Predicting Bean Type Based on Metamorphic Measurements

Analysis by Gavin Gunawardena

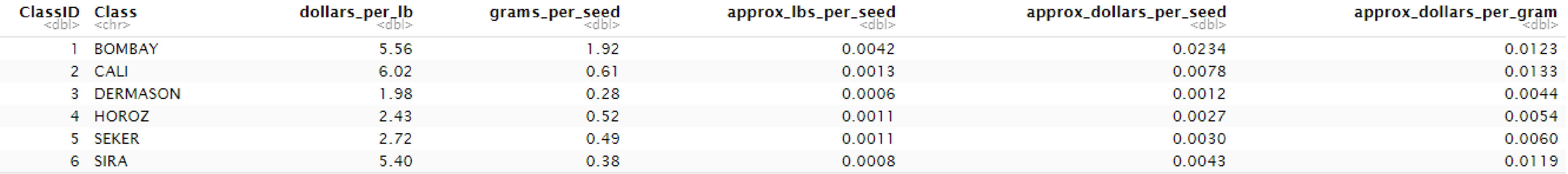
Utilizing a dataset from Seed Size and Shape Analysis of Registered Common Bean (Phaseolus vulgaris L.) Cultivars in Turkey Using Digital Photography
from the Journal of Agricultural Science

Intro and Objective

- Objective: Test various predictive analytics algorithms for multiclass classification to sort beans based on their morphometric measurements
- Dataset
  - 3000 observations
  - 500 observations per class
  - 6 classes
  - No additional assumptions
- Measures
  - Accuracy
  - Weight differential between predictions and actual values
  - Cost differential between predictions and actual values

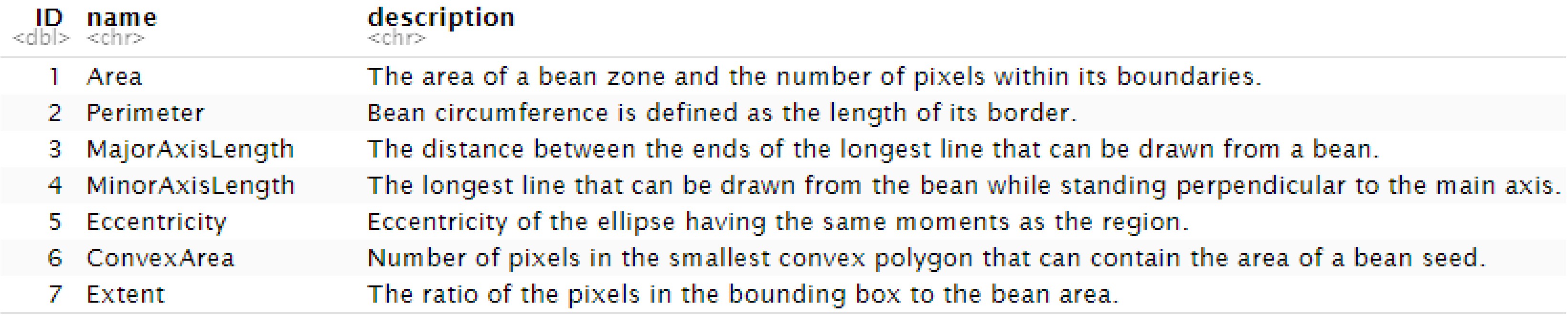
Intro and Objective

- Dependent Variable Classes:



ClassID <dbl>	Class <chr>	dollars_per_lb <dbl>	grams_per_seed <dbl>	approx_lbs_per_seed <dbl>	approx_dollars_per_seed <dbl>	approx_dollars_per_gram <dbl>
1	BOMBAY	5.56	1.92	0.0042	0.0234	0.0123
2	CALI	6.02	0.61	0.0013	0.0078	0.0133
3	DERMASON	1.98	0.28	0.0006	0.0012	0.0044
4	HOROZ	2.43	0.52	0.0011	0.0027	0.0054
5	SEKER	2.72	0.49	0.0011	0.0030	0.0060
6	SIRA	5.40	0.38	0.0008	0.0043	0.0119

- Independent Variables:

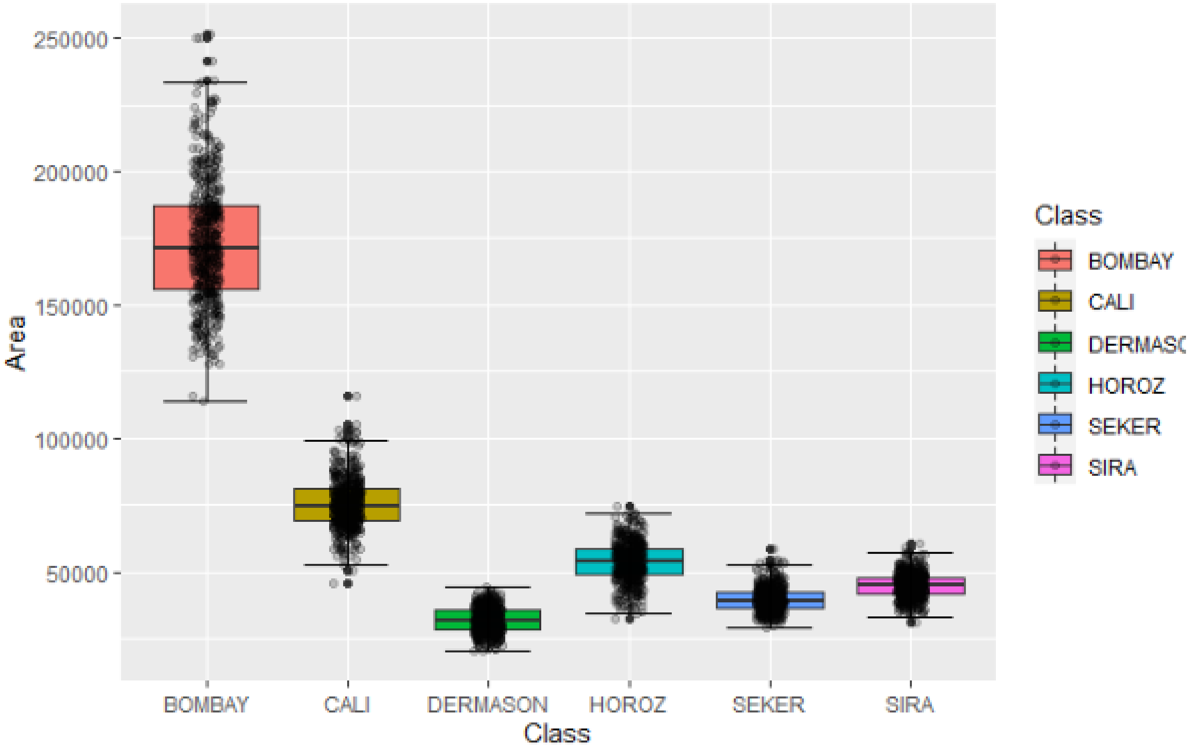


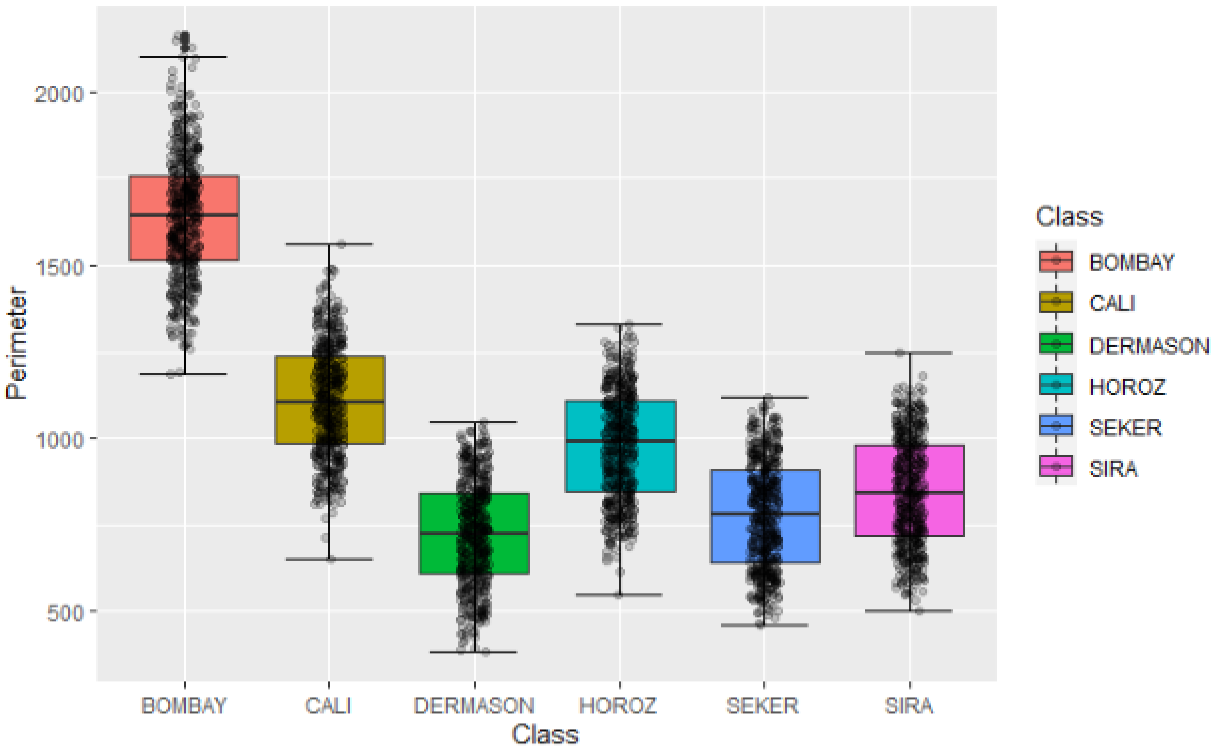
ID <dbl>	name <chr>	description <chr>
1	Area	The area of a bean zone and the number of pixels within its boundaries.
2	Perimeter	Bean circumference is defined as the length of its border.
3	MajorAxisLength	The distance between the ends of the longest line that can be drawn from a bean.
4	MinorAxisLength	The longest line that can be drawn from the bean while standing perpendicular to the main axis.
5	Eccentricity	Eccentricity of the ellipse having the same moments as the region.
6	ConvexArea	Number of pixels in the smallest convex polygon that can contain the area of a bean seed.
7	Extent	The ratio of the pixels in the bounding box to the bean area.

