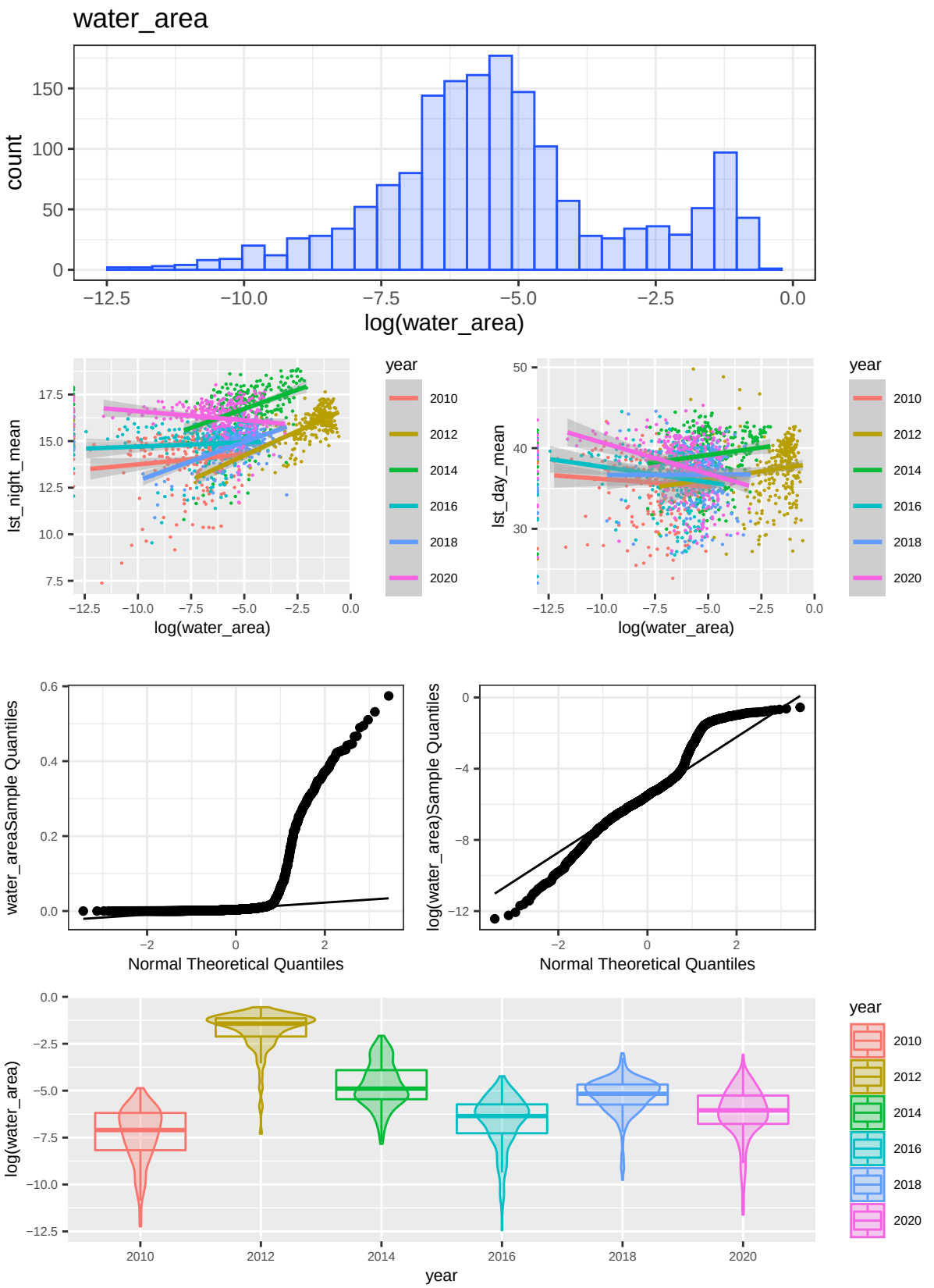
Google Earth: Random Forest Model

Tree Area



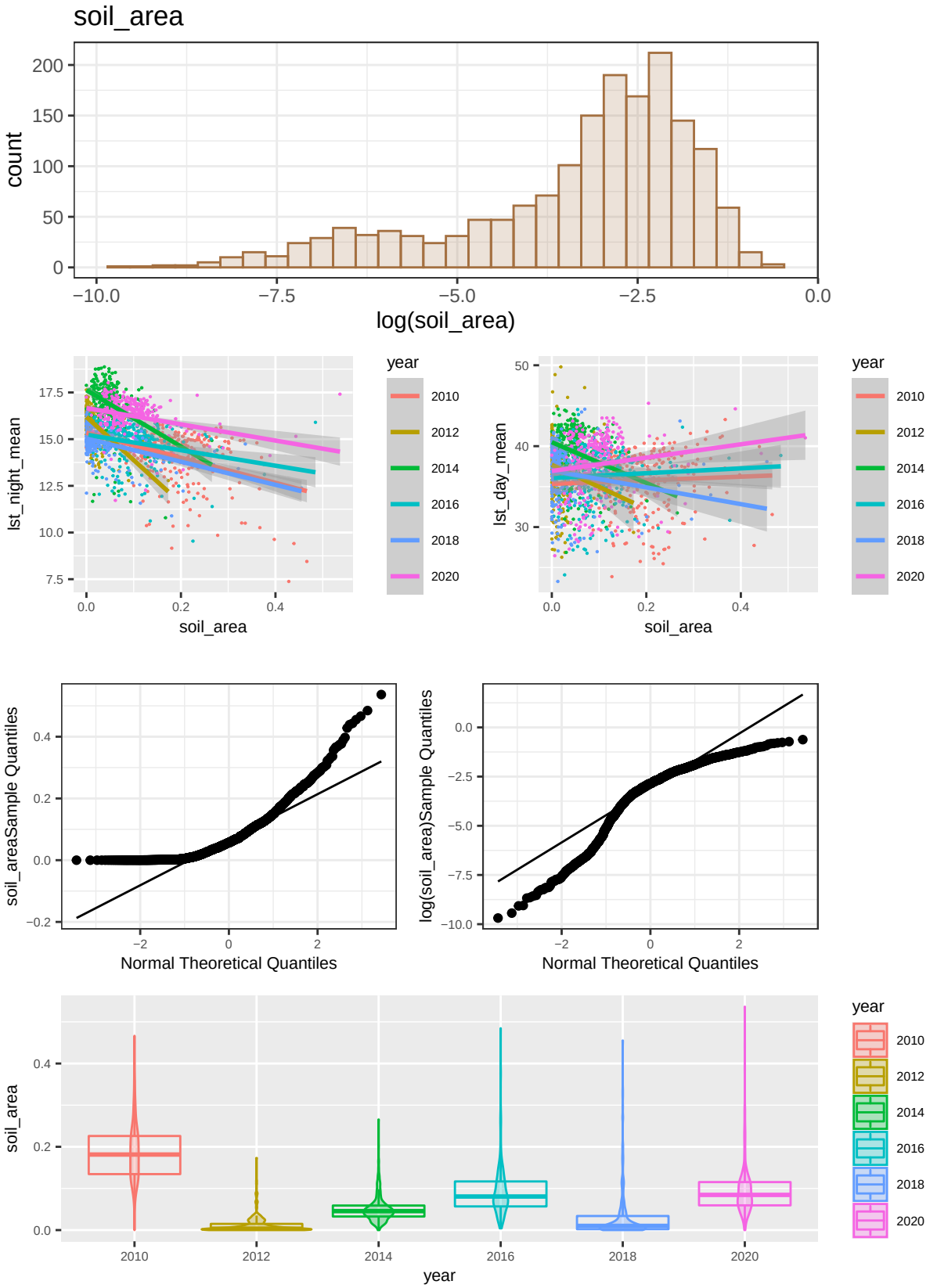
Google Earth: Random Forest Model

Water Area



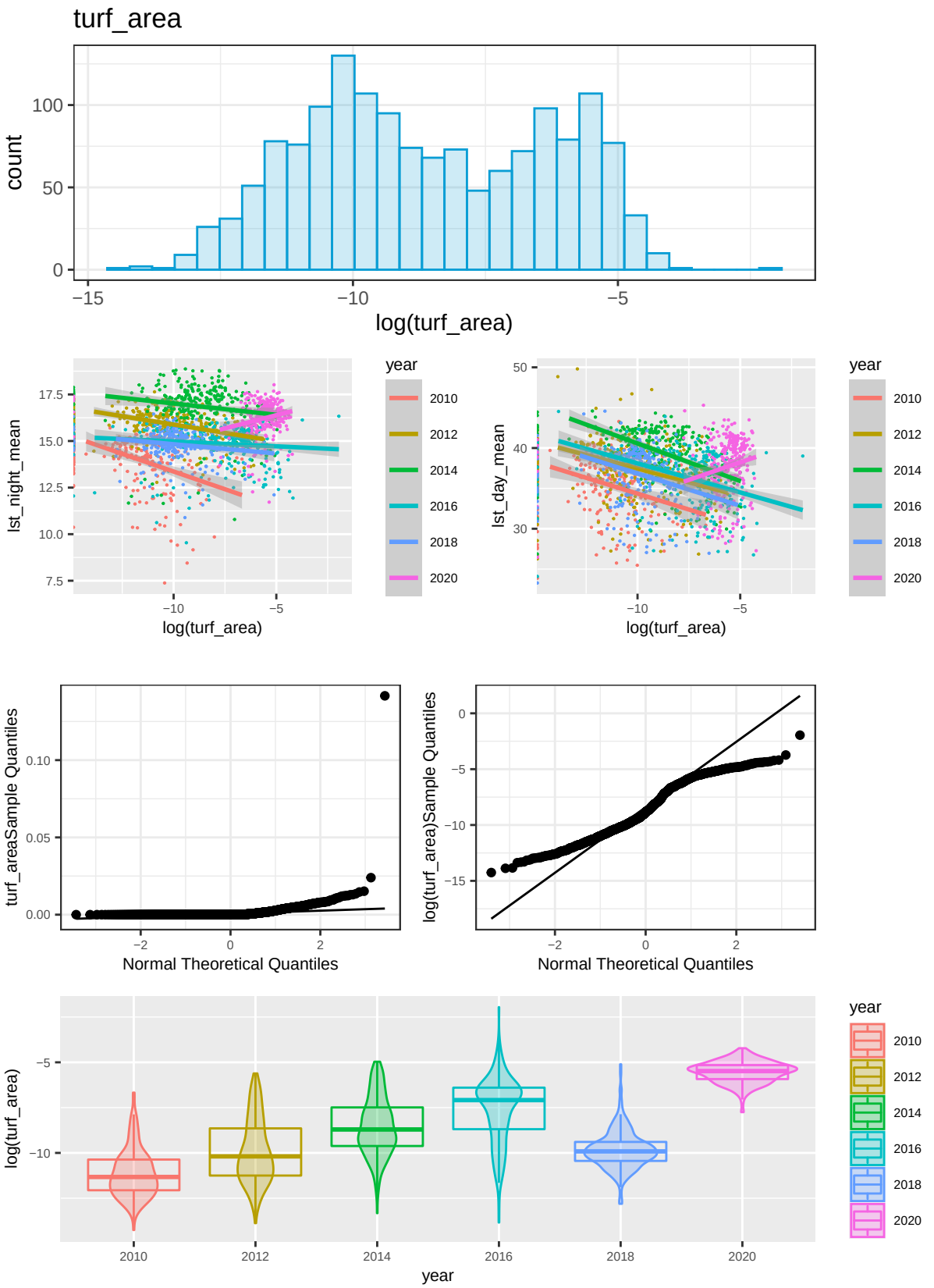
Google Earth: Random Forest Model

Soil Area



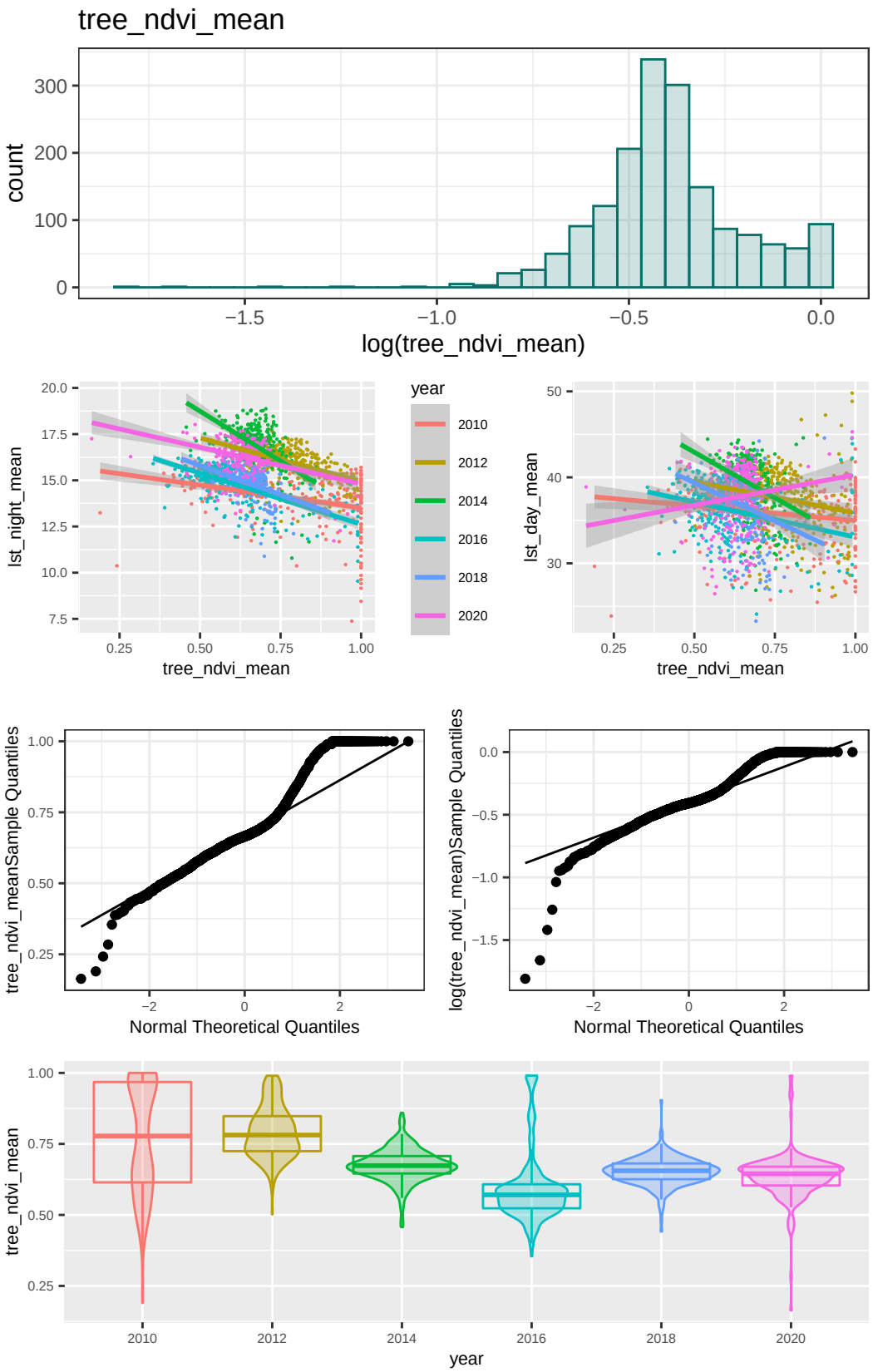
Google Earth: Random Forest Model

Turf Area



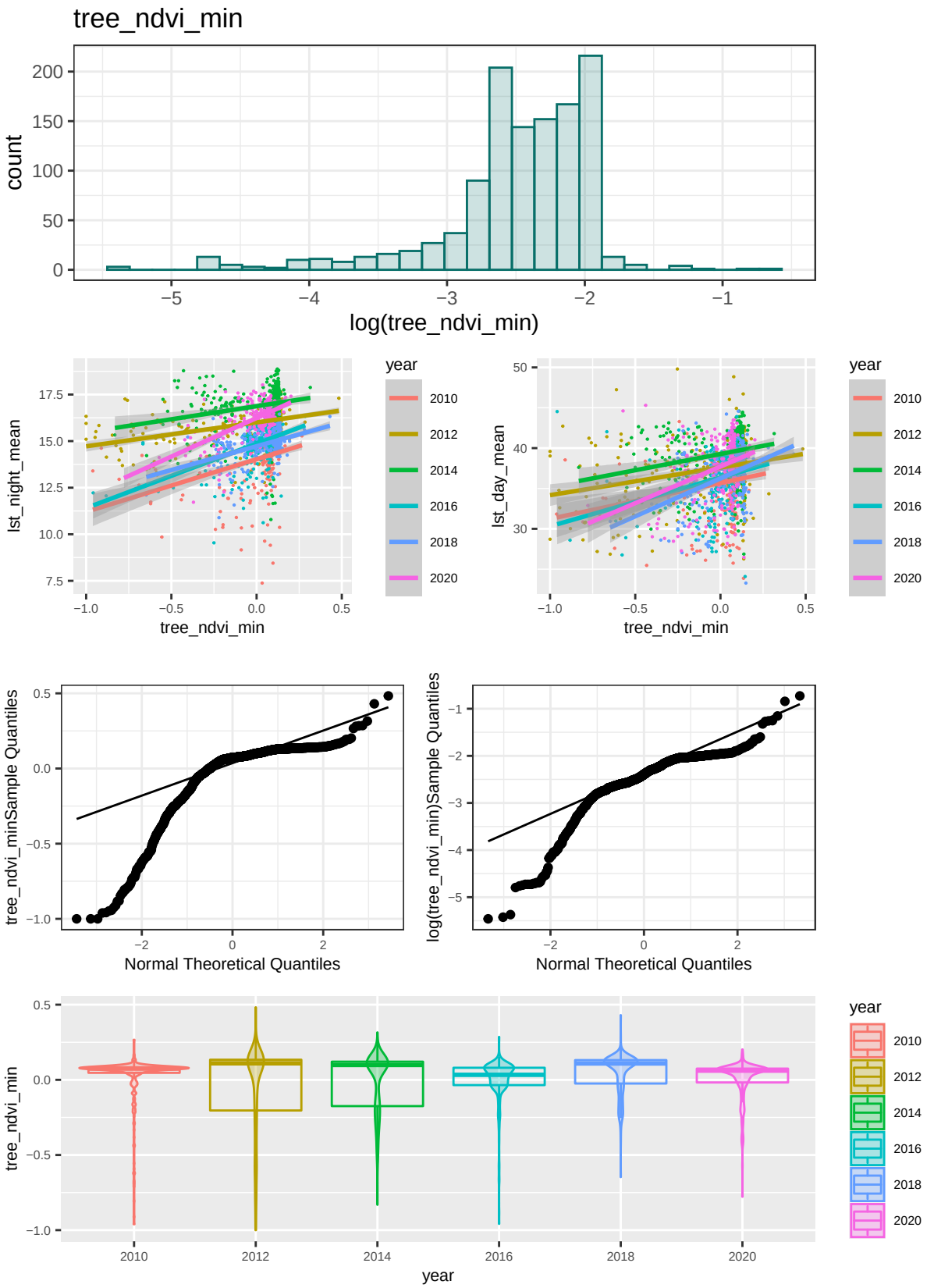
Google Earth: Random Forest Model

Tree NDVI Mean



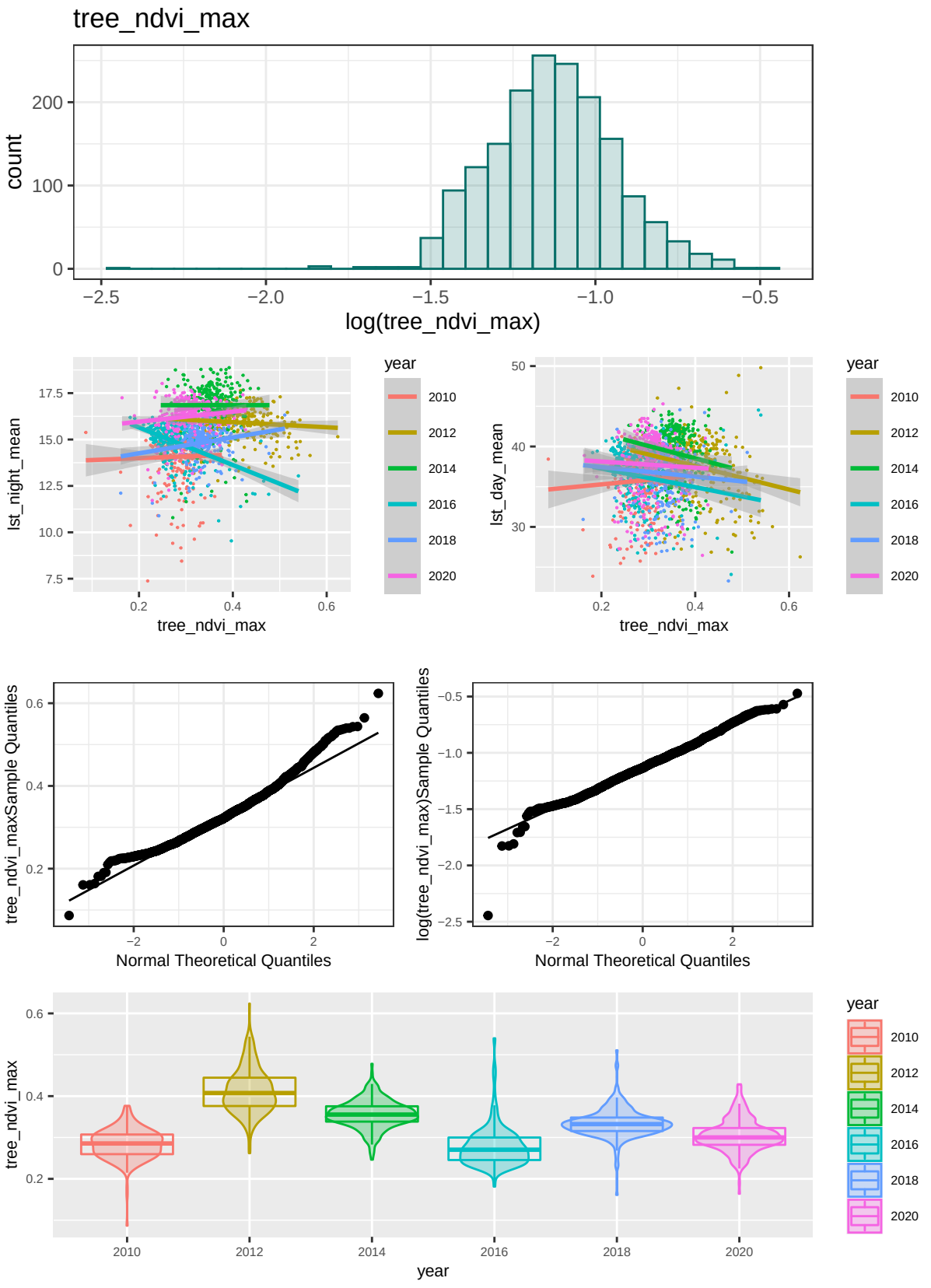
Google Earth: Random Forest Model

Tree NDVI Min



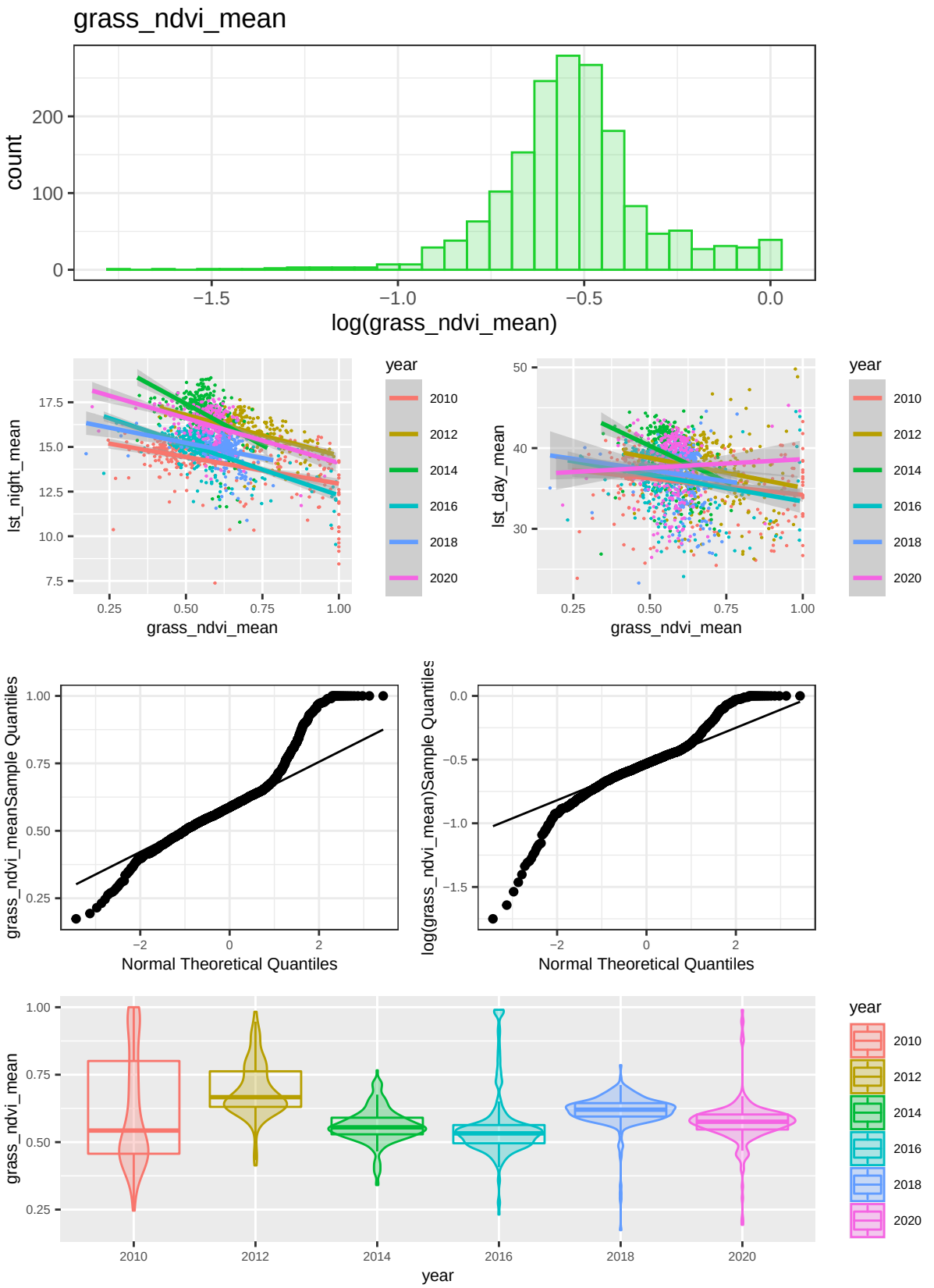
Google Earth: Random Forest Model

Tree NDVI Max



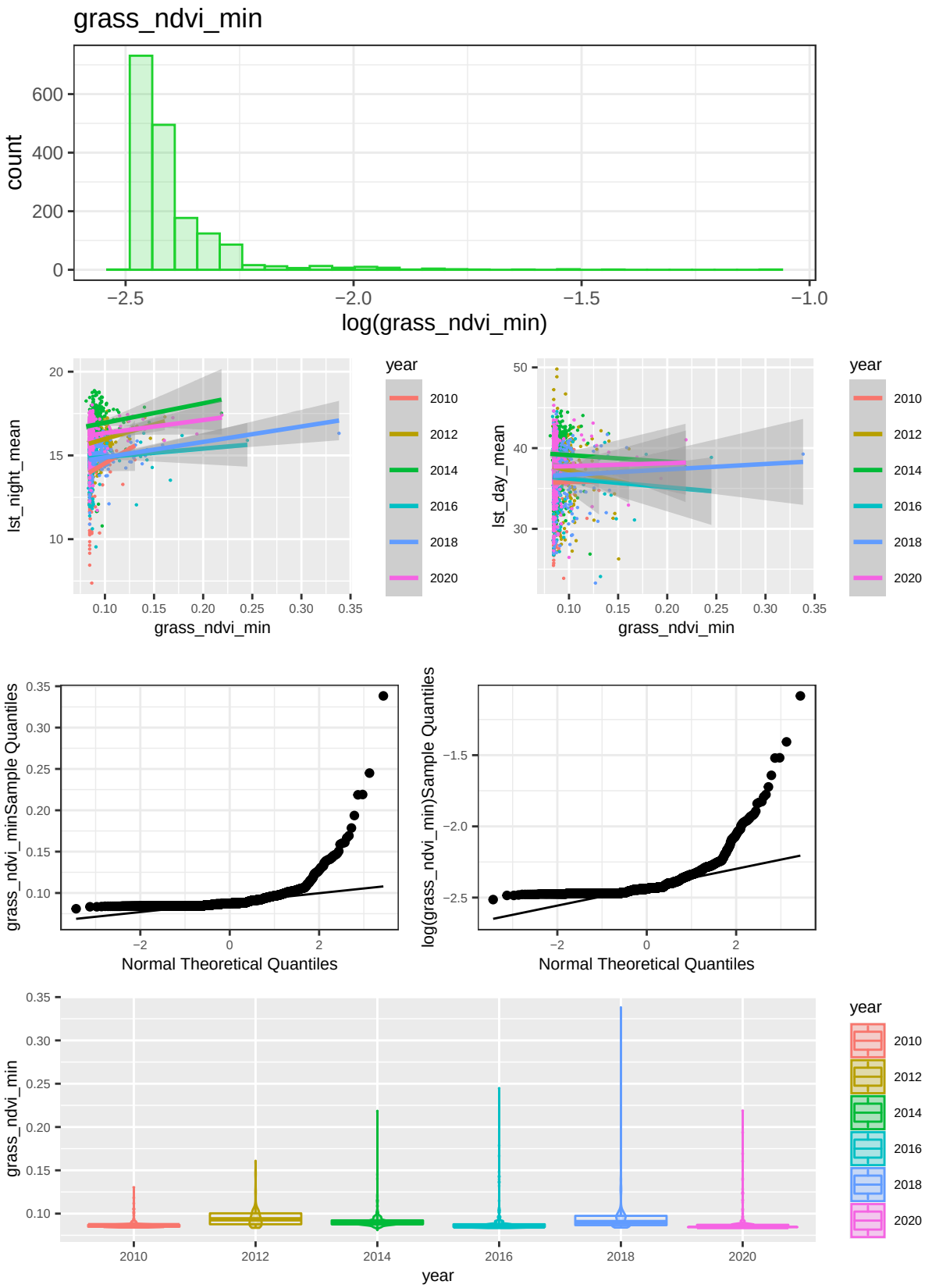
Google Earth: Random Forest Model

Lawn NDVI Mean



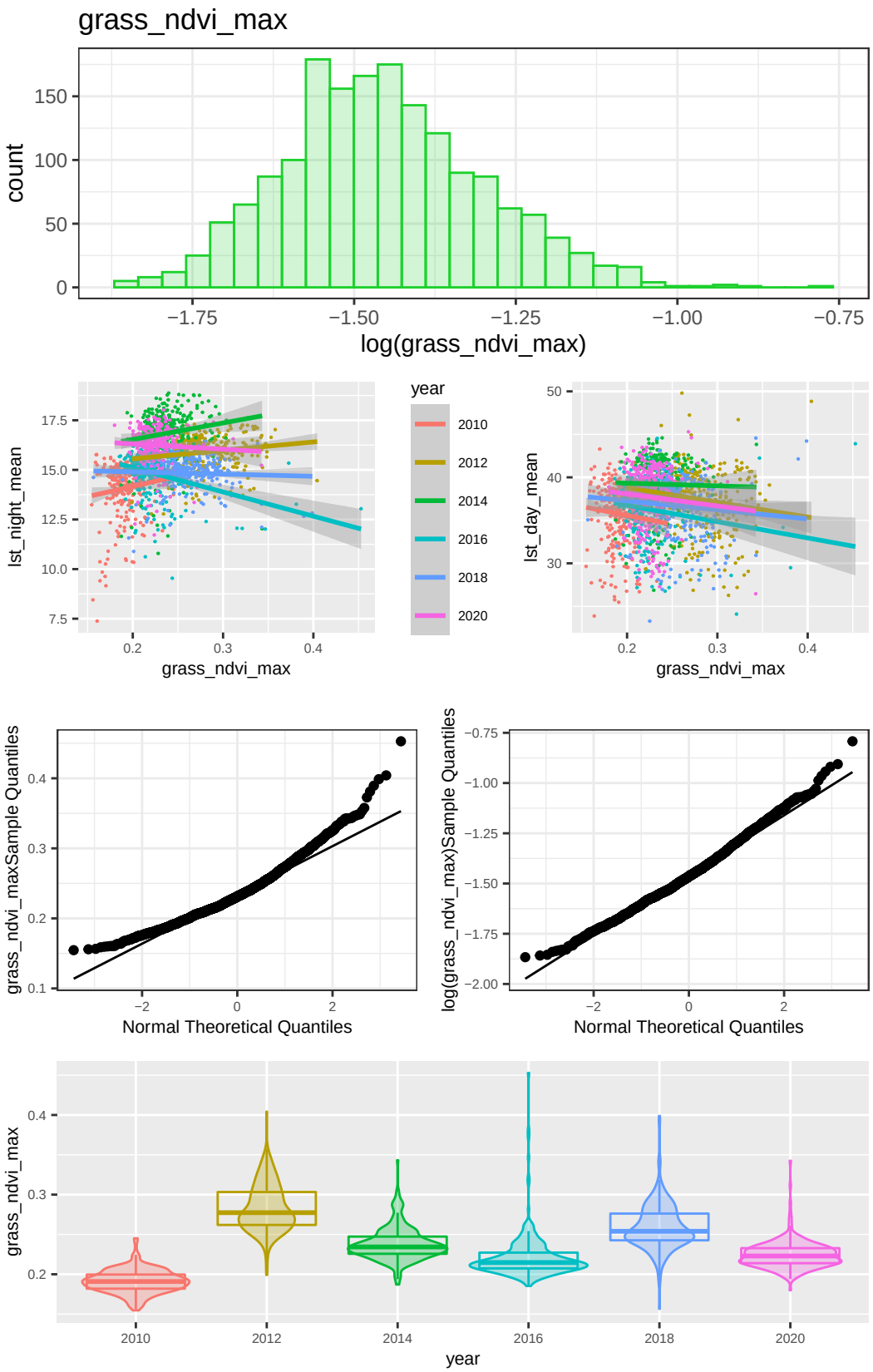
Google Earth: Random Forest Model

Lawn NDVI Min



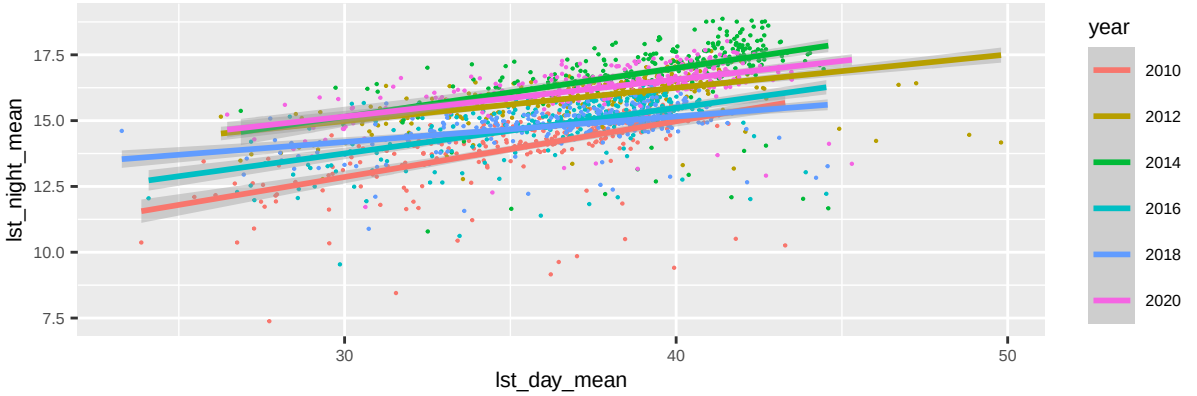
Google Earth: Random Forest Model

