

Maladaptive plastic responses of flowering time to geothermal heating (Cerastium 2)

Logger data preparation

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Read list of all plants with temperature measured in 2018 (including Cerastium and other species)

```
ids_temp_allsp<-read.table("data/edited/ids_temp_allsp.csv",
                           header=T,sep=",",dec=".")
ids_temp_allsp$temp_term<-ids_temp_allsp$temp
ids_temp_allsp$temp<-NULL
head(ids_temp_allsp)
```

```
##  plot id species plot_type temp_term
## 1  H01 H1      cer         H      19.7
## 2  H01 H3      cer         H      29.0
## 3  H01 H4      cer         H      20.0
## 4  H01 H5      cer         H      25.0
## 5  H01 H6      cer         H      27.5
## 6  H01 H7      cer         H      28.7
```

temp_term = soil temperature measured with a thermometer at the time of marking in 2018, measured next to each plant at a depth of 10 cm.

Read list of plants with loggers (including Cerastium and other species)

```
loggers<-read.table("data/edited/ibuttons_AV_allsp.csv",
  header=T,sep="," ,dec=".")
head(loggers)
```

```
##  logger_nr above_below id species sunken
## 1         3          B H1949   bis      0
## 2        18          B H1965   bis      0
## 3        20          B H1969   bis      0
## 4        21          B H1972   bis      0
## 5        28          B H1962   bis      0
## 6        51          B H1958   bis      0
```

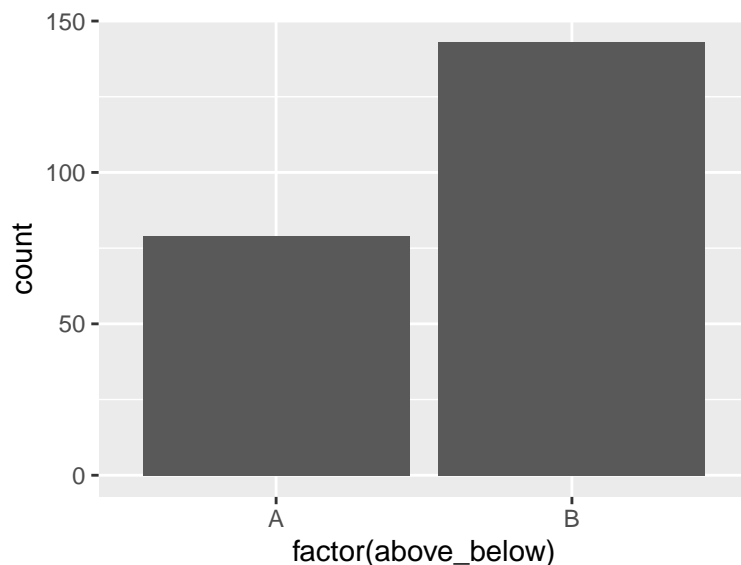
Merge both

Keeping records in both lists (i.e. plants with temperature measured with thermometer and with a logger).

```
temp_loggers<-ids_temp_allsp%>%
  inner_join(loggers)
head(temp_loggers)
```

```
##  plot id species plot_type temp_term logger_nr above_below sunken
## 1 H01 H1   cer         H    19.7       273          A      0
## 2 H01 H4   cer         H    20.0       266          B      0
## 3 H01 H13  cer         H    19.4       268          B      0
## 4 H01 H16  cer         H    20.4       267          B      0
## 5 H01 H17  cer         H    21.0       274          A      0
## 6 H01 H20  cer         H    15.0       270          B      0
```

```
ggplot(temp_loggers,aes(x=factor(above_below)))+geom_bar()
```



79 above and 143 below.

Import raw iButton data

```
all_logger_data <- list()
for(filename in list.files("data/edited/RAW_iButton_data_to_use",
  full.names=T)) {
  all_logger_data[[length(all_logger_data) + 1]] <- read.table(filename,
    header=T,fill=T,sep=" ",
    dec=" ",skip=14)
  all_logger_data[[length(all_logger_data)]]$logger_nr <- substr(filename,
    start=37,
    stop=100)
}
logger_data <- do.call(rbind, all_logger_data)%>%
  rownames_to_column("datetime")%>%
  rename(unit=Date.Time,value_int=Unit,value_dec=Value)
logger_data<-logger_data[c(1,3:5)]%>%
  mutate(temp=as.numeric(ifelse(is.na(value_dec),
    value_int,
    paste(value_int,value_dec,sep="."))))
logger_data<-logger_data[c(1,4:5)]%>%
  mutate(datetime=as.POSIXct(logger_data$datetime,
    format="%d.%m.%Y %H:%M:%S",tz=Sys.timezone()))
logger_data<-logger_data%>%
  mutate(datetime=datetime %m+% years(1))%>%
  # Add one year to dates, as they were wrong - CHECK SOME CASES WERE NOT!
  mutate(logger_nr=as.numeric(gsub(".csv","",logger_nr)))

# Read individually some files that gave problems
log339<-read.table("data/edited/RAW_iButton_data_to_use_problematic/339.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log344<-read.table("data/edited/RAW_iButton_data_to_use_problematic/344.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log352<-read.table("data/edited/RAW_iButton_data_to_use_problematic/352.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log383<-read.table("data/edited/RAW_iButton_data_to_use_problematic/383.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log431<-read.table("data/edited/RAW_iButton_data_to_use_problematic/431.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log585<-read.table("data/edited/RAW_iButton_data_to_use_problematic/585.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log641<-read.table("data/edited/RAW_iButton_data_to_use_problematic/641.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log654<-read.table("data/edited/RAW_iButton_data_to_use_problematic/654.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log663<-read.table("data/edited/RAW_iButton_data_to_use_problematic/663.csv",
  header=T,fill=T,sep=" ",dec=" ",skip=14)
log339$logger_nr<-339
log344$logger_nr<-344
log352$logger_nr<-352
```

```

log383$logger_nr<-383
log431$logger_nr<-431
log585$logger_nr<-585
log641$logger_nr<-641
log654$logger_nr<-654
log663$logger_nr<-663

logger_data_problematic<-rbind(log339,log344,log352,log383,log431,
                               log585,log641,log654,log663)
logger_data_problematic<-logger_data_problematic%>%
  rename(datetime=Date.Time)%>%
  mutate(temp=as.numeric(ifelse(is.na(value_dec),
                                value_int,
                                paste(value_int,value_dec,sep="."))))
logger_data_problematic<-logger_data_problematic[c(1,5:6)]%>%
  mutate(datetime=as.POSIXct(logger_data_problematic$datetime,
                              format="%d.%m.%Y %H:%M:%S",
                              tz=Sys.timezone()))%>%
  mutate(datetime=datetime %m+% years(1))
  # Add one year to dates, as they were wrong - CHECK SOME CASES WERE NOT!

logger_data<-rbind(logger_data,logger_data_problematic)%>%
  inner_join(temp_loggers)
head(logger_data)

```

```

##           datetime logger_nr temp plot   id species plot_type temp_term
## 1 2017-09-23 16:34:00      101 23.5  HC1 H848    cer         C         6.1
## 2 2017-09-23 19:34:00      101 23.5  HC1 H848    cer         C         6.1
## 3 2017-09-23 22:34:00      101 22.5  HC1 H848    cer         C         6.1
## 4 2017-09-24 01:34:00      101 20.0  HC1 H848    cer         C         6.1
## 5 2017-09-24 04:34:00      101 20.0  HC1 H848    cer         C         6.1
## 6 2017-09-24 07:34:00      101 19.5  HC1 H848    cer         C         6.1
##   above_below sunken
## 1           B      0
## 2           B      0
## 3           B      0
## 4           B      0
## 5           B      0
## 6           B      0

```

```
nrow(subset(logger_data,is.na(datetime)))
```

```
## [1] 70
```

There are some NAs for datetime (70 rows - it seems that they were not able to be converted to POSIXct)
 -> We can live with those

Read coordinates of loggers and add to data:

```

coords<-read.table("data/edited/coords_AV.csv",
  header=T,sep=" ",dec=".")
logger_data<-logger_data%>%
  left_join(coords)
head(logger_data)

```

```

##      datetime logger_nr temp plot   id species plot_type temp_term
## 1 2017-09-23 16:34:00    101 23.5 HC1 H848    cer      C      6.1
## 2 2017-09-23 19:34:00    101 23.5 HC1 H848    cer      C      6.1
## 3 2017-09-23 22:34:00    101 22.5 HC1 H848    cer      C      6.1
## 4 2017-09-24 01:34:00    101 20.0 HC1 H848    cer      C      6.1
## 5 2017-09-24 04:34:00    101 20.0 HC1 H848    cer      C      6.1
## 6 2017-09-24 07:34:00    101 19.5 HC1 H848    cer      C      6.1
##   above_below sunken   X   Y
## 1           B      0 7.4 5.8
## 2           B      0 7.4 5.8
## 3           B      0 7.4 5.8
## 4           B      0 7.4 5.8
## 5           B      0 7.4 5.8
## 6           B      0 7.4 5.8

```

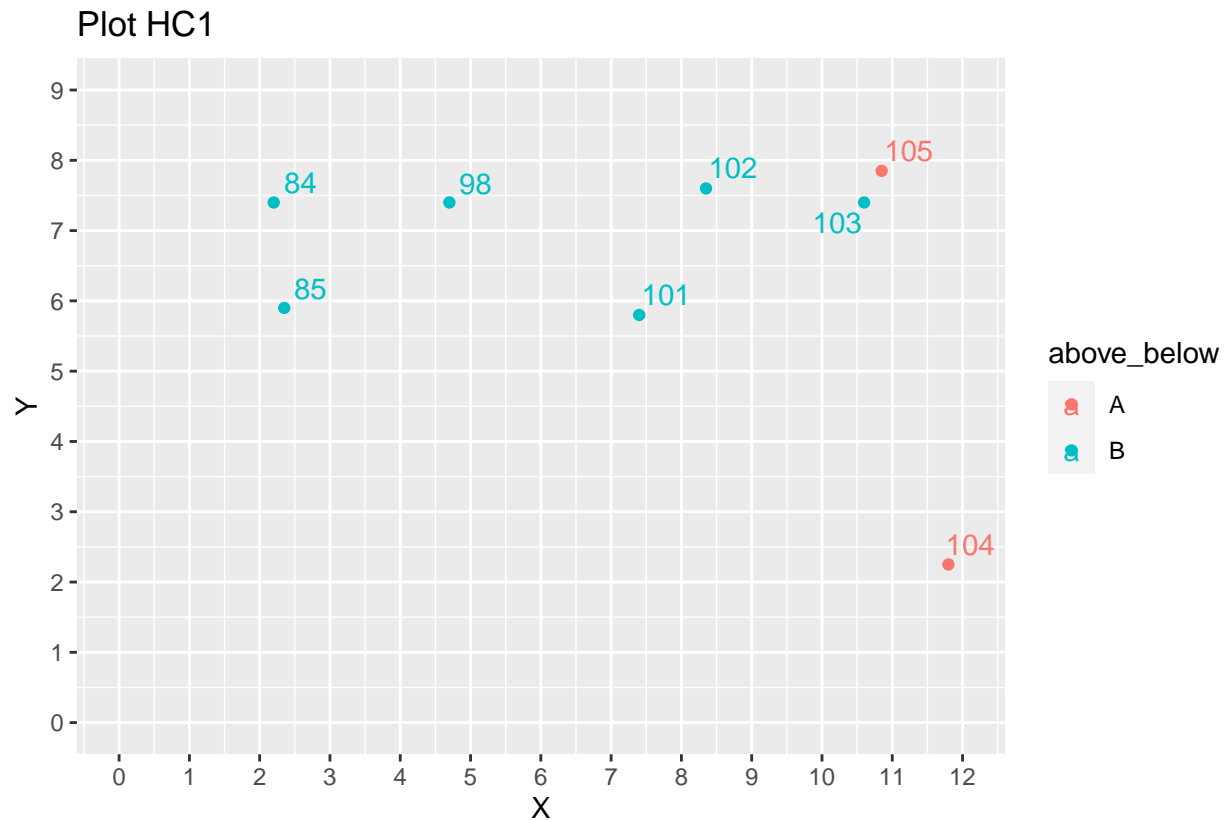
Plot locations of loggers in each plot, calculate distance matrices and make pairs

For each plot, pair each aboveground logger with the closest belowground logger

```

logger_data%>%
  filter(plot=="HC1")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC1")+
  scale_y_continuous(breaks = seq(0,13,by=1)) +
  scale_x_continuous(breaks = seq(0,13,by=1)) +
  coord_fixed(ylim=c(0, 9),xlim=c(0, 12))

```



Distance matrix:

