Methods and ethical considerations for the monitoring of ungulates using UAVs: A systematic review and evaluation

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Import Data-Sets

```
library(readxl)
Ungulate <- read_excel("C:/Users/meyer/Desktop/Ungulate review/Ungulate.xlsx")
```

```
## New names:
## * `` -> ...12
## * `` -> ...13
## * `` -> ...14
```

```
UngulateCluster <- read_excel("C:/Users/meyer/Desktop/Ungulate review/UngulateCluster.xlsx")
Flights <- read_excel("C:/Users/meyer/Desktop/Ungulate review/FlightType.xlsx")
```

```
## New names:
## * `` -> ...13
```

```
##mutate (Type = as_factor(Flights$Type)%>% fct_relevel("Automated", "Piloted"))
View(UngulateCluster)
```

import Libraris

```
library(ggplot2)
library(mgcv, lib.loc = "C:/Program Files/R/R-4.0.2/library")
```

```
## Loading required package: nlme
```

```
## This is mgcv 1.8-31. For overview type 'help("mgcv-package")'.
```

```
library(nlme, lib.loc = "C:/Program Files/R/R-4.0.2/library")
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following object is masked from 'package:nlme':
##
##     collapse
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
```

```
##     intersect, setdiff, setequal, union
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --
```

```
## v tibble  3.1.6     v purrr   0.3.4
## v tidyr   1.1.4     v stringr 1.4.0
## v readr   2.1.0     v forcats 0.5.1
```

```
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::collapse() masks nlme::collapse()
## x dplyr::filter()   masks stats::filter()
## x dplyr::lag()      masks stats::lag()
```

```
library(FactoMineR)
library(factoextra)
```

```
## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```
library(multcompView)
library(ggpubr)
```

```
which (!complete.cases(UngulateCluster))
```

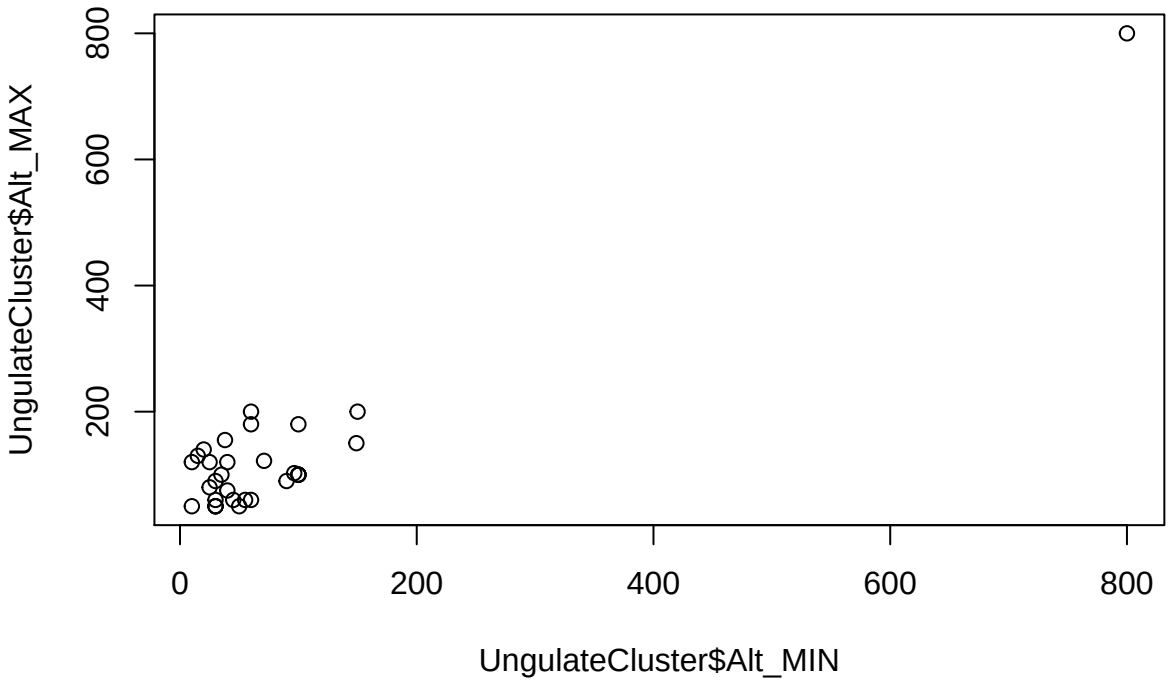
```
## integer(0)
```

```
str(Flights)
```

```
## tibble [122 x 15] (S3: tbl_df/tbl/data.frame)
##  $ 43260        : chr [1:122] "43149" "43149" "43149" "43149" ...
##  $ UAE          : chr [1:122] "Senegal" "Senegal" "Senegal" "Senegal" ...
##  $ SHJ          : chr [1:122] "Bandia" "Bandia" "Bandia" "Bandia" ...
##  $ DJI PH 3 adv : chr [1:122] "PH 3 Pro" "PH 3 Pro" "PH 3 Pro" "PH 3 Pro" ...
##  $ 1000g - 1500g: chr [1:122] "1000g - 1500g" "1000g - 1500g" "1000g - 1500g" "1000g - 1500g" ...
##  $ 5.45         : chr [1:122] "1.49" "3.01" "0.33" "1.01" ...
##  $ 40           : chr [1:122] "45" "45" "45" "45" ...
##  $ 12           : chr [1:122] "11" "10" "10" "10" ...
##  $ Dama         : chr [1:122] "Derby eland" "Derby eland" "Derby eland" "Derby eland" ...
##  $ Targeted     : chr [1:122] "Targeted" "Targeted" "Targeted" "Targeted" ...
##  $ Piloted      : chr [1:122] "Piloted" "Piloted" "Piloted" "Piloted" ...
##  $ N            : chr [1:122] "N" "N" "N" "N" ...
##  $ ...13        : chr [1:122] NA NA NA NA ...
##  $ No Cover     : chr [1:122] "no cover" "Cover" "Cover" "Cover" ...
##  $ Up wind      : chr [1:122] "Up wind" "Up wind" "Up wind" "Up wind" ...
```