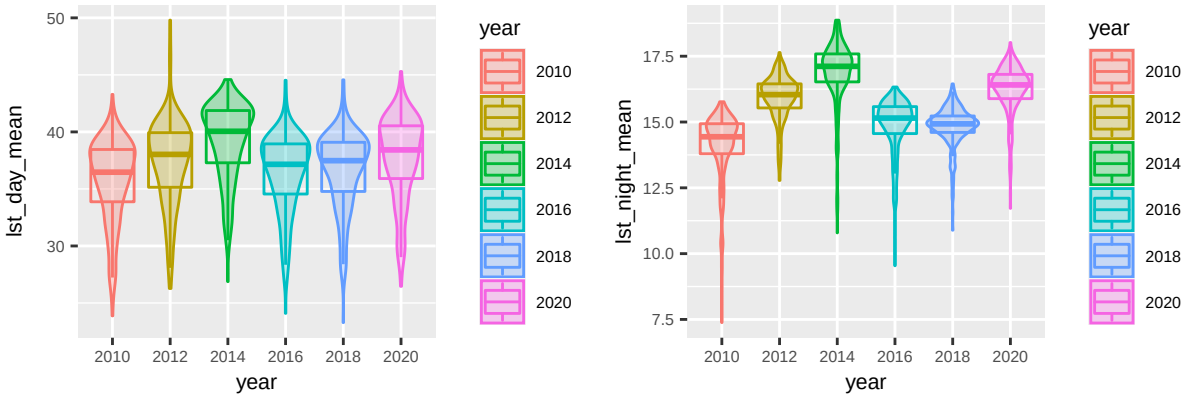
Lawn NDVI Max

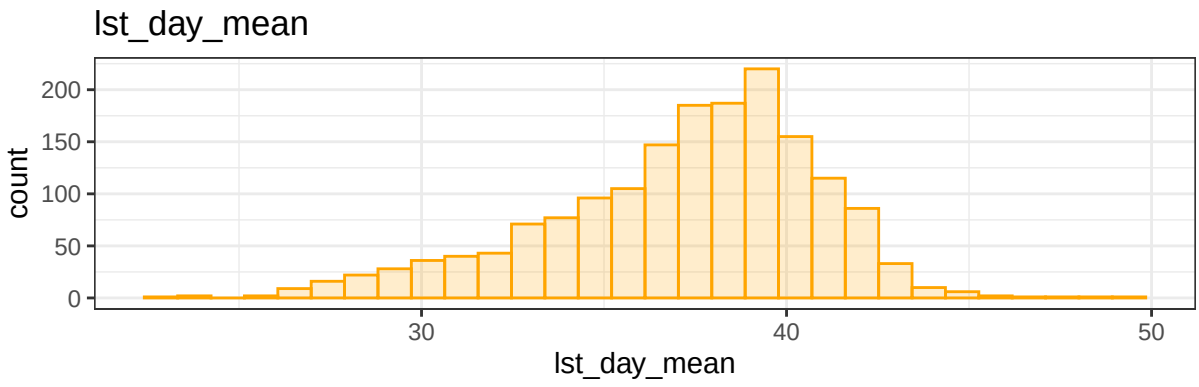


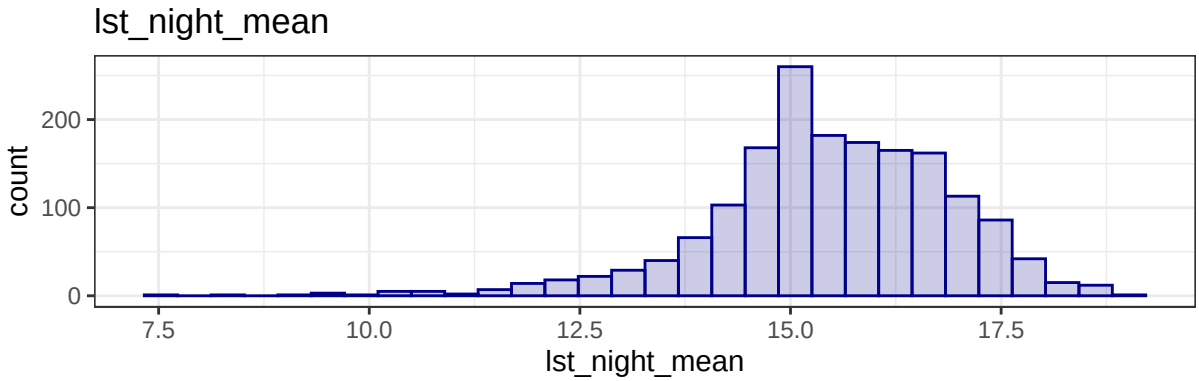
Google Earth: Random Forest Model

Mean Temperature









Google Earth: Random Forest Model

Create MicroClimate Panel Data Set

```
data <- subset(data, subset = year > 2012)

# Create panel dataframe object
microClimatePanel <- pdata.frame(data, index=c("zipcode", "year"))
```

First Attempt with Traditional OLS Model

```
OLSM1 <- lm(
  log(lst_day_mean) ~ 0 + factor(year) + tree_area + lawn_area + water_area + soil_area +
    turf_area + grass_ndvi_mean + tree_ndvi_mean,
  data = microClimatePanel)

stargazer::stargazer(OLSM1, single.row = TRUE, title = 'OLS Model')
```

% Table created by stargazer v.5.2.3 by Marek Hlavac, Social Policy Institute. E-mail: marek.hlavac at gmail.com % Date and time: Tue, Jul 26, 2022 - 9:35:29 PM