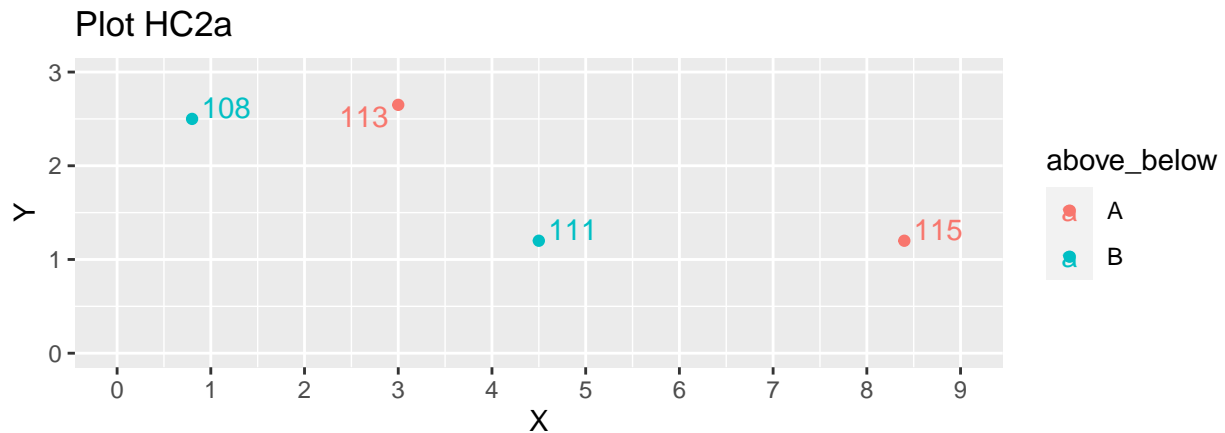
```
logger_data%>%
  filter(plot=="HC1")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      84    85    98   101   102   103   104   105
## 84   0.00   1.51  2.50  5.44  6.15  8.40 10.89  8.66
## 85   1.51   0.00  2.79  5.05  6.24  8.39 10.13  8.72
## 98   2.50   2.79  0.00  3.14  3.66  5.90  8.77  6.17
## 101  5.44   5.05  3.14  0.00  2.04  3.58  5.65  4.01
## 102  6.15   6.24  3.66  2.04  0.00  2.26  6.37  2.51
## 103  8.40   8.39  5.90  3.58  2.26  0.00  5.29  0.51
## 104 10.89  10.13  8.77  5.65  6.37  5.29  0.00  5.68
## 105  8.66   8.72  6.17  4.01  2.51  0.51  5.68  0.00
```

Pairs: 103-105 and 104-101

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==103|logger_nr==105,1,
                      ifelse(logger_nr==104|logger_nr==101,2,NA)))%>%
  mutate(dist=ifelse(pair==1,0.51,
                     ifelse(pair==2,5.65,NA)))
```

```
logger_data%>%
  filter(plot=="HC2a")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC2a")+
  scale_y_continuous(breaks = seq(0,13,by=1)) +
  scale_x_continuous(breaks = seq(0,13,by=1)) +
  coord_fixed(ylim=c(0, 3),xlim=c(0, 9))
```



Distance matrix:

```
logger_data%>%
  filter(plot=="HC2a")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
```

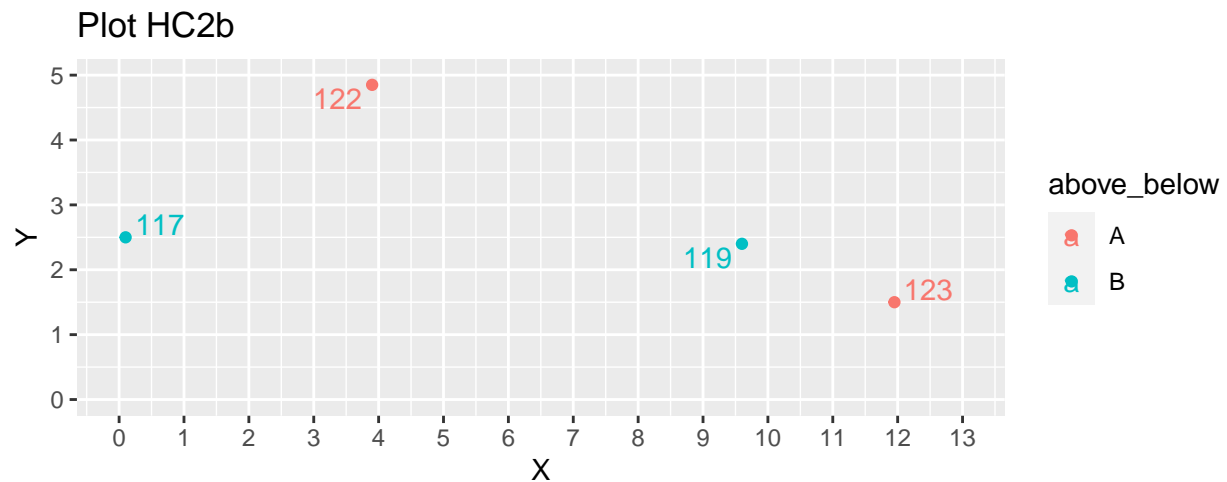
```
# as.data.frame()%>%
# rownames_to_column(var="logger_nr")%>%
# pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
round(digits=2)
```

```
##      108  111  113  115
## 108 0.00 3.92 2.21 7.71
## 111 3.92 0.00 2.09 3.90
## 113 2.21 2.09 0.00 5.59
## 115 7.71 3.90 5.59 0.00
```

Pairs: 108-113 and 111-115

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==108|logger_nr==113,3,
                     ifelse(logger_nr==111|logger_nr==115,4,pair)))%>%
  mutate(dist=ifelse(pair==3,2.21,
                     ifelse(pair==4,3.90,dist)))
```

```
logger_data%>%
  filter(plot=="HC2b")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC2b")+
  scale_y_continuous(breaks = seq(0,13,by=1)) +
  scale_x_continuous(breaks = seq(0,13,by=1)) +
  coord_fixed(ylim=c(0, 5),xlim=c(0, 13))
```

Distance matrix:

```
logger_data%>%
  filter(plot=="HC2b")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

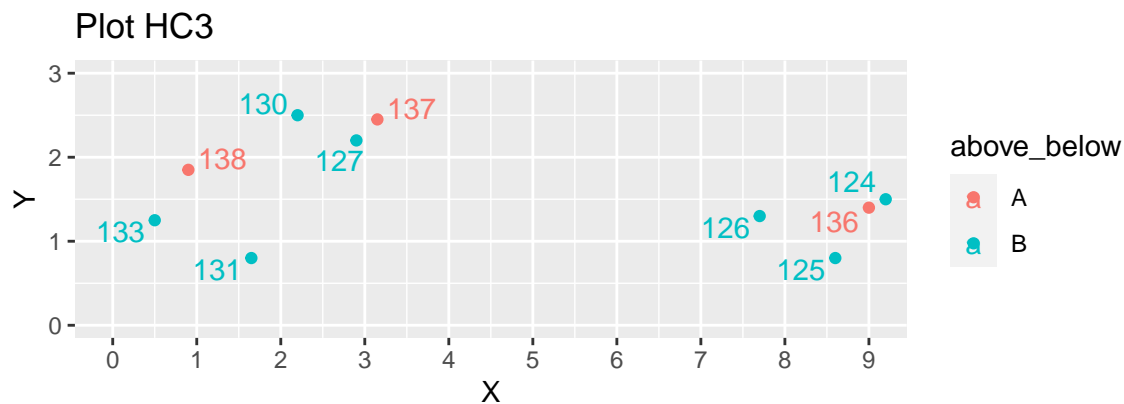
```
##      117  119  122  123
## 117  0.00 9.50 4.47 11.89
## 119  9.50 0.00 6.20  2.52
## 122  4.47 6.20 0.00  8.72
## 123 11.89 2.52 8.72  0.00
```

Pairs: 122-117 and 119-123

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==122|logger_nr==117,5,
    ifelse(logger_nr==119|logger_nr==123,6,pair)))%>%
```

```
mutate(dist=ifelse(pair==5,4.47,
  ifelse(pair==6,2.52,dist)))
```

```
logger_data%>%
  filter(plot=="HC3")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC3")+
  scale_y_continuous(breaks = seq(0,13,by=1)) +
  scale_x_continuous(breaks = seq(0,13,by=1)) +
  coord_fixed(ylim=c(0, 3),xlim=c(0, 9))
```



Distance matrix:

```
logger_data%>%
  filter(plot=="HC3")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
```

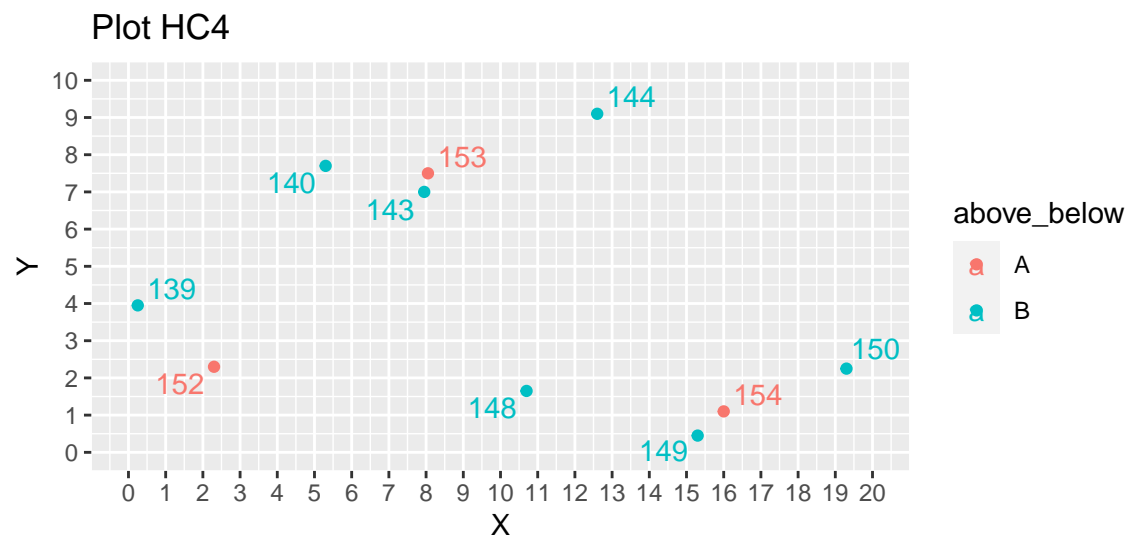
```
# as.data.frame()%>%
# rownames_to_column(var="logger_nr")%>%
# pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
round(digits=2)
```

```
##      124  125  126  127  130  131  133  136  137  138
## 124 0.00 0.92 1.51 6.34 7.07 7.58 8.70 0.22 6.12 8.31
## 125 0.92 0.00 1.03 5.87 6.62 6.95 8.11 0.72 5.69 7.77
## 126 1.51 1.03 0.00 4.88 5.63 6.07 7.20 1.30 4.69 6.82
## 127 6.34 5.87 4.88 0.00 0.76 1.88 2.58 6.15 0.35 2.03
## 130 7.07 6.62 5.63 0.76 0.00 1.79 2.11 6.89 0.95 1.45
## 131 7.58 6.95 6.07 1.88 1.79 0.00 1.23 7.37 2.23 1.29
## 133 8.70 8.11 7.20 2.58 2.11 1.23 0.00 8.50 2.91 0.72
## 136 0.22 0.72 1.30 6.15 6.89 7.37 8.50 0.00 5.94 8.11
## 137 6.12 5.69 4.69 0.35 0.95 2.23 2.91 5.94 0.00 2.33
## 138 8.31 7.77 6.82 2.03 1.45 1.29 0.72 8.11 2.33 0.00
```

Pairs: 137-127, 138-133 and 136-124

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==137|logger_nr==127,7,
                     ifelse(logger_nr==138|logger_nr==133,8,
                             ifelse(logger_nr==136|logger_nr==124,9,pair))))%>%
  mutate(dist=ifelse(pair==7,0.35,
                     ifelse(pair==8,0.72,
                             ifelse(pair==9,0.22,dist))))
```

```
logger_data%>%
  filter(plot=="HC4")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC4")+
  scale_y_continuous(breaks = seq(0,20,by=1)) +
  scale_x_continuous(breaks = seq(0,20,by=1)) +
  coord_fixed(ylim=c(0, 10),xlim=c(0, 20))
```



Distance matrix:

```
logger_data%>%
  filter(plot=="HC4")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