Plot Range

```
df <-UngulateCluster
plot(UngulateCluster$Alt_MIN, UngulateCluster$Alt_MAX)
```




```
kmeans(x = UngulateCluster, centers = 2)
```

```
## K-means clustering with 2 clusters of sizes 31, 1
##
## Cluster means:
##   Covidence #  Alt_MIN  Alt_MAX
## 1    220.7419  57.8871 104.6613
## 2    367.0000 800.0000 800.0000
##
## Clustering vector:
##  [1] 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
##
## Within cluster sum of squares by cluster:
## [1] 422638.5      0.0
##  (between_SS / total_SS =  70.8 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

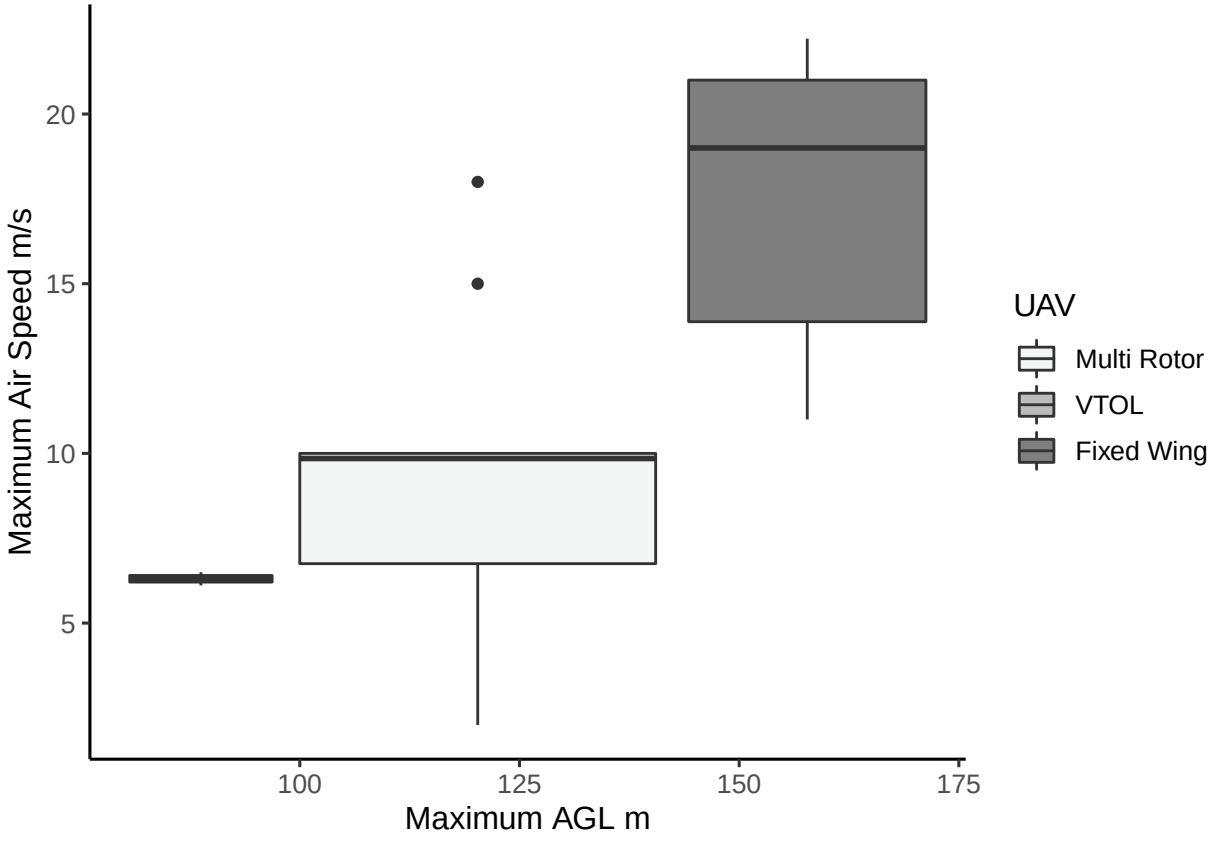
```
review <- read_excel("C:/Users/meyer/Desktop/Ungulate review/review.xlsx")
```

```
## New names:
## * Species -> Species...7
## * Species -> Species...9
```

```
  ggplot(data = review, aes(x= Alt_MAX, y= Speed_Max , fill = UAV))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=review$UAV,
                    values = c ("#f3f6f4", "#bcbcbc","#999999" ))+
    labs(x="Maximum AGL m", y="Maximum Air Speed m/s")
```

```
## Warning: Removed 6 rows containing missing values (stat_boxplot).
```

```
## Warning: Removed 11 rows containing non-finite values (stat_boxplot).
```



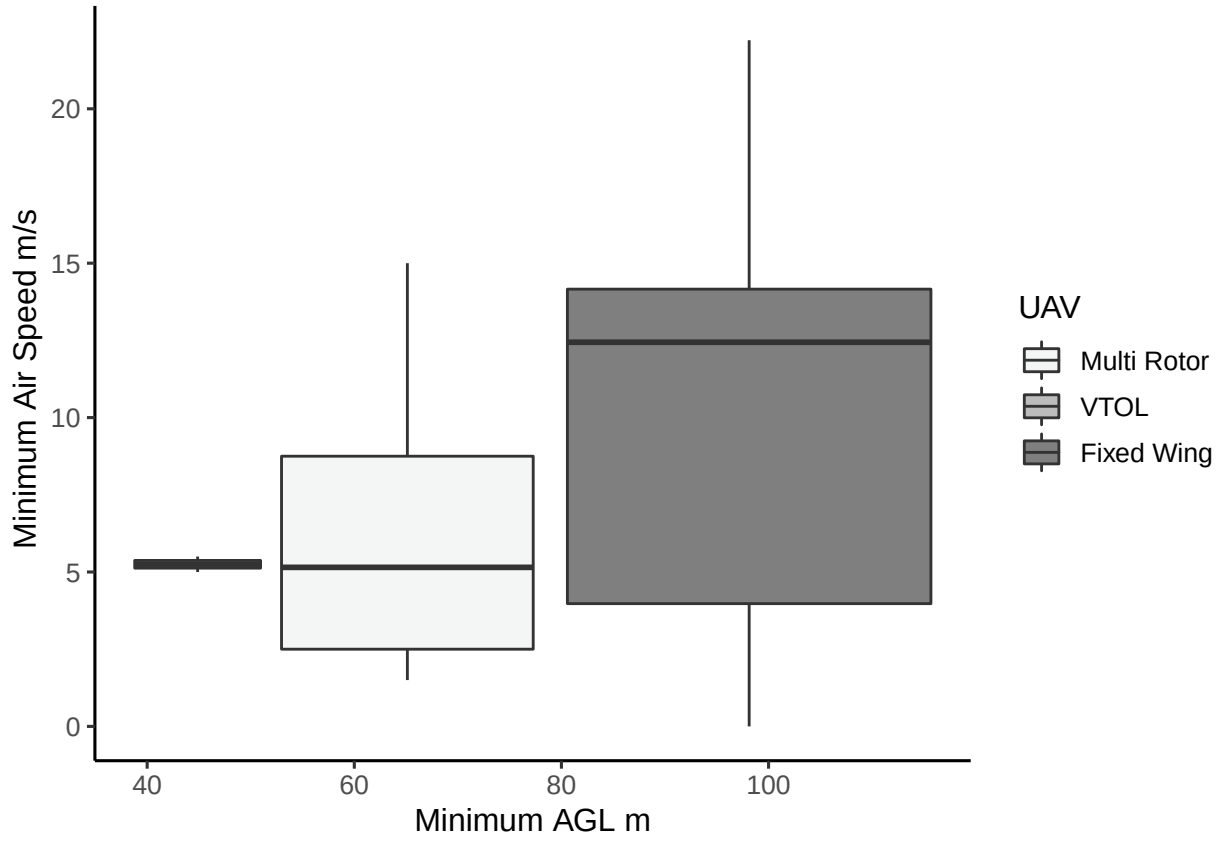

```
  review <- read_excel("C:/Users/meyer/Desktop/Ungulate review/review.xlsx")
```

```
## New names:
## * Species -> Species...7
## * Species -> Species...9
```

```
  par(mfrow=c(2,2))
  ggplot(data = review, aes(x= Alt_MIN, y= Speed_Min , fill = UAV))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=review$UAV,
                    values = c ("#f3f6f4", "#bcbcbc","#999999" ))+
    labs(x="Minimum AGL m", y=" Minimum Air Speed m/s")
```