Table 1: OLS Model

	Dependent variable:
	log(lst_day_mean)
factor(year)2014	3.784*** (0.023)
factor(year)2016	3.729*** (0.020)
factor(year)2018	3.720*** (0.022)
factor(year)2020	3.795*** (0.021)
tree_area	−0.348*** (0.018)
lawn_area	0.051 (0.051)
water_area	0.051 (0.213)
soil_area	−0.020 (0.047)
turf_area	−0.560 (0.544)
grass_ndvi_mean	−0.191*** (0.062)
tree_ndvi_mean	0.067 (0.064)
Observations	1,132
R^2	0.999
Adjusted R^2	0.999
Residual Std. Error	0.083 (df = 1121)
F Statistic	196,731.300*** (df = 11; 1121)
Note:	*p<0.1; **p<0.05; ***p<0.01

Second Attempt with a Mixed Effects Model

```
feM1 <- plm(
  log(lst_day_mean) ~ 0 + factor(year) + tree_area + lawn_area + water_area + soil_area +
    turf_area + grass_ndvi_mean + tree_ndvi_mean,
  index = c(zipcode, year), data = microClimatePanel, model = 'within')

stargazer::stargazer(feM1, single.row = TRUE, title = 'Fixed Effects Model')
```

% Table created by stargazer v.5.2.3 by Marek Hlavac, Social Policy Institute. E-mail: marek.hlavac at gmail.com % Date and time: Tue, Jul 26, 2022 - 9:35:29 PM

Table 2: Fixed Effects Model

	Dependent variable:
	log(lst_day_mean)
factor(year)2014	0.041^{***} (0.002)
factor(year)2016	-0.040^{***} (0.002)
factor(year)2018	-0.032^{***} (0.002)
tree_area	-0.052^{***} (0.012)
lawn_area	-0.065^{***} (0.020)
water_area	-0.168^{***} (0.052)
soil_area	0.042^{***} (0.016)
turf_area	0.096 (0.123)
grass_ndvi_mean	0.042^{**} (0.016)
tree_ndvi_mean	0.009 (0.015)
Observations	1,132
R^2	0.824
Adjusted R^2	0.762
F Statistic	391.058^{***} (df = 10; 837)
Note:	*p<0.1; **p<0.05; ***p<0.01

Compare Performance of OLS vs Mixed Effects Models

```
pFtest(feM1, OLSM1)
```

```