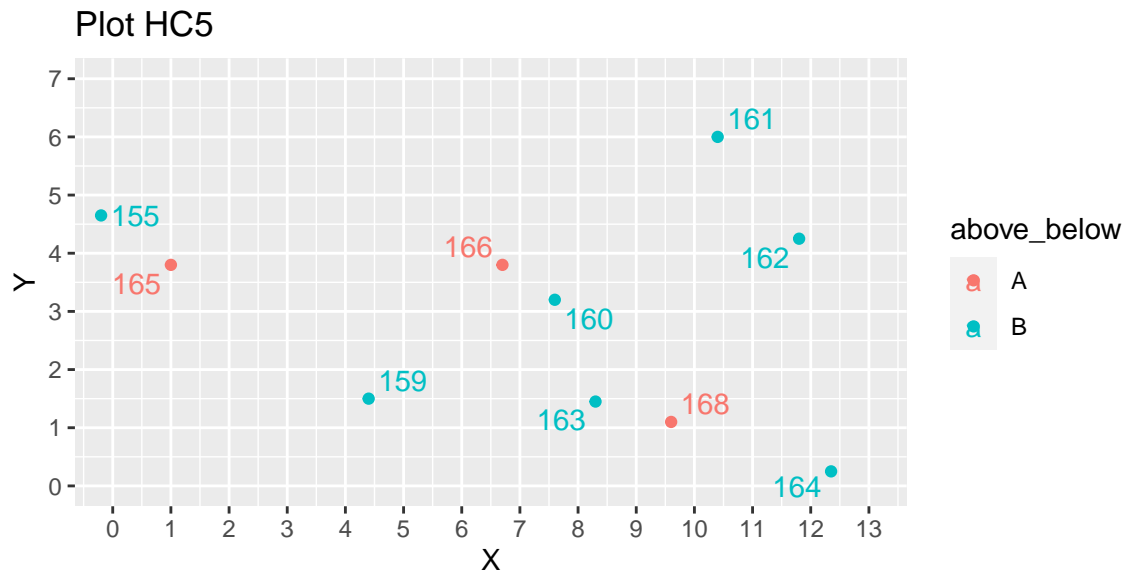
```
##      139   140   143   144   148   149   150   152   153   154
## 139  0.00  6.29  8.28 13.38 10.70 15.45 19.13  2.63  8.57 16.01
## 140  6.29  0.00  2.74  7.43  8.11 12.35 15.02  6.18  2.76 12.57
## 143  8.28  2.74  0.00  5.10  6.02  9.85 12.30  7.35  0.51  9.98
## 144 13.38  7.43  5.10  0.00  7.69  9.06  9.58 12.34  4.82  8.69
## 148 10.70  8.11  6.02  7.69  0.00  4.75  8.62  8.43  6.42  5.33
## 149 15.45 12.35  9.85  9.06  4.75  0.00  4.39 13.13 10.11  0.96
## 150 19.13 15.02 12.30  9.58  8.62  4.39  0.00 17.00 12.41  3.49
## 152  2.63  6.18  7.35 12.34  8.43 13.13 17.00  0.00  7.75 13.75
```

```
## 153  8.57  2.76  0.51  4.82  6.42 10.11 12.41  7.75  0.00 10.21
## 154 16.01 12.57  9.98  8.69  5.33  0.96  3.49 13.75 10.21  0.00
```

Pairs: 139-152, 143-153 and 149-154

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==139|logger_nr==152,10,
                     ifelse(logger_nr==143|logger_nr==153,11,
                           ifelse(logger_nr==149|logger_nr==154,12,pair))))%>%
  mutate(dist=ifelse(pair==10,2.63,
                    ifelse(pair==11,0.51,
                          ifelse(pair==12,0.96,dist))))
```

```
logger_data%>%
  filter(plot=="HC5")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC5")+
  scale_y_continuous(breaks = seq(0,20,by=1)) +
  scale_x_continuous(breaks = seq(0,20,by=1)) +
  coord_fixed(ylim=c(0, 7),xlim=c(0, 13))
```



Distance matrix:

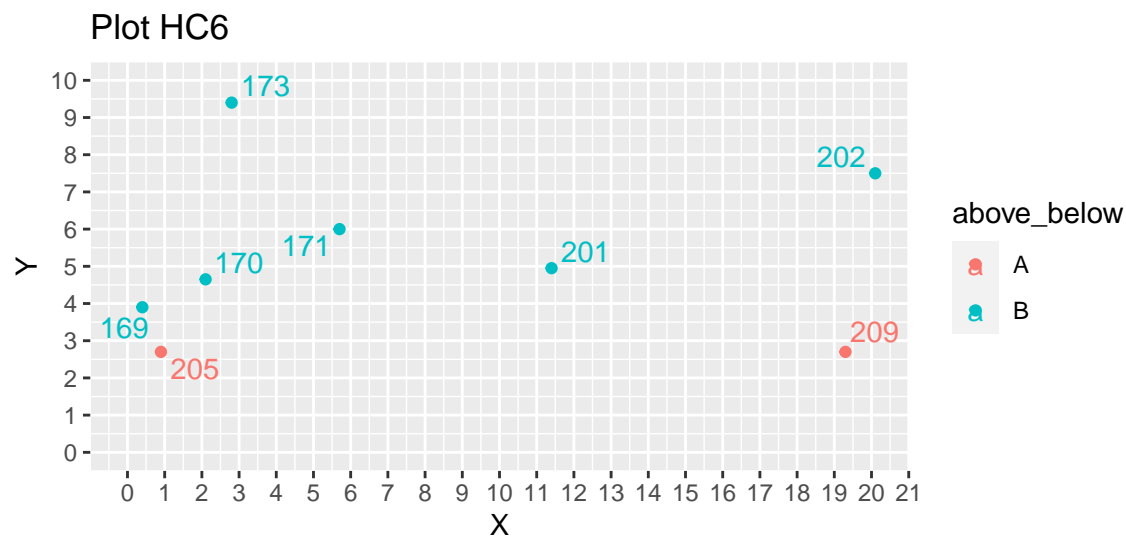
```
logger_data%>%
  filter(plot=="HC5")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      155  159  160  161  162  163  164  165  166  168
## 155  0.00  5.58  7.93 10.69 12.01  9.08 13.30  1.47  6.95 10.42
## 159  5.58  0.00  3.62  7.50  7.89  3.90  8.05  4.10  3.25  5.22
## 160  7.93  3.62  0.00  3.96  4.33  1.88  5.59  6.63  1.08  2.90
## 161 10.69  7.50  3.96  0.00  2.24  5.01  6.07  9.65  4.30  4.96
## 162 12.01  7.89  4.33  2.24  0.00  4.48  4.04 10.81  5.12  3.84
## 163  9.08  3.90  1.88  5.01  4.48  0.00  4.22  7.67  2.84  1.35
## 164 13.30  8.05  5.59  6.07  4.04  4.22  0.00 11.89  6.67  2.88
## 165  1.47  4.10  6.63  9.65 10.81  7.67 11.89  0.00  5.70  9.01
## 166  6.95  3.25  1.08  4.30  5.12  2.84  6.67  5.70  0.00  3.96
## 168 10.42  5.22  2.90  4.96  3.84  1.35  2.88  9.01  3.96  0.00
```

Pairs: 165-155, 166-160 and 168-163

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==165|logger_nr==155,13,
                     ifelse(logger_nr==166|logger_nr==160,14,
                             ifelse(logger_nr==168|logger_nr==163,15,pair))))%>%
  mutate(dist=ifelse(pair==13,1.47,
                     ifelse(pair==14,1.08,
                             ifelse(pair==15,1.35,dist))))
```

```
logger_data%>%
  filter(plot=="HC6")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC6")+
  scale_y_continuous(breaks = seq(0,22,by=1)) +
  scale_x_continuous(breaks = seq(0,22,by=1)) +
  coord_fixed(ylim=c(0, 10),xlim=c(0, 20))
```



Distance matrix:

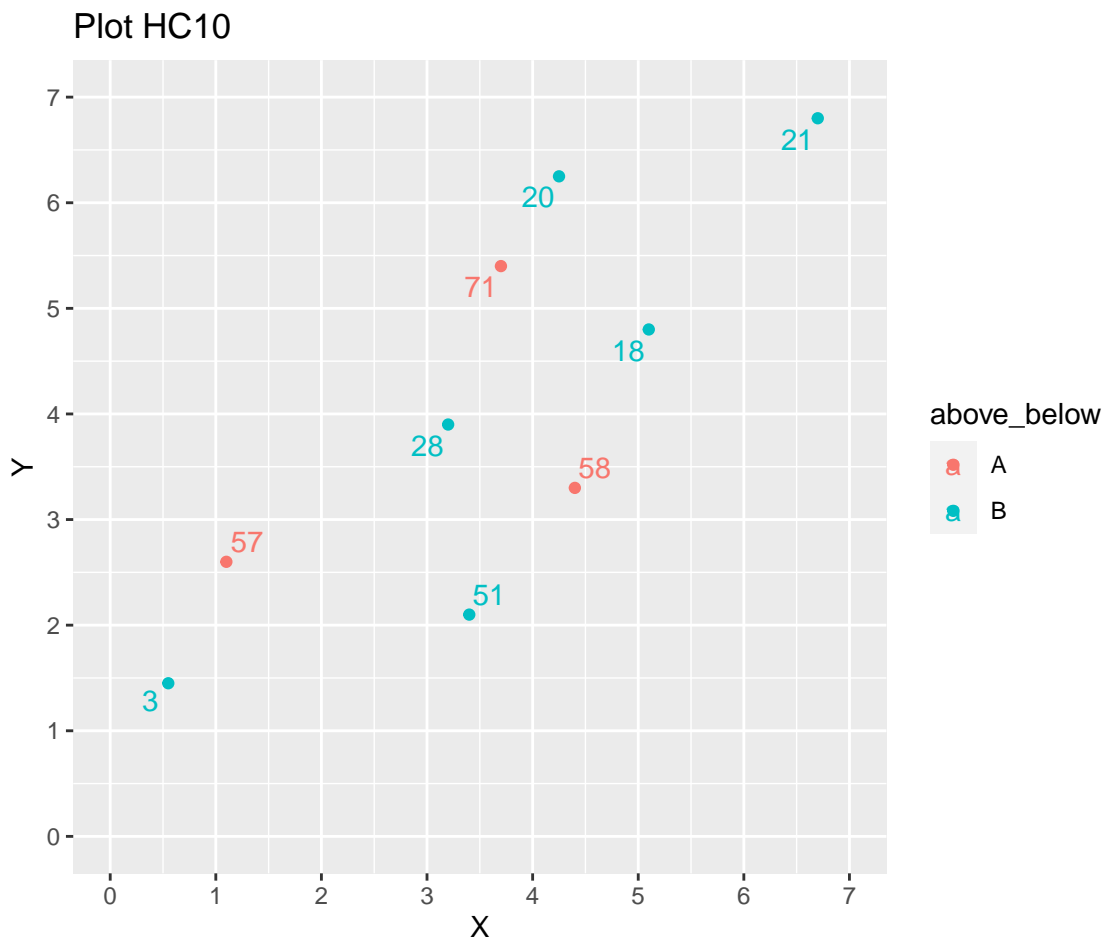
```
logger_data%>%
  filter(plot=="HC6")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      169   170   171   173   201   202   205   209
## 169  0.00  1.86  5.70  6.00 11.05 20.03  1.30 18.94
## 170  1.86  0.00  3.84  4.80  9.30 18.22  2.29 17.31
## 171  5.70  3.84  0.00  4.47  5.80 14.48  5.82 13.99
## 173  6.00  4.80  4.47  0.00  9.68 17.40  6.96 17.81
## 201 11.05  9.30  5.80  9.68  0.00  9.07 10.74  8.21
## 202 20.03 18.22 14.48 17.40  9.07  0.00 19.79  4.87
## 205  1.30  2.29  5.82  6.96 10.74 19.79  0.00 18.40
## 209 18.94 17.31 13.99 17.81  8.21  4.87 18.40  0.00
```

Pairs: 205-169 and 209-202

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==205|logger_nr==169,16,
                     ifelse(logger_nr==209|logger_nr==202,17,pair)))%>%
  mutate(dist=ifelse(pair==16,1.30,
                     ifelse(pair==17,4.87,dist)))
```

```
logger_data%>%
  filter(plot=="HC10")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC10")+
  scale_y_continuous(breaks = seq(0,22,by=1)) +
  scale_x_continuous(breaks = seq(0,22,by=1)) +
  coord_fixed(ylim=c(0, 7),xlim=c(0, 7))
```



Distance matrix:

```
logger_data%>%
  filter(plot=="HC10")%>%
```



```

group_by(logger_nr)%>%
summarise(X=first(X),Y=first(Y))%>%
column_to_rownames(var="logger_nr")%>%
dist()%>%
as.matrix()%>%
# as.data.frame()%>%
# rownames_to_column(var="logger_nr")%>%
# pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
round(digits=2)

```

```

##      3   18   20   21   28   51   57   58   71
## 3  0.00 5.65 6.06 8.15 3.61 2.92 1.27 4.27 5.05
## 18 5.65 0.00 1.68 2.56 2.10 3.19 4.57 1.66 1.52
## 20 6.06 1.68 0.00 2.51 2.57 4.24 4.82 2.95 1.01
## 21 8.15 2.56 2.51 0.00 4.55 5.74 7.00 4.19 3.31
## 28 3.61 2.10 2.57 4.55 0.00 1.81 2.47 1.34 1.58
## 51 2.92 3.19 4.24 5.74 1.81 0.00 2.35 1.56 3.31
## 57 1.27 4.57 4.82 7.00 2.47 2.35 0.00 3.37 3.82
## 58 4.27 1.66 2.95 4.19 1.34 1.56 3.37 0.00 2.21
## 71 5.05 1.52 1.01 3.31 1.58 3.31 3.82 2.21 0.00

```

Pairs: 57-3, 71-20 and 58-28