```
## Warning: Removed 6 rows containing missing values (stat_boxplot).
```

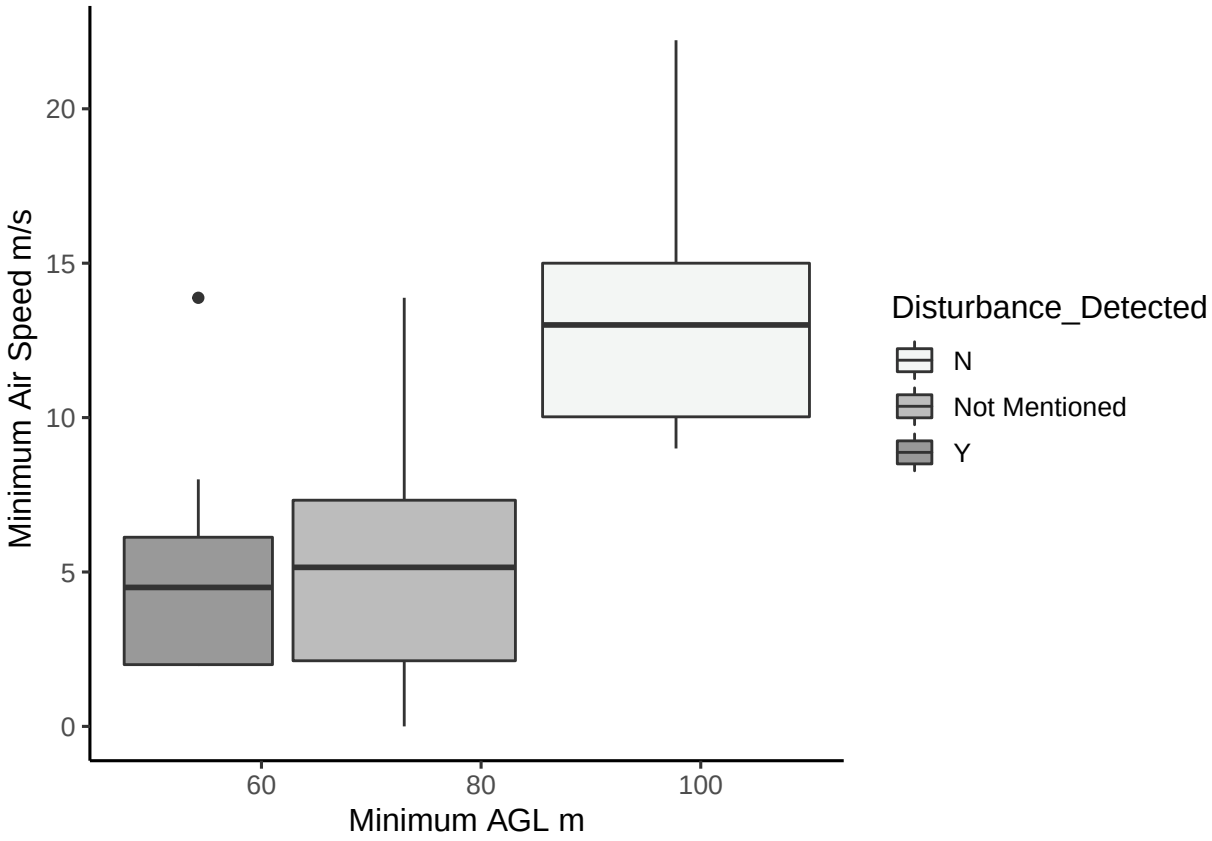
```
## Warning: Removed 11 rows containing non-finite values (stat_boxplot).
```




```
  ggplot(data = review, aes(x= Alt_MIN, y= Speed_Min , fill = Disturbance_Detected))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=review$Disturbance_Detected,
                    values = c ("#f3f6f4", "#bcbcbc","#999999" ))+
    labs(x="Minimum AGL m", y=" Minimum Air Speed m/s")
```

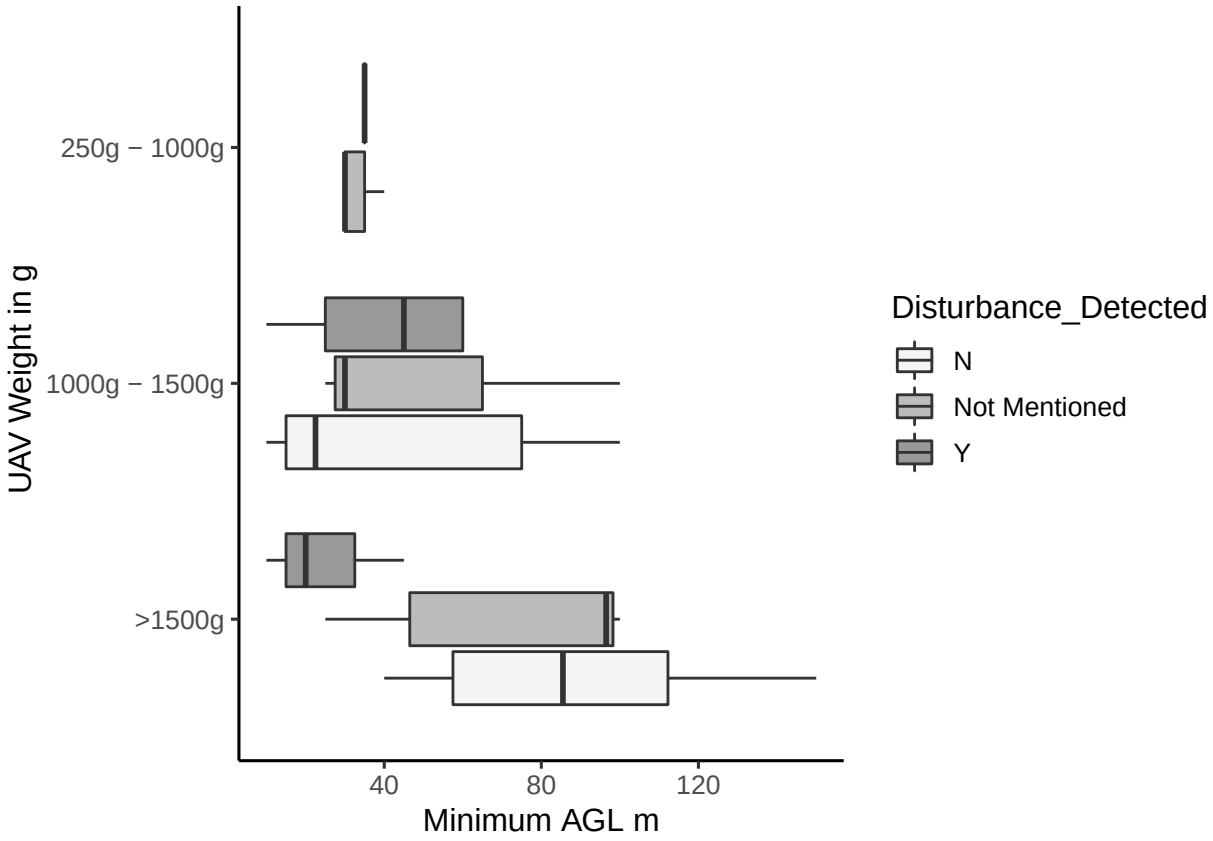
```
## Warning: Removed 6 rows containing missing values (stat_boxplot).
```