##
##  F test for individual effects
##
## data:  log(lst_day_mean) ~ 0 + factor(year) + tree_area + lawn_area +  ...
## F = 98.484, df1 = 284, df2 = 837, p-value < 2.2e-16
## alternative hypothesis: significant effects
```

```
## Fixed effects is a better choice than OLS
```

Fixed Effects is a Better Choice, Discard OLS Model

Try a Random Effects Model

```
reM1 <- plm(
  log(lst_day_mean) ~ 0 + tree_area + lawn_area + water_area + soil_area +
    turf_area + grass_ndvi_mean + tree_ndvi_mean,
  index = c(zipcode, year), data = microClimatePanel, model = 'random')

stargazer::stargazer(reM1, single.row = TRUE, title = 'Random Effects Model')
```

% Table created by stargazer v.5.2.3 by Marek Hlavac, Social Policy Institute. E-mail: marek.hlavac at gmail.com % Date and time: Tue, Jul 26, 2022 - 9:35:30 PM

Table 3: Random Effects Model

	Dependent variable:
	log(lst_day_mean)
tree_area	0.447*** (0.086)
lawn_area	0.981*** (0.162)
water_area	1.146*** (0.434)
soil_area	0.342*** (0.118)
turf_area	1.107 (1.093)
grass_ndvi_mean	0.333*** (0.114)
tree_ndvi_mean	0.853*** (0.105)
Observations	1,132
R^2	0.107
Adjusted R^2	0.102
F Statistic	450.366***
Note:	*p<0.1; **p<0.05; ***p<0.01

Compare Performance of Mixed Effects vs Random Effects Models

```
phtest(feM1, reM1)
```

```
##
##  Hausman Test
##
```

```
## data:  log(lst_day_mean) ~ 0 + factor(year) + tree_area + lawn_area +  ...
## chisq = 452.91, df = 7, p-value < 2.2e-16
## alternative hypothesis: one model is inconsistent
```

```
## the p-value is significant so we choose fixed effects
## (since the unique errors are correlated with the regressors).
```

the p-value is significant so we choose fixed effects (since the unique errors are correlated with the regressors). There is omitted variable bias at the higher level that the RE model has not accounted for (but the FE model has).