```

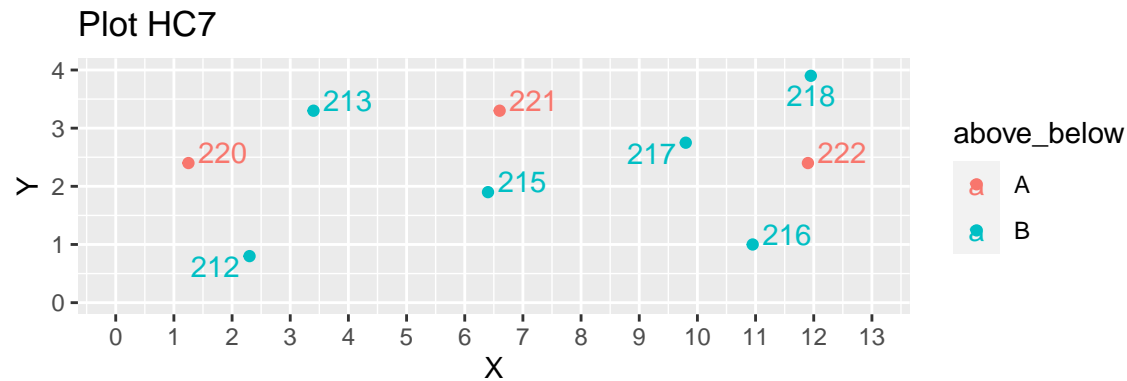
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==57|logger_nr==3,18,
                     ifelse(logger_nr==71|logger_nr==20,19,
                             ifelse(logger_nr==58|logger_nr==28,20,pair))))%>%
  mutate(dist=ifelse(pair==18,1.27,
                     ifelse(pair==19,1.01,
                             ifelse(pair==20,1.34,dist))))

```

```

logger_data%>%
  filter(plot=="HC7")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC7")+
  scale_y_continuous(breaks = seq(0,22,by=1)) +
  scale_x_continuous(breaks = seq(0,22,by=1)) +
  coord_fixed(ylim=c(0, 4),xlim=c(0, 13))

```



Distance matrix:

```
logger_data%>%
  filter(plot=="HC7")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

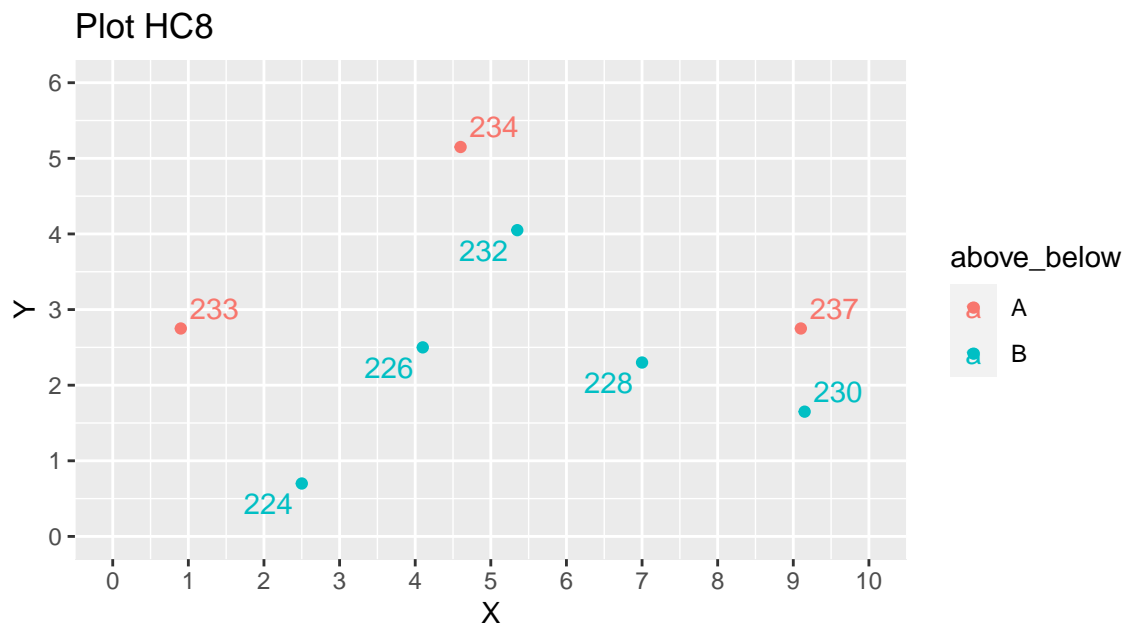
```
##      212  213  215  216  217   218   220  221   222
## 212  0.00  2.73  4.24  8.65  7.75 10.14  1.91  4.97  9.73
## 213  2.73  0.00  3.31  7.89  6.42  8.57  2.33  3.20  8.55
## 215  4.24  3.31  0.00  4.64  3.50  5.90  5.17  1.41  5.52
## 216  8.65  7.89  4.64  0.00  2.09  3.07  9.80  4.92  1.69
## 217  7.75  6.42  3.50  2.09  0.00  2.44  8.56  3.25  2.13
## 218 10.14  8.57  5.90  3.07  2.44  0.00 10.80  5.38  1.50
## 220  1.91  2.33  5.17  9.80  8.56 10.80  0.00  5.43 10.65
## 221  4.97  3.20  1.41  4.92  3.25  5.38  5.43  0.00  5.38
```

```
## 222  9.73 8.55 5.52 1.69 2.13  1.50 10.65 5.38  0.00
```

Pairs: 220-212, 221-215 and 222-218

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==220|logger_nr==212,21,
                     ifelse(logger_nr==221|logger_nr==215,22,
                             ifelse(logger_nr==222|logger_nr==218,23,pair))))%>%
  mutate(dist=ifelse(pair==21,1.91,
                     ifelse(pair==22,1.41,
                             ifelse(pair==23,1.50,dist))))
```

```
logger_data%>%
  filter(plot=="HC8")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC8")+
  scale_y_continuous(breaks = seq(0,22,by=1)) +
  scale_x_continuous(breaks = seq(0,22,by=1)) +
  coord_fixed(ylim=c(0, 6),xlim=c(0, 10))
```



Distance matrix:

```

logger_data%>%
  filter(plot=="HC8")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)

```

```

##      224  226  228  230  232  233  234  237
## 224 0.00 2.41 4.78 6.72 4.40 2.60 4.92 6.91
## 226 2.41 0.00 2.91 5.12 1.99 3.21 2.70 5.01
## 228 4.78 2.91 0.00 2.25 2.41 6.12 3.73 2.15
## 230 6.72 5.12 2.25 0.00 4.49 8.32 5.74 1.10
## 232 4.40 1.99 2.41 4.49 0.00 4.64 1.33 3.97
## 233 2.60 3.21 6.12 8.32 4.64 0.00 4.41 8.20
## 234 4.92 2.70 3.73 5.74 1.33 4.41 0.00 5.10
## 237 6.91 5.01 2.15 1.10 3.97 8.20 5.10 0.00

```

Pairs: 233-224, 234-232 and 237-230

```

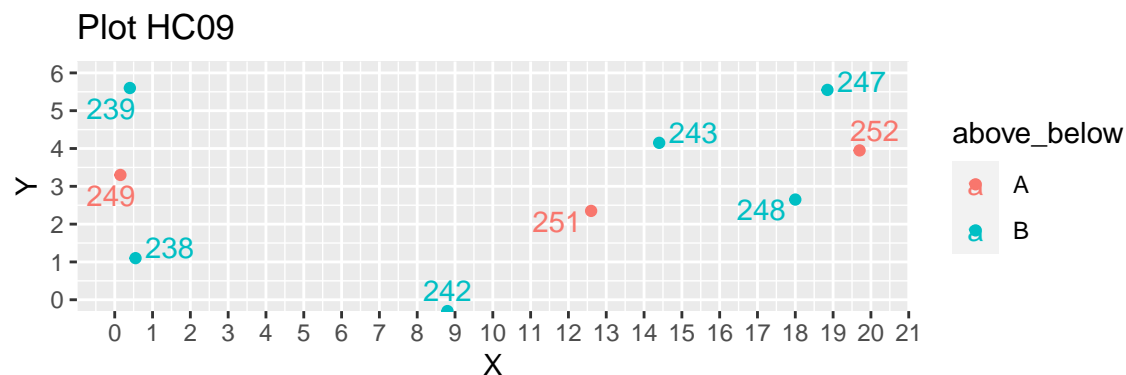
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==233|logger_nr==224,24,
                     ifelse(logger_nr==234|logger_nr==232,25,
                             ifelse(logger_nr==237|logger_nr==230,26,pair))))%>%
  mutate(dist=ifelse(pair==24,2.60,
                     ifelse(pair==25,1.33,
                             ifelse(pair==26,1.10,dist))))

```

```

logger_data%>%
  filter(plot=="HC09")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot HC09")+
  scale_y_continuous(breaks = seq(0,22,by=1)) +
  scale_x_continuous(breaks = seq(0,22,by=1)) +
  coord_fixed(ylim=c(0, 6),xlim=c(0, 20))

```



Distance matrix:

```
logger_data%>%
  filter(plot=="HC09")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

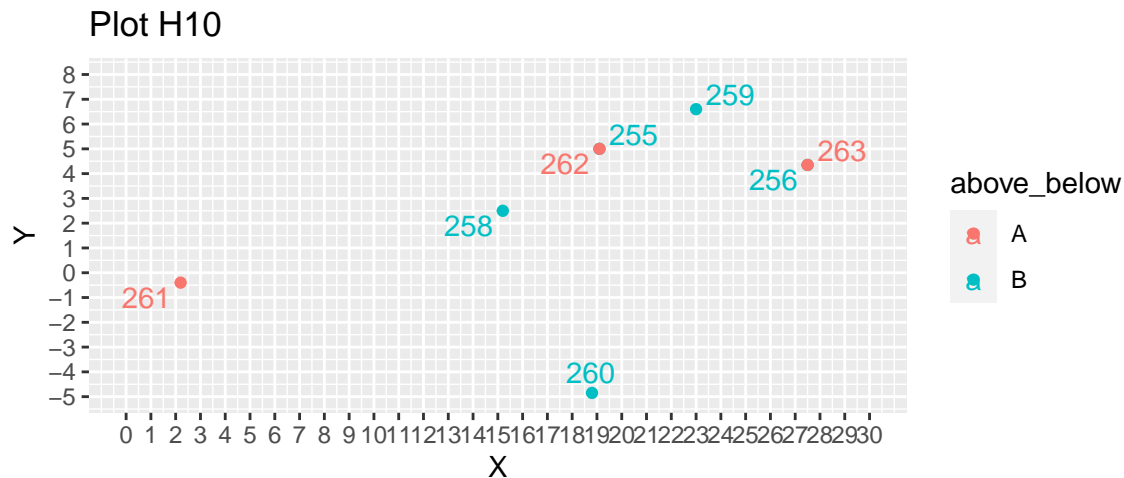
```
##      238   239   242   243   247   248   249   251   252
## 238  0.00  4.50  8.37 14.18 18.83 17.52  2.24 12.11 19.36
## 239  4.50  0.00 10.26 14.07 18.45 17.85  2.31 12.63 19.37
## 242  8.37 10.26  0.00  7.15 11.63  9.66  9.37  4.63 11.70
## 243 14.18 14.07  7.15  0.00  4.67  3.90 14.28  2.55  5.30
## 247 18.83 18.45 11.63  4.67  0.00  3.02 18.83  7.02  1.81
## 248 17.52 17.85  9.66  3.90  3.02  0.00 17.86  5.41  2.14
## 249  2.24  2.31  9.37 14.28 18.83 17.86  0.00 12.49 19.56
## 251 12.11 12.63  4.63  2.55  7.02  5.41 12.49  0.00  7.28
```

```
## 252 19.36 19.37 11.70 5.30 1.81 2.14 19.56 7.28 0.00
```

Pairs: 249-238, 251-243 and 252-247

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==249|logger_nr==238,27,
                     ifelse(logger_nr==251|logger_nr==243,28,
                             ifelse(logger_nr==252|logger_nr==247,29,pair))))%>%
  mutate(dist=ifelse(pair==27,2.24,
                     ifelse(pair==28,2.55,
                             ifelse(pair==29,1.81,dist))))
```

```
logger_data%>%
  filter(plot=="H10")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H10")+
  scale_y_continuous(breaks = seq(-5,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(-5, 8),xlim=c(0, 30))
```



Distance matrix:

```

logger_data%>%
  filter(plot=="H10")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)

```