```
## Warning: Removed 11 rows containing non-finite values (stat_boxplot).
```



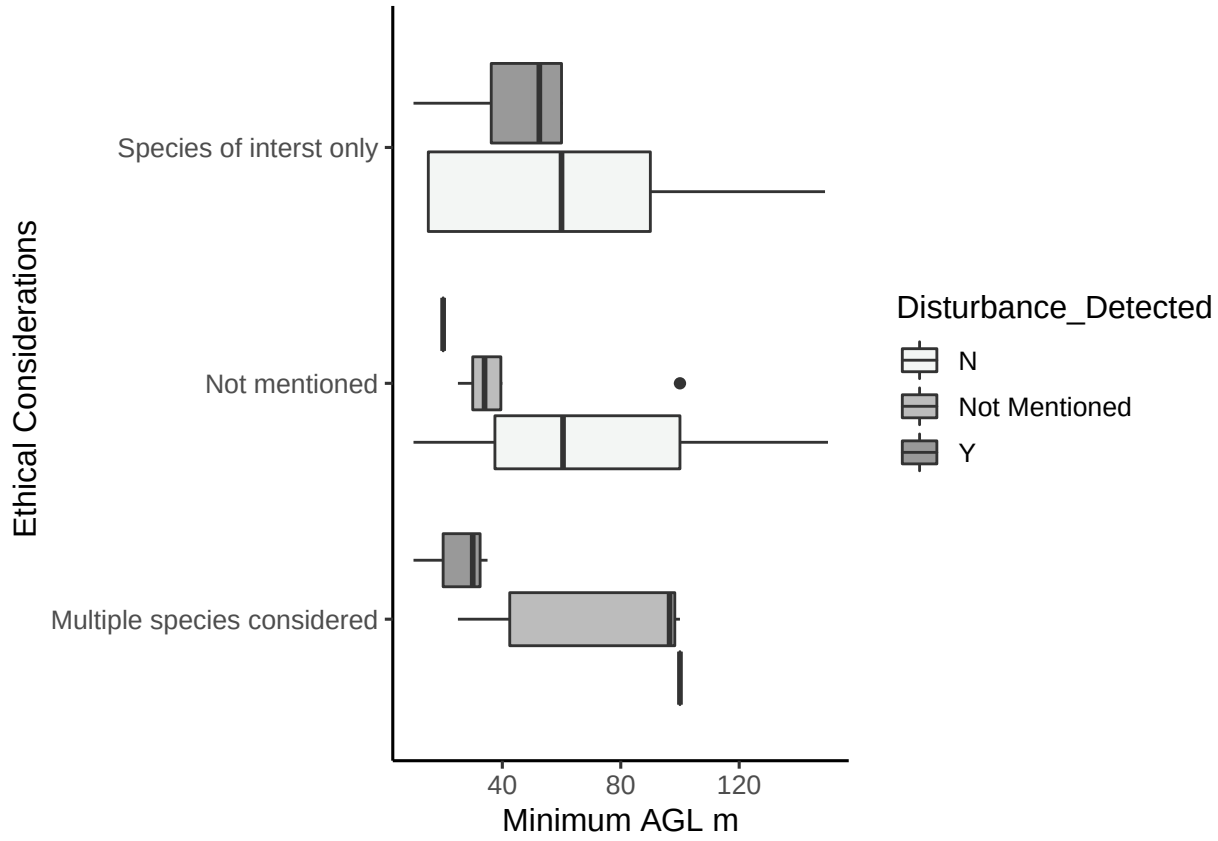

```
  ggplot(data = review, aes(x= Alt_MIN, y= UAV_size , fill = Disturbance_Detected))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=review$Disturbance_Detected,
                    values = c ("#f3f6f4", "#bcbcbc","#999999" ))+
    labs(x="Minimum AGL m", y=" UAV Weight in g")
```

```
## Warning: Removed 6 rows containing non-finite values (stat_boxplot).
```




```
 ggplot(data = review, aes(x= Alt_MIN, y= Ethical_considerations
, fill = Disturbance_Detected))+
 geom_boxplot ()+
 theme_classic2()+
 scale_fill_manual(breaks=review$Disturbance_Detected,
                   values = c ("#f3f6f4", "#bcbcbc","#999999" ))+
   labs(x="Minimum AGL m", y=" Ethical Considerations")
```