Try a Fixed Effects Model with Fixed Time

```
feM2FixedTime <- plm(
  log(lst_day_mean) ~ 0 + tree_area + lawn_area + water_area + soil_area +
    turf_area + grass_ndvi_mean + tree_ndvi_mean,
  index = c(zipcode, year), data = microClimatePanel, model = 'within')

stargazer::stargazer(feM2FixedTime, single.row = TRUE)
```

% Table created by stargazer v.5.2.3 by Marek Hlavac, Social Policy Institute. E-mail: marek.hlavac at gmail.com % Date and time: Tue, Jul 26, 2022 - 9:35:30 PM

Table 4:

	Dependent variable:
	log(lst_day_mean)
tree_area	0.064*** (0.017)
lawn_area	0.203*** (0.032)
water_area	0.685*** (0.085)
soil_area	−0.026 (0.023)
turf_area	0.190 (0.214)
grass_ndvi_mean	−0.368*** (0.023)
tree_ndvi_mean	0.386*** (0.021)
Observations	1,132
R^2	0.431
Adjusted R^2	0.235
F Statistic	91.079*** (df = 7; 840)
Note:	*p<0.1; **p<0.05; ***p<0.01

```
pFtest(feM1,feM2FixedTime)
```

```
##
##  F test for individual effects
##
## data:  log(lst_day_mean) ~ 0 + factor(year) + tree_area + lawn_area +  ...
## F = 620.68, df1 = 3, df2 = 837, p-value < 2.2e-16
## alternative hypothesis: significant effects
```

```
plmtest(feM1, effect="time", type="bp")
```

```
##
##  Lagrange Multiplier Test - time effects (Breusch-Pagan) for unbalanced
##  panels
##
## data:  log(lst_day_mean) ~ 0 + factor(year) + tree_area + lawn_area +  ...
## chisq = 2.0071, df = 1, p-value = 0.1566
## alternative hypothesis: significant effects
```

```
pbgtest(feM1)
```

```
##
##  Breusch-Godfrey/Wooldridge test for serial correlation in panel models
##
## data:  log(lst_day_mean) ~ 0 + factor(year) + tree_area + lawn_area +  ...
## chisq = 55.205, df = 1, p-value = 1.086e-13
## alternative hypothesis: serial correlation in idiosyncratic errors
```

```
coeftest(feM1, vcovHC)
```

```
##
## t test of coefficients:
##
##                    Estimate Std. Error  t value  Pr(>|t|)
## factor(year)2014  0.0409630  0.0023898  17.1407 < 2.2e-16 ***
## factor(year)2016 -0.0402422  0.0018599 -21.6370 < 2.2e-16 ***
## factor(year)2018 -0.0319612  0.0024204 -13.2048 < 2.2e-16 ***
## tree_area        -0.0523011  0.0148201  -3.5291 0.0004398 ***
## lawn_area        -0.0652285  0.0286661  -2.2755 0.0231304 *
## water_area       -0.1679960  0.0413353  -4.0642 5.273e-05 ***
## soil_area         0.0422364  0.0197583   2.1377 0.0328339 *
## turf_area         0.0956626  0.0533841   1.7920 0.0734991 .
## grass_ndvi_mean   0.0417854  0.0165033   2.5319 0.0115249 *
## tree_ndvi_mean    0.0090166  0.0162302   0.5555 0.5786732
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
coeftest(feM1, vcovHC(feM1, method = "arellano"))
```

```
##
## t test of coefficients:
##
##                     Estimate Std. Error  t value  Pr(>|t|)
## factor(year)2014  0.0409630  0.0023898  17.1407 < 2.2e-16 ***
## factor(year)2016 -0.0402422  0.0018599 -21.6370 < 2.2e-16 ***
## factor(year)2018 -0.0319612  0.0024204 -13.2048 < 2.2e-16 ***
## tree_area        -0.0523011  0.0148201  -3.5291 0.0004398 ***
## lawn_area        -0.0652285  0.0286661  -2.2755 0.0231304 *
## water_area       -0.1679960  0.0413353  -4.0642 5.273e-05 ***
## soil_area         0.0422364  0.0197583   2.1377 0.0328339 *
## turf_area         0.0956626  0.0533841   1.7920 0.0734991 .
## grass_ndvi_mean   0.0417854  0.0165033   2.5319 0.0115249 *
## tree_ndvi_mean    0.0090166  0.0162302   0.5555 0.5786732
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
t(sapply(c("HC0", "HC1", "HC2", "HC3", "HC4"), function(x) sqrt(diag(vcovHC(feM1, method = "are
```

```
##     factor(year)2014 factor(year)2016 factor(year)2018  tree_area  lawn_area
## HC0      0.002389807      0.001859880      0.002420429 0.01482012 0.02866607
## HC1      0.002400433      0.001868150      0.002431191 0.01488601 0.02879354
## HC2      0.002415570      0.001877275      0.002443308 0.01507436 0.02923489
## HC3      0.002443217      0.001896080      0.002467702 0.01533764 0.02982467
## HC4      0.002489705      0.001926482      0.002505385 0.01578775 0.03091299
##     water_area  soil_area  turf_area grass_ndvi_mean tree_ndvi_mean
## HC0 0.04133528 0.01975830 0.05338408      0.01650326     0.01623023
## HC1 0.04151907 0.01984615 0.05362145      0.01657664     0.01630240
## HC2 0.04171210 0.02009951 0.05666708      0.01668467     0.01640315
## HC3 0.04209604 0.02045095 0.06370743      0.01687048     0.01657960
## HC4 0.04238859 0.02103423 0.10820002      0.01708566     0.01677279
```

```r
totalRobust <- coeftest(feM1, vcov = vcovHC(feM1, type = 'HC0'))
cInterval <- coefci(feM1, vcov. = vcovHC(feM1, type = 'HC0'))
```

```r
print(totalRobust)
```

```
##
## t test of coefficients:
##
##                     Estimate Std. Error  t value  Pr(>|t|)
## factor(year)2014  0.0409630  0.0023898  17.1407 < 2.2e-16 ***
## factor(year)2016 -0.0402422  0.0018599 -21.6370 < 2.2e-16 ***
```

```
## factor(year)2018 -0.0319612  0.0024204 -13.2048 < 2.2e-16 ***
## tree_area        -0.0523011  0.0148201  -3.5291 0.0004398 ***
## lawn_area        -0.0652285  0.0286661  -2.2755 0.0231304 *
## water_area       -0.1679960  0.0413353  -4.0642 5.273e-05 ***
## soil_area         0.0422364  0.0197583   2.1377 0.0328339 *
## turf_area         0.0956626  0.0533841   1.7920 0.0734991 .
## grass_ndvi_mean   0.0417854  0.0165033   2.5319 0.0115249 *
## tree_ndvi_mean    0.0090166  0.0162302   0.5555 0.5786732
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
print(cInterval)
```

```
##                           2.5 %       97.5 %
## factor(year)2014  0.036272319  0.045653756
## factor(year)2016 -0.043892796 -0.036591641
## factor(year)2018 -0.036712032 -0.027210386
## tree_area        -0.081390018 -0.023212103
## lawn_area        -0.121494335 -0.008962668
## water_area       -0.249128985 -0.086863039
## soil_area         0.003454781  0.081018044
## turf_area        -0.009119798  0.200445000
## grass_ndvi_mean   0.009392787  0.074178055
## tree_ndvi_mean   -0.022840181  0.040873298
```

```
stargazer::stargazer(OLSM1,feM1,reM1,feM2FixedTime,
                     font.size = 'tiny',
                     title = 'Regression Models Sumamry',
                     column.labels = c("OLS", "FixedEffects",
                                       "RandomEffects",
                                       "FixedEffectsFixedTime"))
```