```

##      255  256  258  259  260  261  262  263
## 255  0.00  8.43  4.63  4.22  9.85 17.74  0.00  8.43
## 256  8.43  0.00 12.44  5.03 12.66 25.74  8.43  0.00
## 258  4.63 12.44  0.00  8.81  8.18 13.32  4.63 12.44
## 259  4.22  5.03  8.81  0.00 12.20 21.95  4.22  5.03
## 260  9.85 12.66  8.18 12.20  0.00 17.19  9.85 12.66
## 261 17.74 25.74 13.32 21.95 17.19  0.00 17.74 25.74
## 262  0.00  8.43  4.63  4.22  9.85 17.74  0.00  8.43
## 263  8.43  0.00 12.44  5.03 12.66 25.74  8.43  0.00

```

Pairs: 261-258, 262-255 (same plant/location), 263-256 (same plant/location)

```

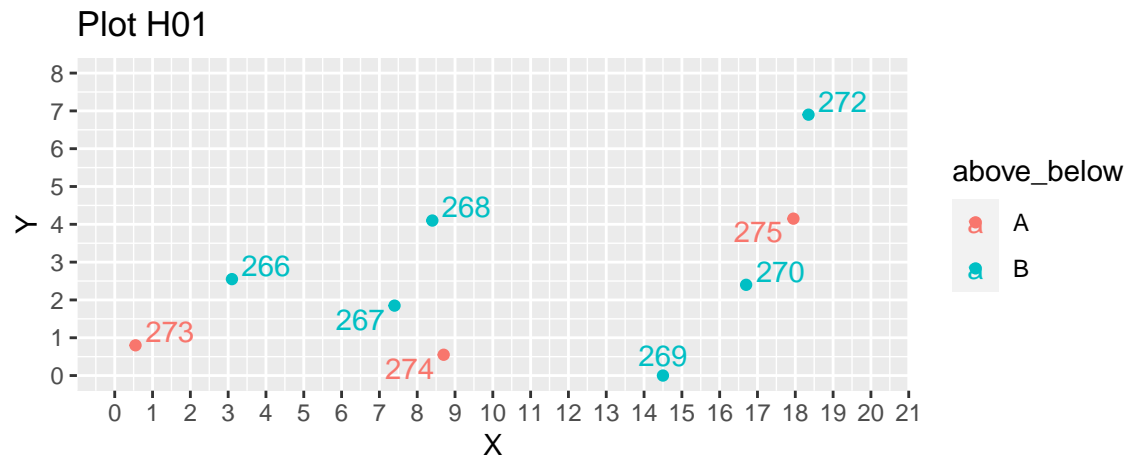
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==261|logger_nr==258,30,
                     ifelse(logger_nr==262|logger_nr==255,31,
                             ifelse(logger_nr==263|logger_nr==256,32,pair))))%>%
  mutate(dist=ifelse(pair==30,13.32,
                     ifelse(pair==31,0,
                             ifelse(pair==32,0,dist))))

```

```

logger_data%>%
  filter(plot=="H01")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H01")+
  scale_y_continuous(breaks = seq(0,22,by=1)) +
  scale_x_continuous(breaks = seq(0,22,by=1)) +
  coord_fixed(ylim=c(0, 8),xlim=c(0, 20))

```



Distance matrix:

```
logger_data%>%
  filter(plot=="H01")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      266  267  268  269  270  272  273  274  275
## 266  0.00  4.36  5.52 11.68 13.60 15.86  3.09  5.95 14.94
## 267  4.36  0.00  2.46  7.34  9.32 12.06  6.93  1.84 10.80
## 268  5.52  2.46  0.00  7.35  8.47 10.34  8.52  3.56  9.55
## 269 11.68  7.34  7.35  0.00  3.26  7.90 13.97  5.83  5.40
## 270 13.60  9.32  8.47  3.26  0.00  4.79 16.23  8.21  2.15
## 272 15.86 12.06 10.34  7.90  4.79  0.00 18.82 11.55  2.78
## 273  3.09  6.93  8.52 13.97 16.23 18.82  0.00  8.15 17.72
## 274  5.95  1.84  3.56  5.83  8.21 11.55  8.15  0.00  9.93
```

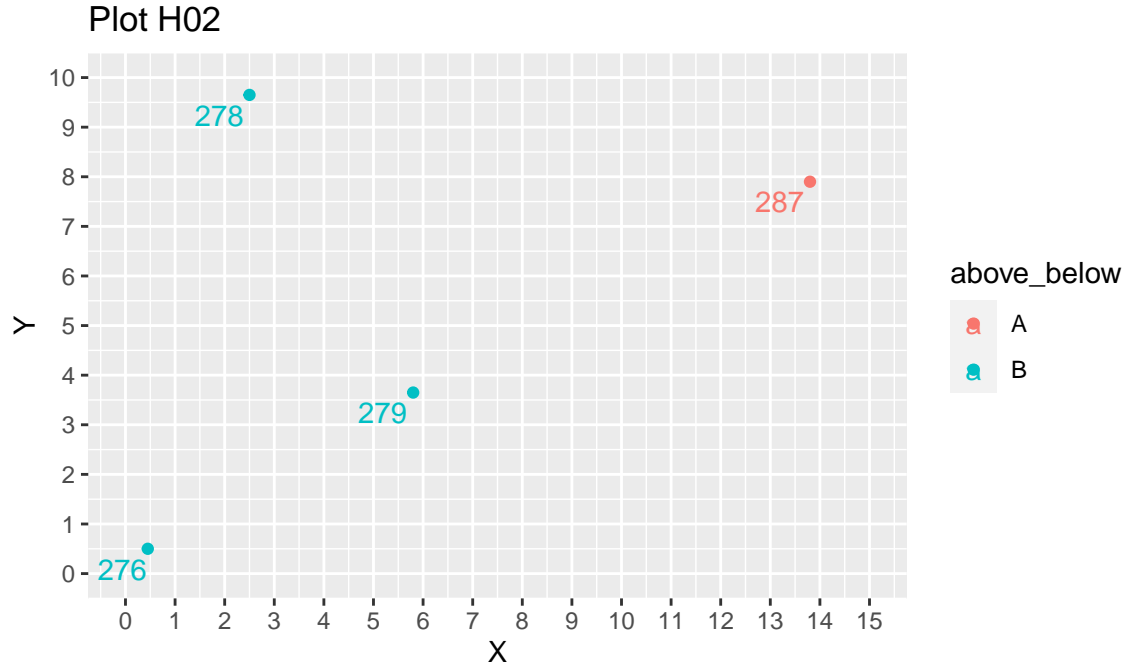


```
## 275 14.94 10.80 9.55 5.40 2.15 2.78 17.72 9.93 0.00
```

Pairs: 273-266, 274-267 and 275-270

```
logger_data<-logger_data%>%  
  mutate(pair=ifelse(logger_nr==273|logger_nr==266,33,  
    ifelse(logger_nr==274|logger_nr==267,34,  
      ifelse(logger_nr==275|logger_nr==270,35,pair))))%>%  
  mutate(dist=ifelse(pair==33,3.09,  
    ifelse(pair==34,1.84,  
      ifelse(pair==35,2.15,dist))))
```

```
logger_data%>%  
  filter(plot=="H02")%>%  
  group_by(plot,logger_nr,above_below)%>%  
  summarise(X=first(X),Y=first(Y))%>%  
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+  
  geom_text_repel()+ggtitle("Plot H02")+  
  scale_y_continuous(breaks = seq(0,22,by=1)) +  
  scale_x_continuous(breaks = seq(0,22,by=1)) +  
  coord_fixed(ylim=c(0, 10),xlim=c(0, 15))
```



Distance matrix:

```

logger_data%>%
  filter(plot=="H02")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)

```

```

##      276   278   279   287
## 276  0.00  9.38  6.21 15.26
## 278  9.38  0.00  6.85 11.43
## 279  6.21  6.85  0.00  9.06
## 287 15.26 11.43  9.06  0.00

```

Pairs: 287-279

```

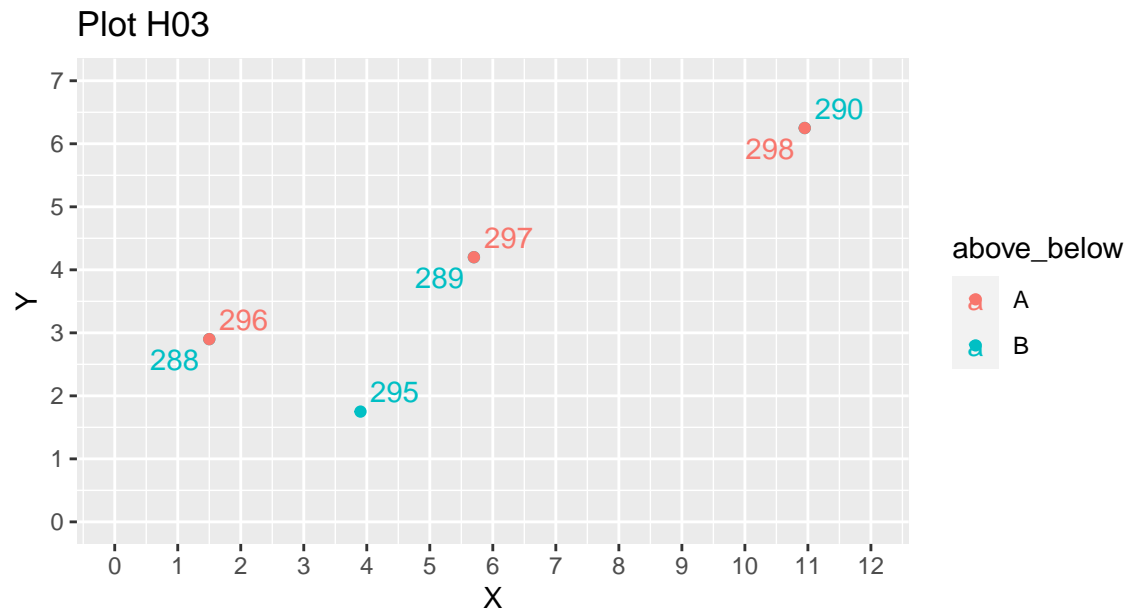
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==287|logger_nr==279,36,pair))%>%
  mutate(dist=ifelse(pair==36,9.06,dist))

```

```

logger_data%>%
  filter(plot=="H03")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H03")+
  scale_y_continuous(breaks = seq(0,22,by=1)) +
  scale_x_continuous(breaks = seq(0,22,by=1)) +
  coord_fixed(ylim=c(0, 7),xlim=c(0, 12))

```



Distance matrix:

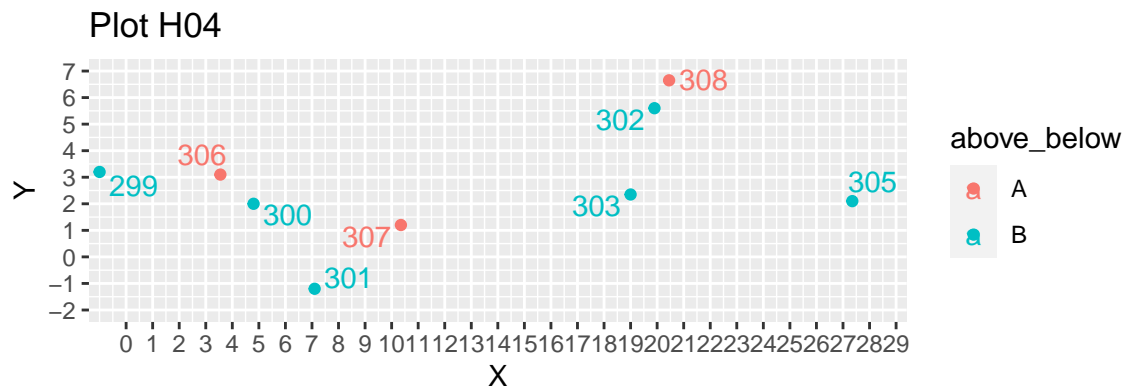
```
logger_data%>%
  filter(plot=="H03")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      288  289  290  295  296  297  298
## 288  0.00 4.40 10.03 2.66  0.00 4.40 10.03
## 289  4.40 0.00  5.64 3.04  4.40 0.00  5.64
## 290 10.03 5.64  0.00 8.36 10.03 5.64  0.00
## 295  2.66 3.04  8.36 0.00  2.66 3.04  8.36
## 296  0.00 4.40 10.03 2.66  0.00 4.40 10.03
## 297  4.40 0.00  5.64 3.04  4.40 0.00  5.64
## 298 10.03 5.64  0.00 8.36 10.03 5.64  0.00
```

Pairs: 296-288, 297-289 and 298-290 (same locations/plants)

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==296|logger_nr==288,37,
                     ifelse(logger_nr==297|logger_nr==289,38,
                             ifelse(logger_nr==298|logger_nr==290,39,pair))))%>%
  mutate(dist=ifelse(pair==37,0,
                     ifelse(pair==38,0,
                             ifelse(pair==39,0,dist))))
```

```
logger_data%>%
  filter(plot=="H04")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H04")+
  scale_y_continuous(breaks = seq(-2,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(-2, 7),xlim=c(0, 28))
```



Distance matrix:

```

logger_data%>%
  filter(plot=="H04")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)