```
## Warning: Removed 6 rows containing non-finite values (stat_boxplot).
```



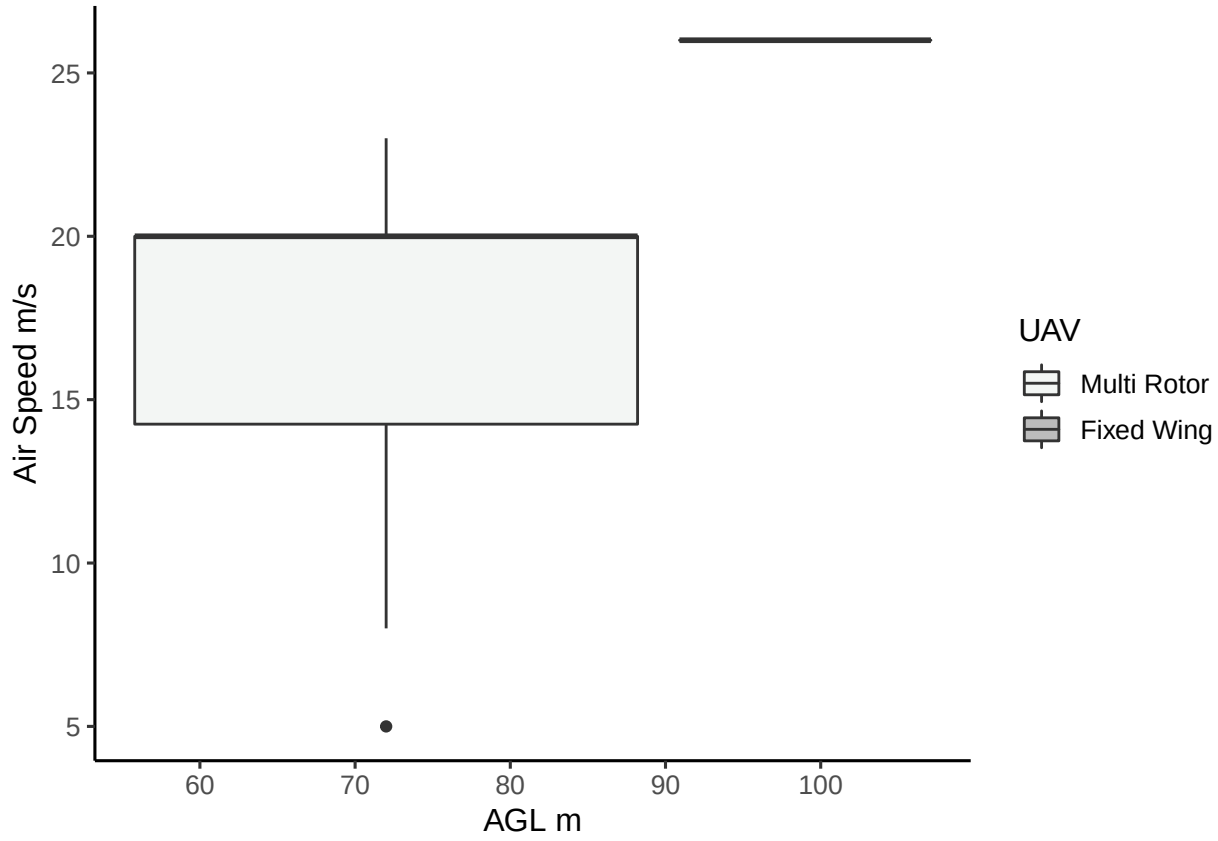
Review data collection

For the purpose of this review, we searched for scientific peer-reviewed papers using the Web of ScienceTM database on 2022/04/24. We used the timeframe from 2000/01/01 to 2022/04/24 and a topic search with the following Boolean operators: (((ALL=(Ungulates OR Wildlife OR Mammals)) AND ALL=(Drones OR UAV OR RPAS)) NOT ALL=(marine OR whale)) and only considered publications in the English language.

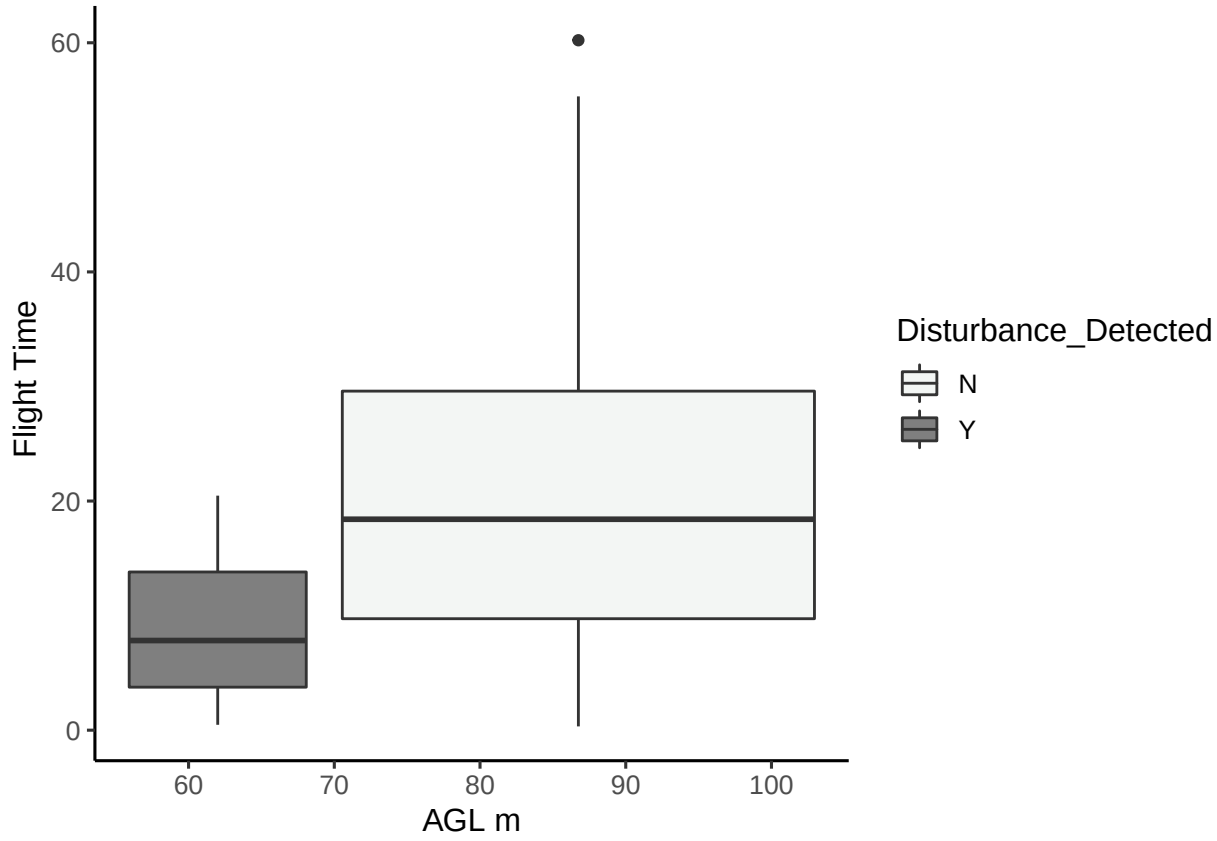
```
Flights <- read_excel("E:/Ungulate review/Ungulate.xlsx")
```