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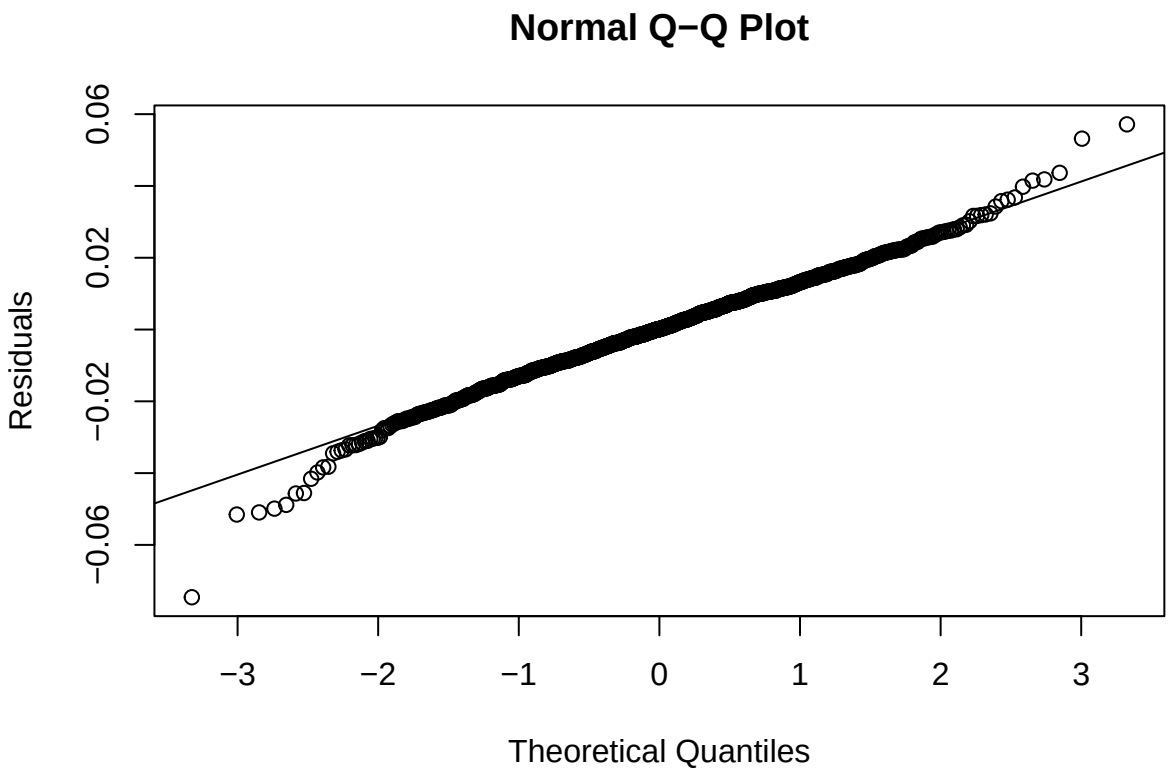
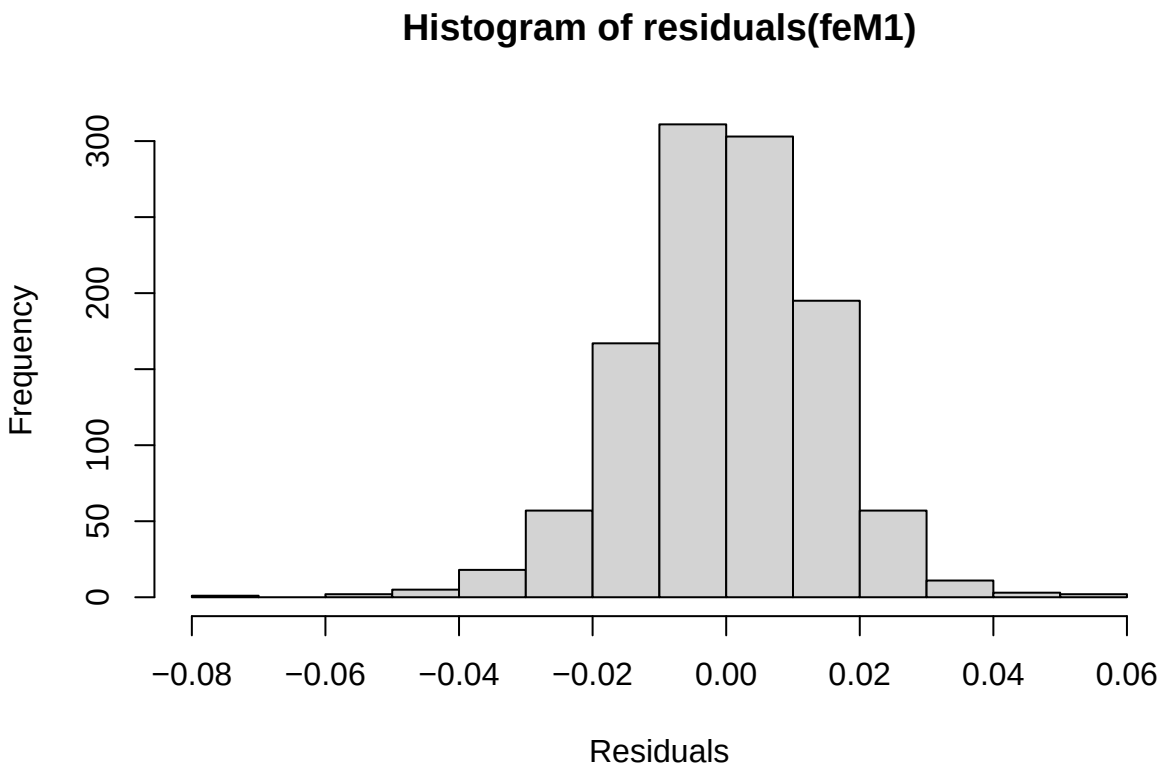
```
qqnorm(residuals(feM1), ylab = 'Residuals')
qqline(residuals(feM1))
```

Table 5: Regression Models Sumamry

	Dependent variable:			
	log(lst_day_mean)			
	OLS		*panel linear*	
	OLS	FixedEffects	RandomEffects	FixedEffectsFixedTime
	(1)	(2)	(3)	(4)
factor(year)2014	3.784***	0.041***		
	(0.023)	(0.002)		
factor(year)2016	3.729***	−0.040***		
	(0.020)	(0.002)		
factor(year)2018	3.720***	−0.032***		
	(0.022)	(0.002)		
factor(year)2020	3.795***			
	(0.021)			
tree_area	−0.348***	−0.052***	0.447***	0.064***
	(0.018)	(0.012)	(0.086)	(0.017)
lawn_area	0.051	−0.065***	0.981***	0.203***
	(0.051)	(0.020)	(0.162)	(0.032)
water_area	0.051	−0.168***	1.146***	0.685***
	(0.213)	(0.052)	(0.434)	(0.085)
soil_area	−0.020	0.042***	0.342***	−0.026
	(0.047)	(0.016)	(0.118)	(0.023)
turf_area	−0.560	0.096	1.107	0.190
	(0.544)	(0.123)	(1.093)	(0.214)
grass_ndvi_mean	−0.191***	0.042**	0.333***	−0.368***
	(0.062)	(0.016)	(0.114)	(0.023)
tree_ndvi_mean	0.067	0.009	0.853***	0.386***
	(0.064)	(0.015)	(0.105)	(0.021)
Observations	1,132	1,132	1,132	1,132
R^2	0.999	0.824	0.107	0.431
Adjusted R^2	0.999	0.762	0.102	0.235
Residual Std. Error	0.083 (df = 1121)			
F Statistic	196,731.300*** (df = 11; 1121)	391.058*** (df = 10; 837)	450.366***	91.079*** (df = 7; 840)
Note:				*p<0.1; **p<0.05; ***p<0.01




```
hist(residuals(feM1), xlab = 'Residuals')
```


Histogram of residuals(feM1)
Frequency
0
50
100
200
300
−0.08
−0.06
−0.04
−0.02
0.00
0.02
0.04
0.06
Residuals