```

```

##      299   300   301   302   303   305   306   307   308
## 299  0.00  5.92  9.22 21.04 20.02 28.37  4.55 11.52 21.73
## 300  5.92  0.00  3.94 15.52 14.20 22.55  1.67  5.61 16.33
## 301  9.22  3.94  0.00 14.49 12.42 20.52  5.58  4.04 15.49
## 302 21.04 15.52 14.49  0.00  3.37  8.23 16.54 10.51  1.19
## 303 20.02 14.20 12.42  3.37  0.00  8.35 15.47  8.73  4.54
## 305 28.37 22.55 20.52  8.23  8.35  0.00 23.82 17.02  8.27
## 306  4.55  1.67  5.58 16.54 15.47 23.82  0.00  7.06 17.27
## 307 11.52  5.61  4.04 10.51  8.73 17.02  7.06  0.00 11.48
## 308 21.73 16.33 15.49  1.19  4.54  8.27 17.27 11.48  0.00

```

Pairs: 306-300, 307-301 and 308-302

```

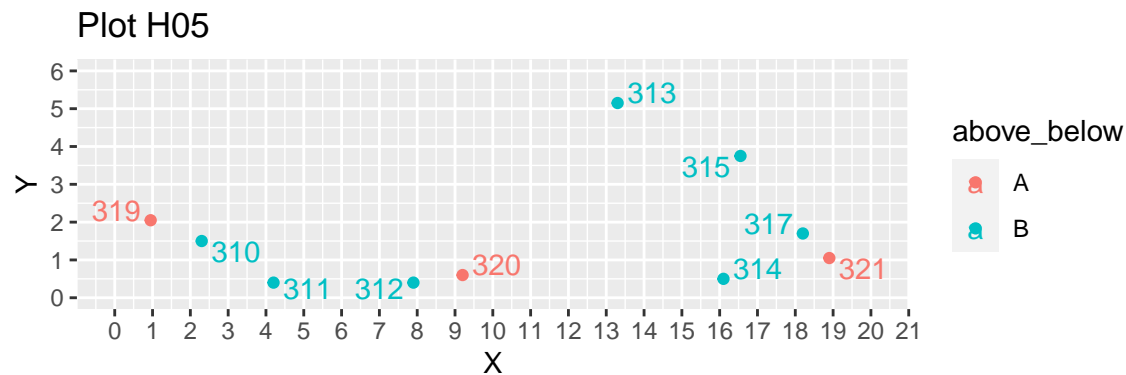
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==306|logger_nr==300,40,
                     ifelse(logger_nr==307|logger_nr==301,41,
                             ifelse(logger_nr==308|logger_nr==302,42,pair))))%>%
  mutate(dist=ifelse(pair==40,1.67,
                     ifelse(pair==41,4.04,
                             ifelse(pair==42,1.19,dist))))

```

```

logger_data%>%
  filter(plot=="H05")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H05")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 6),xlim=c(0, 20))

```



Distance matrix:

```
logger_data%>%
  filter(plot=="H05")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

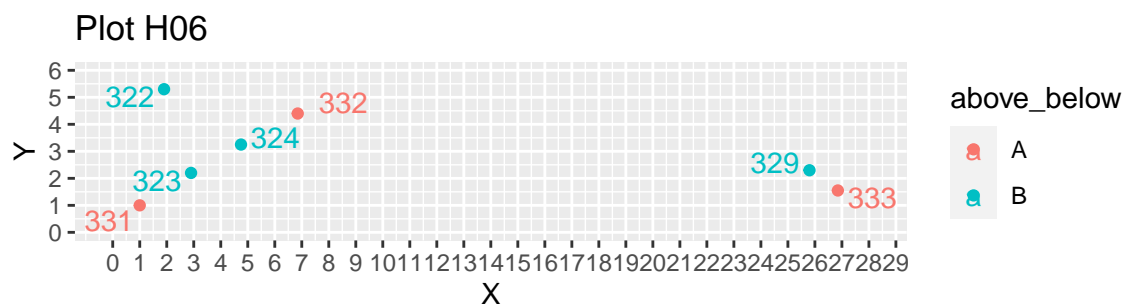
```
##      310   311   312   313   314   315   317   319   320   321
## 310  0.00  2.20  5.71 11.59 13.84 14.43 15.90  1.46  6.96 16.61
## 311  2.20  0.00  3.70 10.27 11.90 12.80 14.06  3.64  5.00 14.71
## 312  5.71  3.70  0.00  7.19  8.20  9.28 10.38  7.14  1.32 11.02
## 313 11.59 10.27  7.19  0.00  5.43  3.54  5.99 12.73  6.12  6.94
## 314 13.84 11.90  8.20  5.43  0.00  3.28  2.42 15.23  6.90  2.85
## 315 14.43 12.80  9.28  3.54  3.28  0.00  2.63 15.69  8.00  3.58
## 317 15.90 14.06 10.38  5.99  2.42  2.63  0.00 17.25  9.07  0.96
## 319  1.46  3.64  7.14 12.73 15.23 15.69 17.25  0.00  8.38 17.98
```

```
## 320 6.96 5.00 1.32 6.12 6.90 8.00 9.07 8.38 0.00 9.71
## 321 16.61 14.71 11.02 6.94 2.85 3.58 0.96 17.98 9.71 0.00
```

Pairs: 319-310, 320-312 and 321-317

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==319|logger_nr==310,43,
                     ifelse(logger_nr==320|logger_nr==312,44,
                           ifelse(logger_nr==321|logger_nr==317,45,pair))))%>%
  mutate(dist=ifelse(pair==43,1.46,
                    ifelse(pair==44,1.32,
                          ifelse(pair==45,0.96,dist))))
```

```
logger_data%>%
  filter(plot=="H06")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H06")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 6),xlim=c(0, 28))
```



Distance matrix:

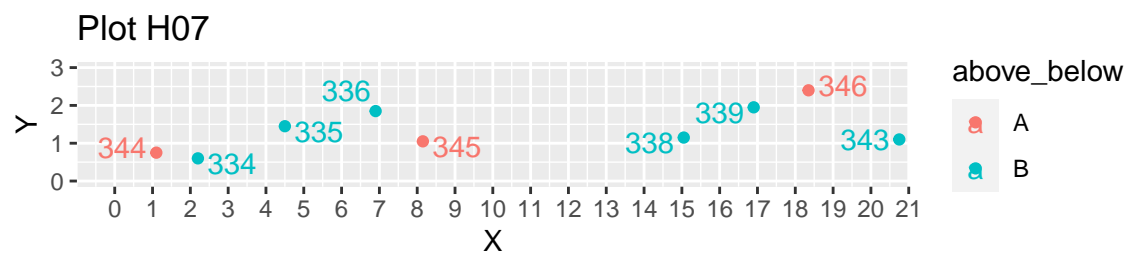
```
logger_data%>%
  filter(plot=="H06")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      322  323  324  329  331  332  333
## 322  0.00  3.26  3.51 24.09  4.39  5.03 25.23
## 323  3.26  0.00  2.13 22.90  2.25  4.52 23.96
## 324  3.51  2.13  0.00 21.07  4.37  2.39 22.17
## 329 24.09 22.90 21.07  0.00 24.83 19.07  1.29
## 331  4.39  2.25  4.37 24.83  0.00  6.77 25.86
## 332  5.03  4.52  2.39 19.07  6.77  0.00 20.20
## 333 25.23 23.96 22.17  1.29 25.86 20.20  0.00
```

Pairs: 331-323, 332-324 and 333-329

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==331|logger_nr==323,46,
                     ifelse(logger_nr==332|logger_nr==324,47,
                             ifelse(logger_nr==333|logger_nr==329,48,pair))))%>%
  mutate(dist=ifelse(pair==46,2.25,
                     ifelse(pair==47,2.39,
                             ifelse(pair==48,1.29,dist))))
```

```
logger_data%>%
  filter(plot=="H07")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H07")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 3),xlim=c(0, 20))
```

Distance matrix:

```
logger_data%>%
  filter(plot=="H07")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

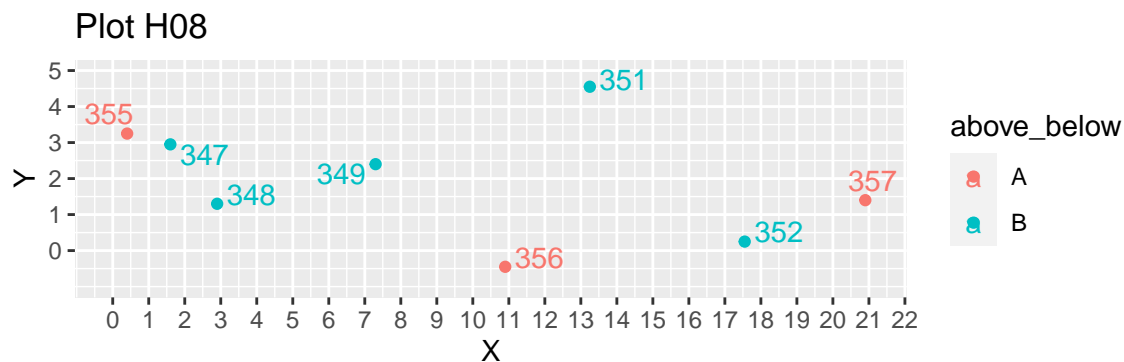
```
##      334   335   336   338   339   343   344   345   346
## 334  0.00  2.45  4.86 12.86 14.76 18.56  1.11  5.97 16.25
## 335  2.45  0.00  2.43 10.55 12.41 16.25  3.47  3.67 13.88
## 336  4.86  2.43  0.00  8.18 10.00 13.87  5.90  1.48 11.46
## 338 12.86 10.55  8.18  0.00  2.02  5.70 13.96  6.90  3.53
## 339 14.76 12.41 10.00  2.02  0.00  3.94 15.85  8.80  1.52
## 343 18.56 16.25 13.87  5.70  3.94  0.00 19.65 12.60  2.73
## 344  1.11  3.47  5.90 13.96 15.85 19.65  0.00  7.06 17.33
## 345  5.97  3.67  1.48  6.90  8.80 12.60  7.06  0.00 10.29
```

```
## 346 16.25 13.88 11.46 3.53 1.52 2.73 17.33 10.29 0.00
```

Pairs: 344-334, 345-336 and 346-339

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==344|logger_nr==334,49,
                     ifelse(logger_nr==345|logger_nr==336,50,
                             ifelse(logger_nr==346|logger_nr==339,51,pair))))%>%
  mutate(dist=ifelse(pair==49,1.11,
                     ifelse(pair==50,1.48,
                             ifelse(pair==51,1.52,dist))))
```

```
logger_data%>%
  filter(plot=="H08")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H08")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(-1, 5),xlim=c(0, 21))
```



Distance matrix:

```

logger_data%>%
  filter(plot=="H08")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)

```

```

##      347   348   349   351   352   355   356   357
## 347  0.00  2.10  5.73 11.76 16.18  1.24  9.90 19.36
## 348  2.10  0.00  4.54 10.85 14.69  3.17  8.19 18.00
## 349  5.73  4.54  0.00  6.33 10.47  6.95  4.59 13.64
## 351 11.76 10.85  6.33  0.00  6.08 12.92  5.52  8.27
## 352 16.18 14.69 10.47  6.08  0.00 17.41  6.69  3.54
## 355  1.24  3.17  6.95 12.92 17.41  0.00 11.13 20.58
## 356  9.90  8.19  4.59  5.52  6.69 11.13  0.00 10.17
## 357 19.36 18.00 13.64  8.27  3.54 20.58 10.17  0.00

```

Pairs: 355-347, 356-349 and 357-352

```

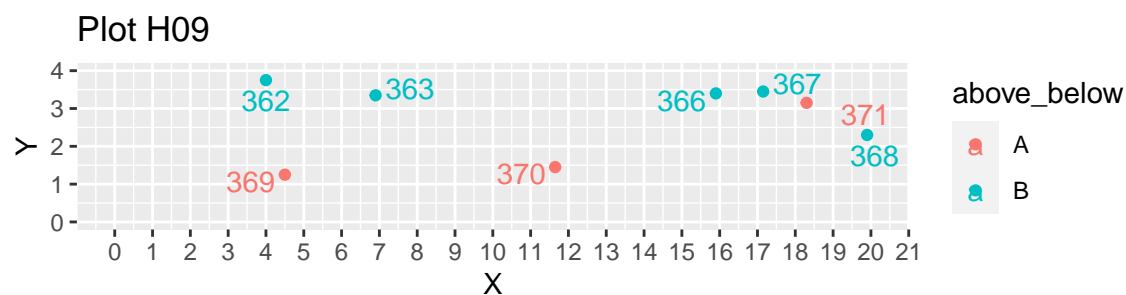
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==355|logger_nr==347,52,
                     ifelse(logger_nr==356|logger_nr==349,53,
                             ifelse(logger_nr==357|logger_nr==352,54,pair))))%>%
  mutate(dist=ifelse(pair==52,1.24,
                     ifelse(pair==53,4.59,
                             ifelse(pair==54,3.54,dist))))

```