```
## New names:
## * Area -> Area...4
## * Species -> Species...5
## * Species -> Species...7
## * Area -> Area...15
```

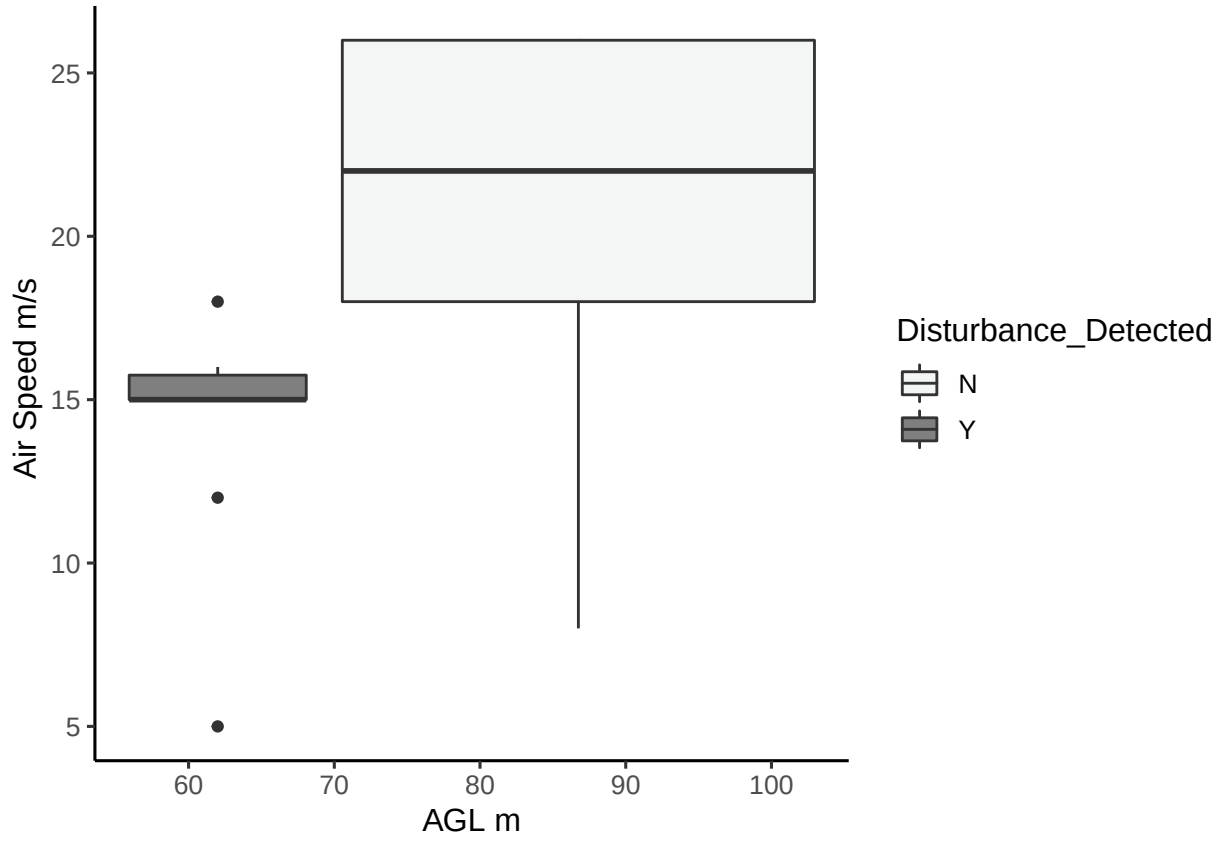
```
  ggplot(data = Flights, aes(x= Alt_Max, , y= Speed, fill = UAV))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=Flights$UAV,
                    values = c ("#f3f6f4", "#bcbcbc", "#999999" ))+
    labs(x="AGL m", y="Air Speed m/s")
```



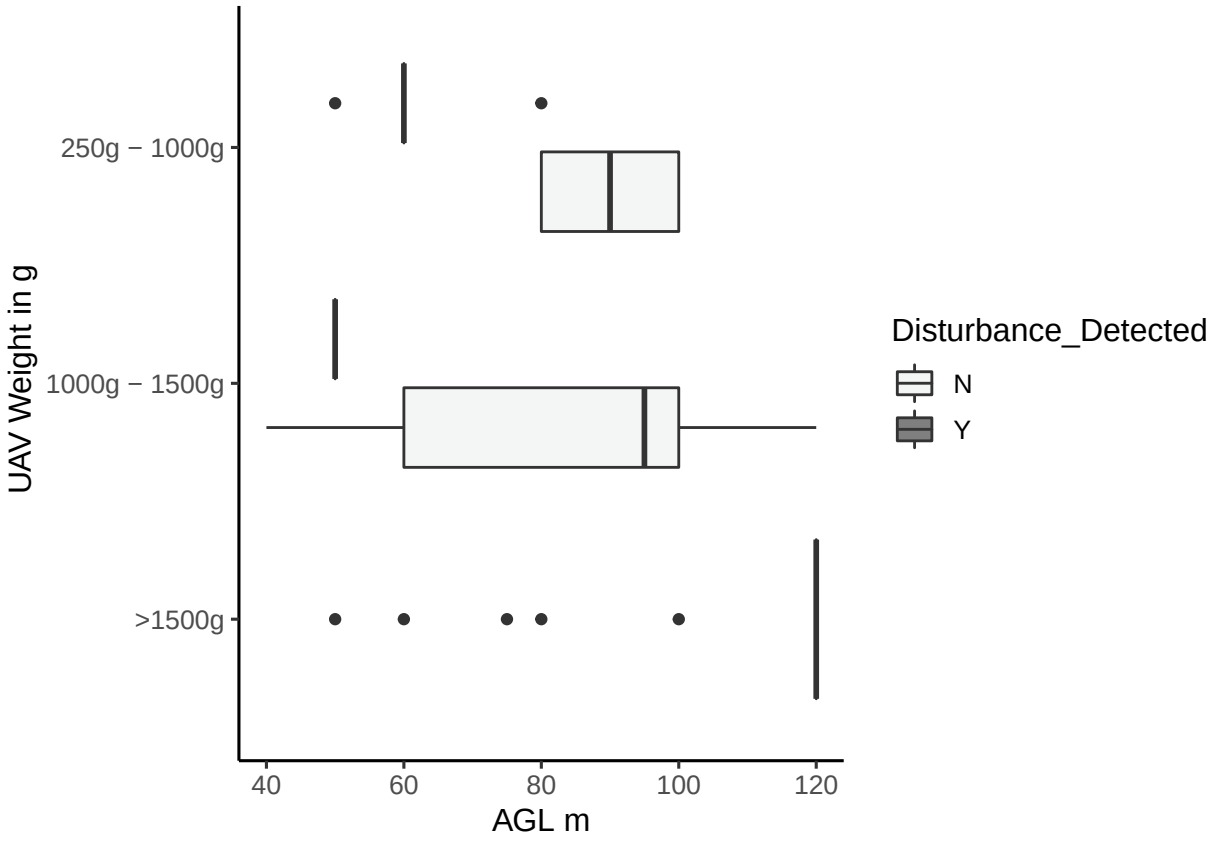

```
ggplot(data = Flights, aes(x= Alt_Max, , y= Flight_time, fill = Disturbance_Detected))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=Flights$Disturbance_Detected,
                    values = c ("#f3f6f4", "#bcbcbc"))+
    labs(x="AGL m", y=" Flight Time")
```




```
ggplot(data = Flights, aes(x= Alt_Max, , y= Speed, fill = Disturbance_Detected))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=Flights$Disturbance_Detected,
                    values = c ("#f3f6f4", "#bcbcbc"))+
    labs(x="AGL m", y=" Air Speed m/s")
```



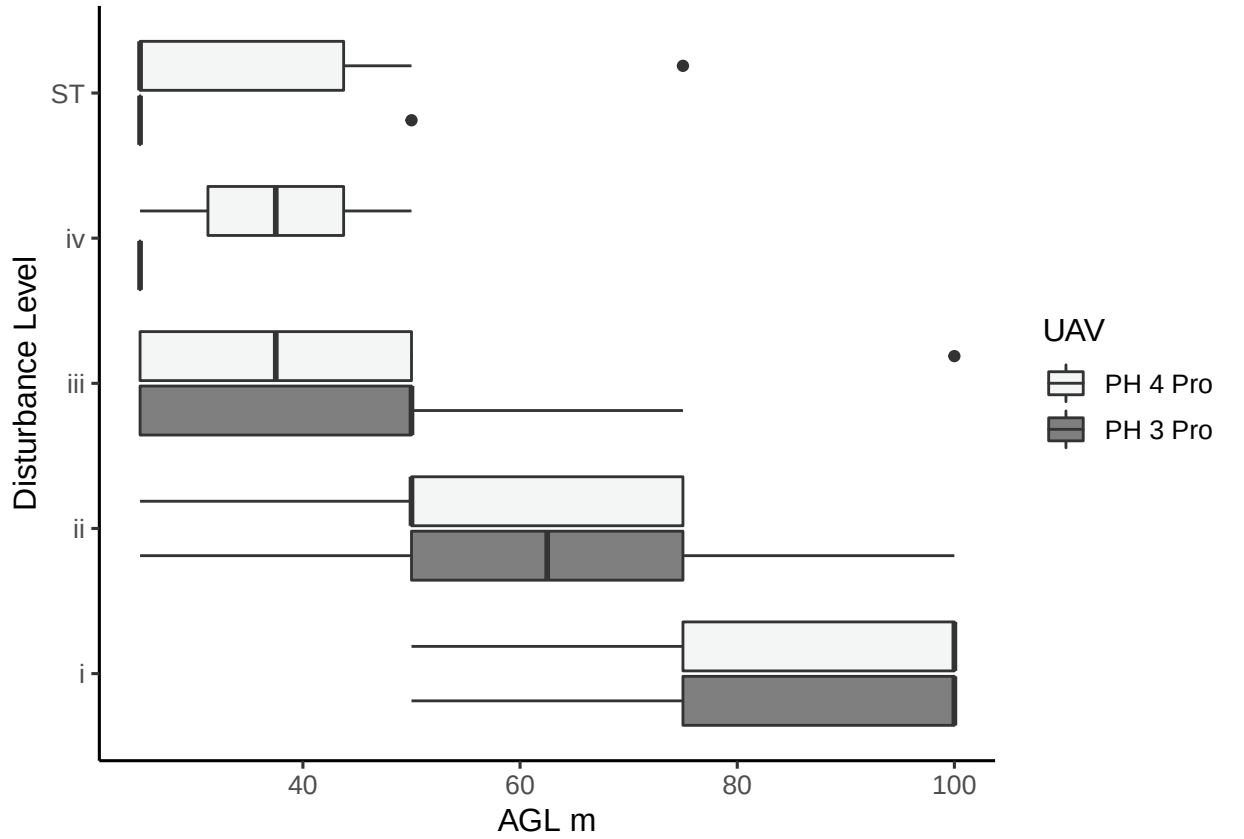

```
ggplot(data = Flights, aes(x= Alt_Max, , y= UAV_size, fill = Disturbance_Detected))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=Flights$Disturbance_Detected,
                    values = c ("#f3f6f4", "#bcbcbc"))+
    labs(x="AGL m", y=" UAV Weight in g")
```



Quantifying disturbance: a case study on the Western Derby Eland (Taurotragus derbianus derbianus)

The disturbance study was done on the Western Derby Eland (Taurotragus derbianus derbianus) in Bandia Reserve (Senegal). We used two types of multi-rotor UAVs: DJI (Da-Jiang Innovations Science and Technology Co., Ltd.) Phantom 3 Pro and DJI Phantom 4 Pro. All flights were launched > 200m away from the target.

```
Disturb <- read_excel("C:/Users/meyer/Desktop/Ungulate review/Q_disturb.xlsx")
  ggplot(data = Disturb, aes(x= AGL, , y= Disturbance, fill = UAV))+
  geom_boxplot ()+
  theme_classic2()+
  scale_fill_manual(breaks=Disturb$UAV,
                    values = c ("#f3f6f4", "#bcbcbc"))+
    labs(x="AGL m", y="Disturbance Level")
```



Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.

##Decision-tree Analysis

Import Libraries

```
library(FSelector)
library(rpart)
library(rpart.plot)
library(caret)
```

```
## Loading required package: lattice
```

```
##
## Attaching package: 'caret'
```

```
## The following object is masked from 'package:purrr':
##
##     lift
```

```
library(lattice)
library(dplyr)
library(xlsx)
library(data.tree)
library(data.table)
```

```
##
## Attaching package: 'data.table'
```

```
## The following object is masked from 'package:purrr':
##
##     transpose
```

```
## The following objects are masked from 'package:dplyr':
##
##     between, first, last
```

```
library(caTools)
```

Decision-tree Analysis

The decision-tree models using the minimum and maximum AGL altitude, and minimum and maximum speed to predict disturbance

```
review <- read_excel("E:/Ungulate review/review.xlsx")
```

```
## New names:
## * Species -> Species...6
## * Species -> Species...8
```

```
review <- select(review,Alt_Max, Alt_MIN, Speed_Min, Speed_Max, Disturbance_Detected)
str(review)
```

```
## tibble [36 x 5] (S3: tbl_df/tbl/data.frame)
##  $ Alt_Max             : num [1:36] 200 100 140 100 NA 100 60 50 100 NA ...
##  $ Alt_MIN             : num [1:36] 150 100 20 100 NA 100 30 30 35 180 ...
##  $ Speed_Min           : num [1:36] 22.2 13.9 13.9 11 NA ...
##  $ Speed_Max           : num [1:36] 22.2 13.9 13.9 11 NA ...
##  $ Disturbance_Detected: chr [1:36] "N" NA "Y" "N" ...
```

```
review$Disturbance_Detected <- factor(review$Disturbance_Detected)
str(review)
```

```
## tibble [36 x 5] (S3: tbl_df/tbl/data.frame)
##  $ Alt_Max             : num [1:36] 200 100 140 100 NA 100 60 50 100 NA ...
##  $ Alt_MIN             : num [1:36] 150 100 20 100 NA 100 30 30 35 180 ...
##  $ Speed_Min           : num [1:36] 22.2 13.9 13.9 11 NA ...
##  $ Speed_Max           : num [1:36] 22.2 13.9 13.9 11 NA ...
##  $ Disturbance_Detected: Factor w/ 2 levels "N","Y": 1 NA 2 1 2 1 2 NA 2 NA ...
```

Decision-tree Analysis

The decision tree model using minimum altitude and UAV size as an input to predict disturbance detected

```
set.seed(123)
sample = sample.split (review$Disturbance_Detected, SplitRatio = .70)
train = subset(review, sample == TRUE)
test= subset(review,sample== FALSE)
##Training the Decision tree Classifier To Predict Pregnacy
tree <- rpart(Disturbance_Detected~.,data=train)
tree.Disturbance_Detected.predicted <- predict (tree, test, type ='class')
confusionMatrix(tree.Disturbance_Detected.predicted,test$Disturbance_Detected)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction N Y
```

```
##          N 4 2
##          Y 0 0
##
##                Accuracy : 0.6667
##                  95% CI : (0.2228, 0.9567)
##     No Information Rate : 0.6667
##     P-Value [Acc > NIR] : 0.6804
##
##                   Kappa : 0
##
##  Mcnemar's Test P-Value : 0.4795
##
##             Sensitivity : 1.0000
##             Specificity : 0.0000
##          Pos Pred Value : 0.6667
##          Neg Pred Value :    NaN
##              Prevalence : 0.6667
##          Detection Rate : 0.6667
##    Detection Prevalence : 1.0000
##       Balanced Accuracy : 0.5000
##
##        'Positive' Class : N
##
```

```
prp(tree)
```

```
review <- read_excel("E:/Ungulate review/review.xlsx")
```

```
## New names:
## * Species -> Species...6
## * Species -> Species...8
```

```
review <- select(review, Alt_MIN, UAV_size, Disturbance_Detected)
str(review)
```

```
## tibble [36 x 3] (S3: tbl_df/tbl/data.frame)
##  $ Alt_MIN             : num [1:36] 150 100 20 100 NA 100 30 30 35 180 ...
##  $ UAV_size            : chr [1:36] ">1500g" ">1500g" ">1500g" ">1500g" ...
##  $ Disturbance_Detected: chr [1:36] "N" NA "Y" "N" ...
```

```
review$Disturbance_Detected <- factor(review$Disturbance_Detected)
str(review)
```

```
## tibble [36 x 3] (S3: tbl_df/tbl/data.frame)
##  $ Alt_MIN             : num [1:36] 150 100 20 100 NA 100 30 30 35 180 ...
##  $ UAV_size            : chr [1:36] ">1500g" ">1500g" ">1500g" ">1500g" ...
##  $ Disturbance_Detected: Factor w/ 2 levels "N","Y": 1 NA 2 1 2 1 2 NA 2 NA ...
```

```
set.seed(123)
sample = sample.split (review$Disturbance_Detected, SplitRatio = .70)
train = subset(review, sample == TRUE)
test= subset(review,sample== FALSE)
##Training the Decision tree Classifier To Predict Pregnacy
tree <- rpart(Disturbance_Detected~.,data=train)
tree.Disturbance_Detected.predicted <- predict (tree, test, type ='class')
confusionMatrix(tree.Disturbance_Detected.predicted,test$Disturbance_Detected)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction N Y
##          N 4 2
##          Y 0 0
##
##                Accuracy : 0.6667
##                  95% CI : (0.2228, 0.9567)
##     No Information Rate : 0.6667
##     P-Value [Acc > NIR] : 0.6804
##
##                   Kappa : 0
##
##  Mcnemar's Test P-Value : 0.4795
##
##             Sensitivity : 1.0000
##             Specificity : 0.0000
##          Pos Pred Value : 0.6667
##          Neg Pred Value :    NaN
##              Prevalence : 0.6667
##          Detection Rate : 0.6667
##    Detection Prevalence : 1.0000
##       Balanced Accuracy : 0.5000
##
```