```

logger_data%>%
  filter(plot=="H09")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H09")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 4),xlim=c(0, 20))

```



Distance matrix:

```
logger_data%>%
  filter(plot=="H09")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

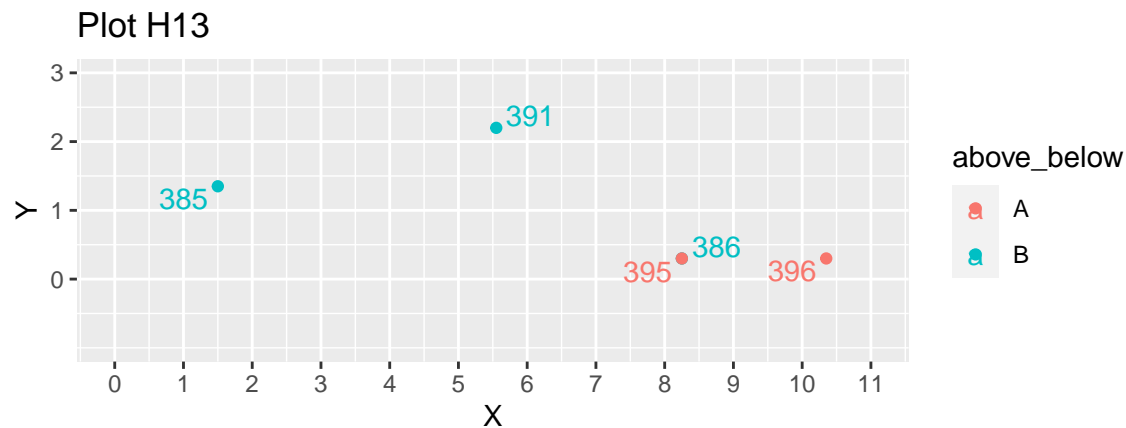
```
##      362  363  366  367  368  369  370  371
## 362  0.00  2.93 11.91 13.15 15.97  2.55  7.99 14.31
## 363  2.93  0.00  9.00 10.25 13.04  3.19  5.12 11.40
## 366 11.91  9.00  0.00  1.25  4.15 11.60  4.68  2.41
## 367 13.15 10.25  1.25  0.00  2.98 12.84  5.85  1.19
## 368 15.97 13.04  4.15  2.98  0.00 15.44  8.29  1.81
## 369  2.55  3.19 11.60 12.84 15.44  0.00  7.15 13.93
## 370  7.99  5.12  4.68  5.85  8.29  7.15  0.00  6.86
## 371 14.31 11.40  2.41  1.19  1.81 13.93  6.86  0.00
```

Pairs: 369-362, 370-366 and 371-367

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==369|logger_nr==362,55,
    ifelse(logger_nr==370|logger_nr==366,56,
      ifelse(logger_nr==371|logger_nr==367,57,pair))))%>%
  mutate(dist=ifelse(pair==55,2.55,
    ifelse(pair==56,4.68,
      ifelse(pair==57,1.19,dist))))
```

Plot H11 not included because there are only aboveground loggers

```
logger_data%>%
  filter(plot=="H13")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H13")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(-1, 3),xlim=c(0, 11))
```



Distance matrix:

```

logger_data%>%
  filter(plot=="H13")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)

```

```

##      385  386  391  395  396
## 385 0.00 6.83 4.14 6.83 8.91
## 386 6.83 0.00 3.30 0.00 2.10
## 391 4.14 3.30 0.00 3.30 5.16
## 395 6.83 0.00 3.30 0.00 2.10
## 396 8.91 2.10 5.16 2.10 0.00

```

Pairs: 395-386 (same location/plant) and 396-391

```

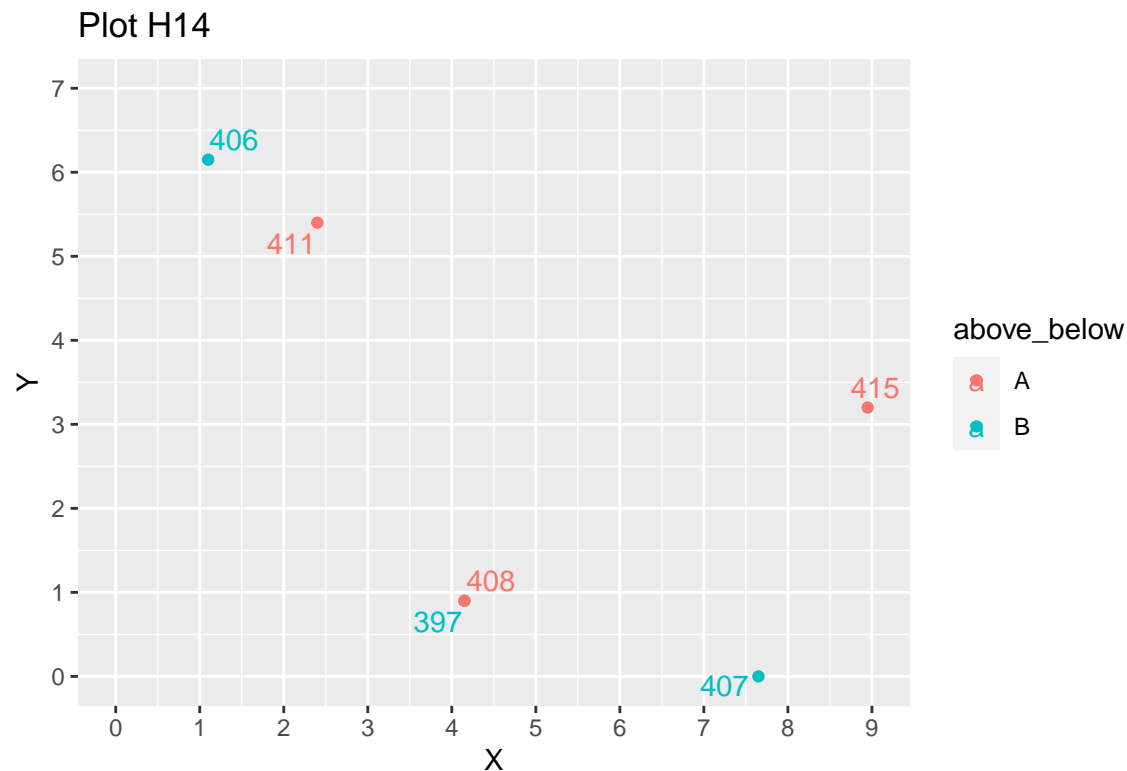
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==395|logger_nr==386,58,
                     ifelse(logger_nr==396|logger_nr==391,59,pair)))%>%
  mutate(dist=ifelse(pair==58,0,
                     ifelse(pair==59,5.16,dist)))

```

```

logger_data%>%
  filter(plot=="H14")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H14")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0,7),xlim=c(0, 9))

```



Distance matrix:

```
logger_data%>%
  filter(plot=="H14")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

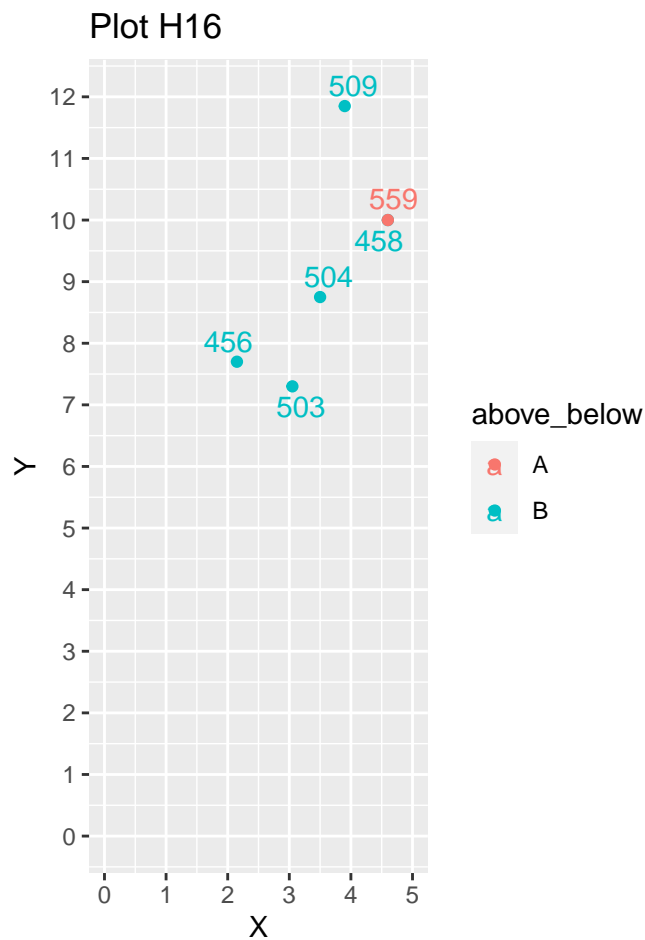
```
##      397  406  407  408  411  415
## 397 0.00 6.07 3.61 0.00 4.83 5.32
## 406 6.07 0.00 8.98 6.07 1.50 8.39
## 407 3.61 8.98 0.00 3.61 7.53 3.45
## 408 0.00 6.07 3.61 0.00 4.83 5.32
## 411 4.83 1.50 7.53 4.83 0.00 6.91
## 415 5.32 8.39 3.45 5.32 6.91 0.00
```

Pairs: 411-406, 408-397 and 415-407

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==411|logger_nr==406,60,
    ifelse(logger_nr==408|logger_nr==397,61,
      ifelse(logger_nr==415|logger_nr==407,62,pair))))%>%
  mutate(dist=ifelse(pair==60,1.50,
    ifelse(pair==61,0,
      ifelse(pair==62,3.45,dist))))
```

Plot H11 not included because there are only aboveground loggers

```
logger_data%>%
  filter(plot=="H16")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H16")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 12),xlim=c(0, 5))
```



Distance matrix:


```

logger_data%>%
  filter(plot=="H16")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)

```

```

##      456  458  503  504  509  559
## 456 0.00  3.36  0.98  1.71  4.50  3.36
## 458 3.36  0.00  3.11  1.67  1.98  0.00
## 503 0.98  3.11  0.00  1.52  4.63  3.11
## 504 1.71  1.67  1.52  0.00  3.13  1.67
## 509 4.50  1.98  4.63  3.13  0.00  1.98
## 559 3.36  0.00  3.11  1.67  1.98  0.00

```

Pairs: 458-559

```

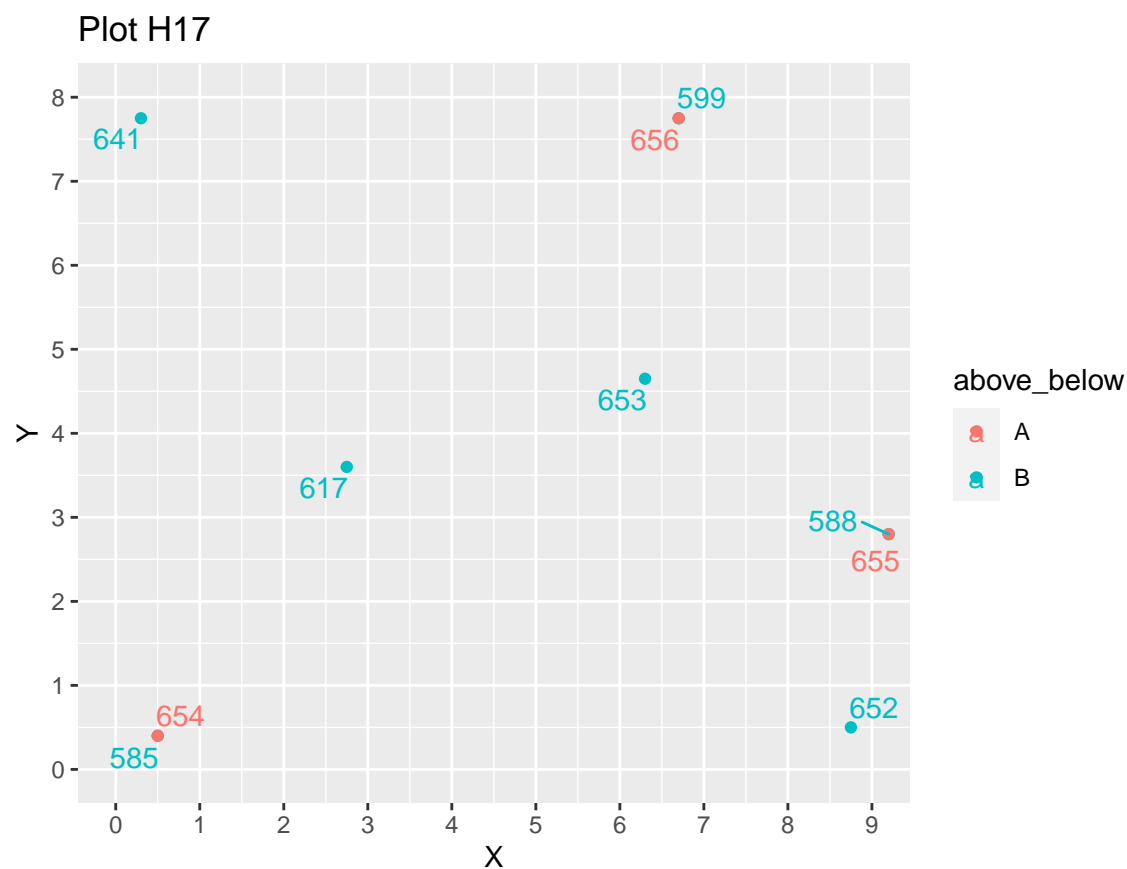
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==458|logger_nr==559,63,pair))%>%
  mutate(dist=ifelse(pair==63,0,dist))

```