```
##        'Positive' Class : N
##
```

```
prp(tree)
```


```
UngulateB <- read_excel("E:/Ungulate review/Ungulate.xlsx")
```

```
## New names:
## * Area -> Area...4
## * Species -> Species...5
## * Species -> Species...7
## * Area -> Area...15
```

```
UngulateB <- select(UngulateB, Alt_Max, Flight_time, UAV)
str(UngulateB)
```

```
## tibble [121 x 3] (S3: tbl_df/tbl/data.frame)
##  $ Alt_Max    : num [1:121] 60 80 120 120 120 120 120 120 120 120 ...
##  $ Flight_time: num [1:121] 16.2 21.4 51.7 27.3 18.4 ...
##  $ UAV        : chr [1:121] "Multi Rotor" "Fixed Wing" "Fixed Wing" "Fixed Wing" ...
```

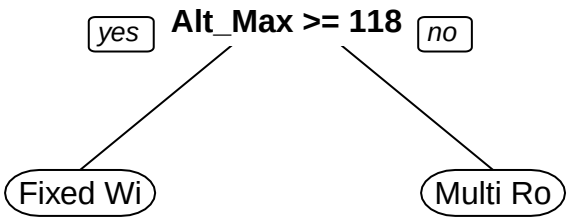
```
UngulateB$UAV <- factor(UngulateB$UAV)
str(UngulateB)
```

```
## tibble [121 x 3] (S3: tbl_df/tbl/data.frame)
##  $ Alt_Max    : num [1:121] 60 80 120 120 120 120 120 120 120 120 ...
##  $ Flight_time: num [1:121] 16.2 21.4 51.7 27.3 18.4 ...
##  $ UAV        : Factor w/ 2 levels "Fixed Wing","Multi Rotor": 2 1 1 1 1 1 1 1 1 1 ...
```

```r
set.seed(123)
sample = sample.split (UngulateB$UAV, SplitRatio = .70)
train = subset(UngulateB, sample == TRUE)
test= subset(UngulateB,sample== FALSE)
##Training the Decision tree Classifier To Predict Pregnacy
tree <- rpart(UAV~.,data=train)
tree.UAV.predicted <- predict (tree, test, type ='class')
confusionMatrix(tree.UAV.predicted,test$UAV)
```

```
## Confusion Matrix and Statistics
##
##              Reference
## Prediction    Fixed Wing Multi Rotor
##   Fixed Wing          10           0
##   Multi Rotor          1          26
##
##                Accuracy : 0.973
##                  95% CI : (0.8584, 0.9993)
##     No Information Rate : 0.7027
##     P-Value [Acc > NIR] : 3.565e-05
##
##                   Kappa : 0.9336
##
##  Mcnemar's Test P-Value : 1
##
##             Sensitivity : 0.9091
##             Specificity : 1.0000
##          Pos Pred Value : 1.0000
##          Neg Pred Value : 0.9630
##              Prevalence : 0.2973
##          Detection Rate : 0.2703
##    Detection Prevalence : 0.2703
##       Balanced Accuracy : 0.9545
##
##        'Positive' Class : Fixed Wing
##
```

```r
prp(tree)
```




```
disturb1 <- read_excel("E:/Ungulate review/disturb.xlsx")
disturb1 <- select(disturb1, AGL, Disturbance, UAV)
str(disturb1)
```

```
## tibble [80 x 3] (S3: tbl_df/tbl/data.frame)
##  $ AGL        : num [1:80] 100 75 50 25 100 75 50 25 100 75 ...
##  $ Disturbance: chr [1:80] "i" "i" "ii" "iii" ...
##  $ UAV        : chr [1:80] "PH 4 Pro" "PH 4 Pro" "PH 4 Pro" "PH 4 Pro" ...
```

```
disturb1$UAV <- factor(disturb1$UAV)
str(disturb1)
```

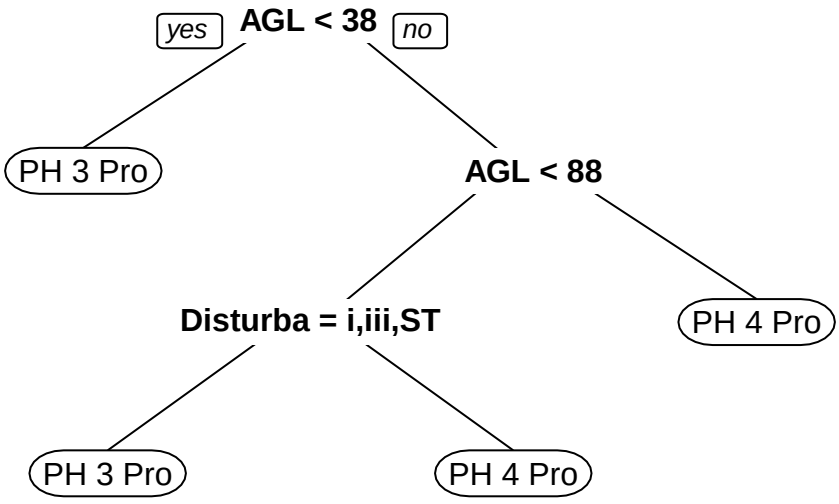
```
## tibble [80 x 3] (S3: tbl_df/tbl/data.frame)
##  $ AGL        : num [1:80] 100 75 50 25 100 75 50 25 100 75 ...
##  $ Disturbance: chr [1:80] "i" "i" "ii" "iii" ...
##  $ UAV        : Factor w/ 2 levels "PH 3 Pro","PH 4 Pro": 2 2 2 2 2 2 2 2 2 2 ...
```

```
set.seed(123)
sample = sample.split (disturb1$UAV, SplitRatio = .70)
train = subset(disturb1, sample == TRUE)
test= subset(disturb1,sample== FALSE)
##Training the Decision tree
tree <- rpart(UAV~.,data=train)
tree.UAV.predicted <- predict (tree, test, type ='class')
confusionMatrix(tree.UAV.predicted,test$UAV)
```

```
## Confusion Matrix and Statistics
##
```

```
##           Reference
## Prediction PH 3 Pro PH 4 Pro
##   PH 3 Pro        5        9
##   PH 4 Pro        7        3
##
##                Accuracy : 0.3333
##                  95% CI : (0.1563, 0.5532)
##     No Information Rate : 0.5
##     P-Value [Acc > NIR] : 0.9680
##
##                   Kappa : -0.3333
##
##  Mcnemar's Test P-Value : 0.8026
##
##             Sensitivity : 0.4167
##             Specificity : 0.2500
##          Pos Pred Value : 0.3571
##          Neg Pred Value : 0.3000
##              Prevalence : 0.5000
##          Detection Rate : 0.2083
##    Detection Prevalence : 0.5833
##       Balanced Accuracy : 0.3333
##
##        'Positive' Class : PH 3 Pro
##
```

```
prp(tree)
```


yes
AGL < 38
no
PH 3 Pro
AGL < 88
Disturba = i,iii,ST
PH 4 Pro
PH 3 Pro
PH 4 Pro