```

logger_data%>%
  filter(plot=="H17")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H17")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 8),xlim=c(0, 9))

```



Distance matrix:

```
logger_data%>%
  filter(plot=="H17")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

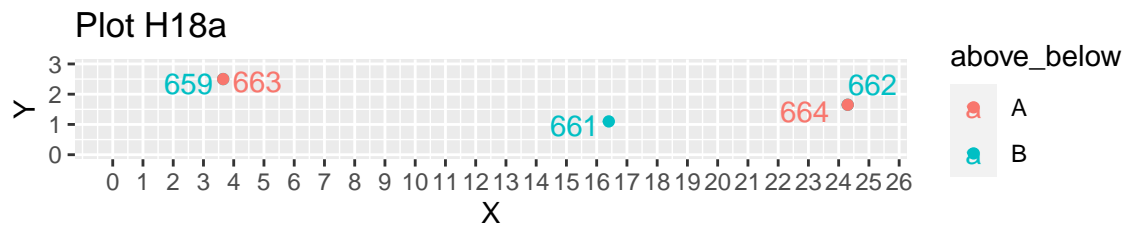
```
##      585    588    599    617    641    652    653    654    655    656
## 585 0.00   9.02   9.62   3.91   7.35   8.25   7.19   0.00   9.02   9.62
## 588 9.02   0.00   5.55   6.50  10.18   2.34   3.44   9.02   0.00   5.55
## 599 9.62   5.55   0.00   5.73   6.40   7.53   3.13   9.62   5.55   0.00
## 617 3.91   6.50   5.73   0.00   4.82   6.75   3.70   3.91   6.50   5.73
## 641 7.35  10.18   6.40   4.82   0.00  11.13   6.75   7.35  10.18   6.40
## 652 8.25   2.34   7.53   6.75  11.13   0.00   4.82   8.25   2.34   7.53
## 653 7.19   3.44   3.13   3.70   6.75   4.82   0.00   7.19   3.44   3.13
## 654 0.00   9.02   9.62   3.91   7.35   8.25   7.19   0.00   9.02   9.62
```

```
## 655 9.02 0.00 5.55 6.50 10.18 2.34 3.44 9.02 0.00 5.55
## 656 9.62 5.55 0.00 5.73 6.40 7.53 3.13 9.62 5.55 0.00
```

Pairs: 654-585, 655-588 and 656-599 (all same locations / plants)

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==654|logger_nr==588,64,
                     ifelse(logger_nr==655|logger_nr==588,65,
                           ifelse(logger_nr==656|logger_nr==599,66,pair))))%>%
  mutate(dist=ifelse(pair==64,0,
                    ifelse(pair==65,0,
                          ifelse(pair==66,0,dist))))
```

```
logger_data%>%
  filter(plot=="H18a")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H18a")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 3),xlim=c(0, 25))
```



Distance matrix:

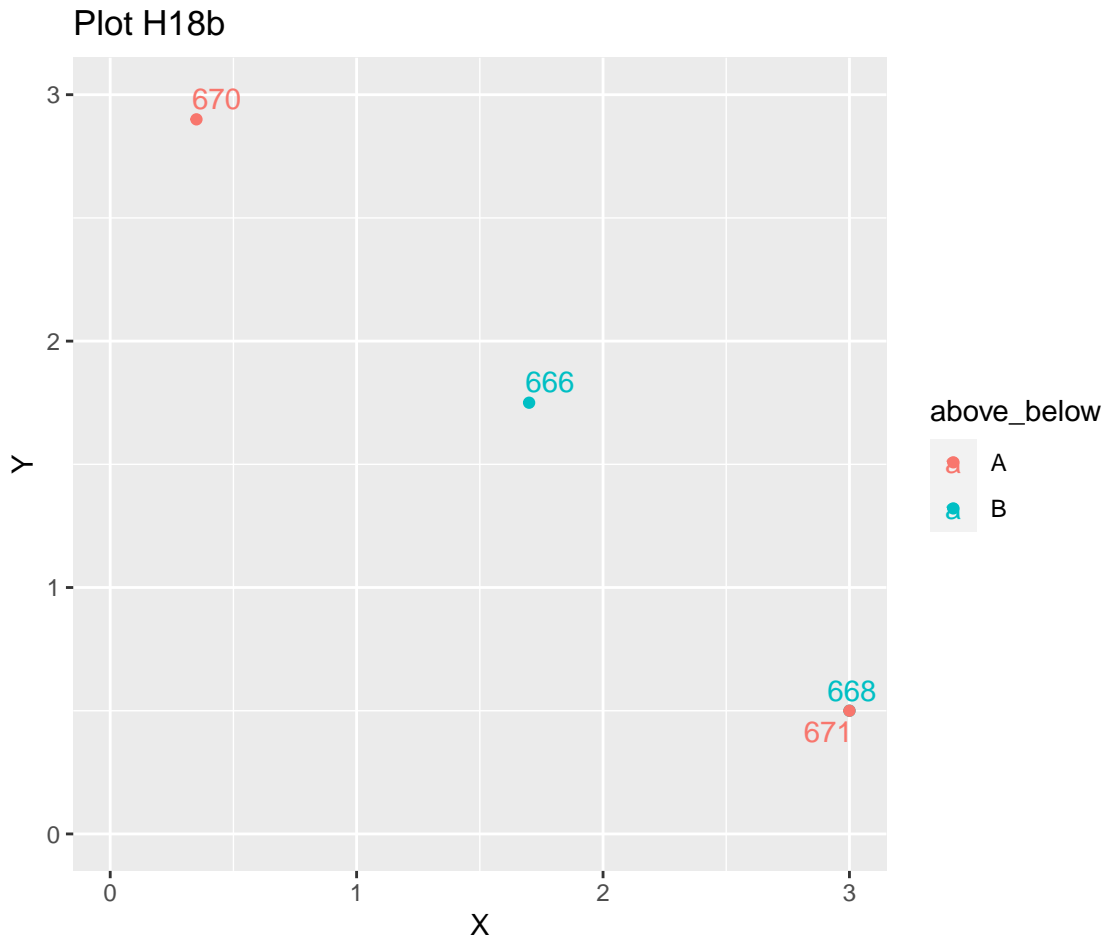
```
logger_data%>%
  filter(plot=="H18a")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      659   661   662   663   664
## 659  0.00 12.83 20.67  0.00 20.67
## 661 12.83  0.00  7.92 12.83  7.92
## 662 20.67  7.92  0.00 20.67  0.00
## 663  0.00 12.83 20.67  0.00 20.67
## 664 20.67  7.92  0.00 20.67  0.00
```

Pairs: 663-659 and 664-662 (all same locations / plants)

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==663|logger_nr==659,67,
                     ifelse(logger_nr==664|logger_nr==662,68,pair)))%>%
  mutate(dist=ifelse(pair==67,0,
                     ifelse(pair==68,0,dist)))
```

```
logger_data%>%
  filter(plot=="H18b")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H18b")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 3),xlim=c(0, 3))
```



Distance matrix:

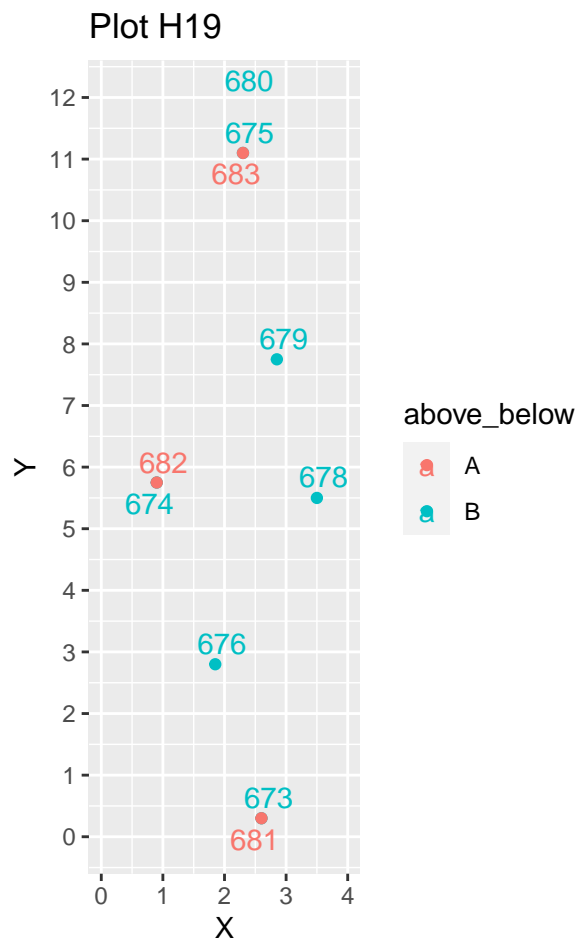
```
logger_data%>%
  filter(plot=="H18b")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
  column_to_rownames(var="logger_nr")%>%
  dist()%>%
  as.matrix()%>%
  # as.data.frame()%>%
  # rownames_to_column(var="logger_nr")%>%
  # pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
  round(digits=2)
```

```
##      666  668  670  671
## 666 0.00 1.80 1.77 1.80
## 668 1.80 0.00 3.58 0.00
## 670 1.77 3.58 0.00 3.58
## 671 1.80 0.00 3.58 0.00
```

Pairs: 671-668 (same location / plant) and 670-666

```
logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==671|logger_nr==668,69,
    ifelse(logger_nr==670|logger_nr==666,70,pair)))%>%
  mutate(dist=ifelse(pair==69,0,
    ifelse(pair==70,1.77,dist)))
```

```
logger_data%>%
  filter(plot=="H19")%>%
  group_by(plot,logger_nr,above_below)%>%
  summarise(X=first(X),Y=first(Y))%>%
  ggplot(aes(x=X,y=Y,color=above_below,label=logger_nr))+geom_point()+
  geom_text_repel()+ggtitle("Plot H19")+
  scale_y_continuous(breaks = seq(0,30,by=1)) +
  scale_x_continuous(breaks = seq(0,30,by=1)) +
  coord_fixed(ylim=c(0, 12),xlim=c(0, 4))
```



Distance matrix:

```
logger_data%>%
  filter(plot=="H19")%>%
  group_by(logger_nr)%>%
  summarise(X=first(X),Y=first(Y))%>%
```

```

column_to_rownames(var="logger_nr")%>%
dist()%>%
as.matrix()%>%
# as.data.frame()%>%
# rownames_to_column(var="logger_nr")%>%
# pivot_longer(cols=-logger_nr,names_to="logger_nr_2",values_to="distance")
round(digits=2)

```

```

##      673 674 675 676 678 679 680 681 682 683
## 673 0.00 5.71 10.80 2.61 5.28 7.45 12.50 0.00 5.71 10.80
## 674 5.71 0.00 5.53 3.10 2.61 2.79 7.21 5.71 0.00 5.53
## 675 10.80 5.53 0.00 8.31 5.73 3.39 1.70 10.80 5.53 0.00
## 676 2.61 3.10 8.31 0.00 3.16 5.05 10.02 2.61 3.10 8.31
## 678 5.28 2.61 5.73 3.16 0.00 2.34 7.38 5.28 2.61 5.73
## 679 7.45 2.79 3.39 5.05 2.34 0.00 5.07 7.45 2.79 3.39
## 680 12.50 7.21 1.70 10.02 7.38 5.07 0.00 12.50 7.21 1.70
## 681 0.00 5.71 10.80 2.61 5.28 7.45 12.50 0.00 5.71 10.80
## 682 5.71 0.00 5.53 3.10 2.61 2.79 7.21 5.71 0.00 5.53
## 683 10.80 5.53 0.00 8.31 5.73 3.39 1.70 10.80 5.53 0.00

```

Pairs: 683-675, 682-674, 681-673 (all same locations / plants)

```

logger_data<-logger_data%>%
  mutate(pair=ifelse(logger_nr==683|logger_nr==675,71,
                     ifelse(logger_nr==682|logger_nr==674,72,
                             ifelse(logger_nr==681|logger_nr==673,73,pair))))%>%
  mutate(dist=ifelse(pair==71,0,
                     ifelse(pair==72,0,
                             ifelse(pair==73,0,dist))))

```

```

logger_data_pairs<-subset(logger_data,!is.na(pair))

```

Write logger__data and logger__data__pairs to csv files