Methods

- Validation Technique
  - Leave One Out Cross-Validation
  - 80/20 data split with 80% of the data being used for training and validation while the last 20 is used to test the final model(s) and obtain a final accuracy rate
- Normalization/Standardization Technique
  - Z-Score
- Feature Selection Method
  - Best Subset Selection with residual sum of squares and then adjusted R^2 as the criteria for feature selection
- Statistical Models
  - Multinomial Logistic Regression
  - Linear Discriminant Analysis
  - K-Nearest Neighbors Classifier
  - Quadratic Discriminant Analysis
  - Naïve Bayes

Exploratory Analysis





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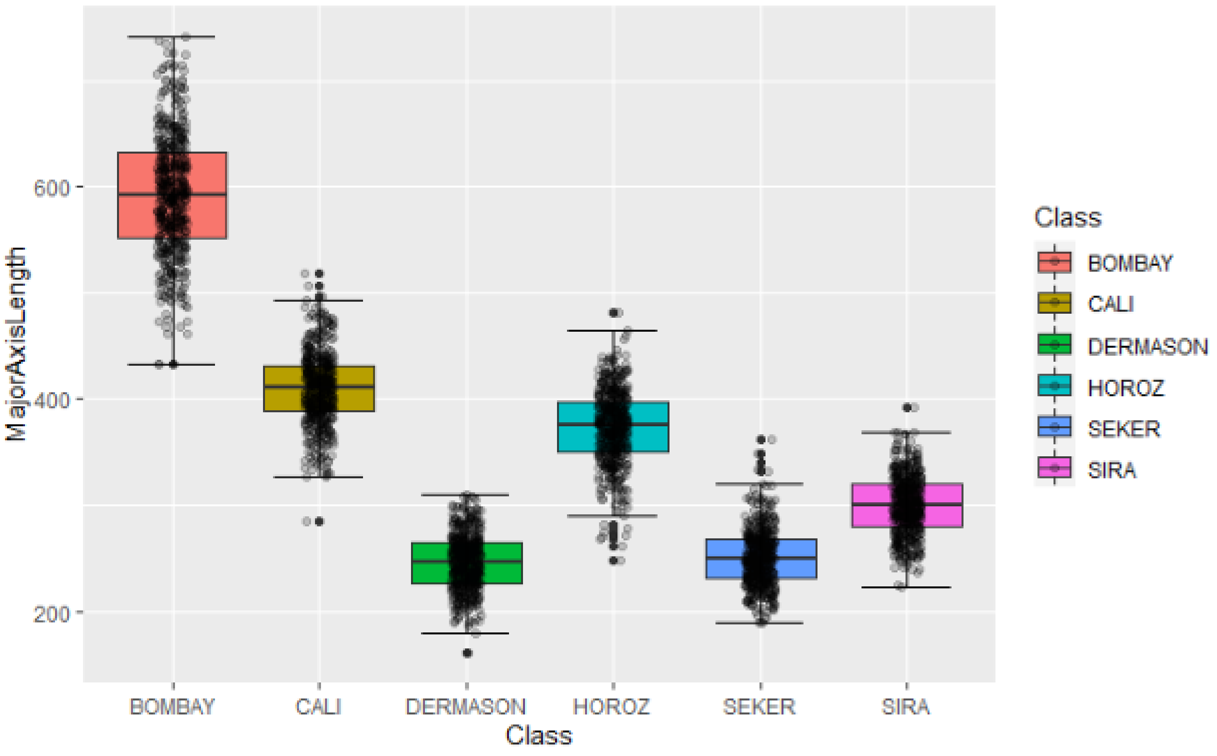

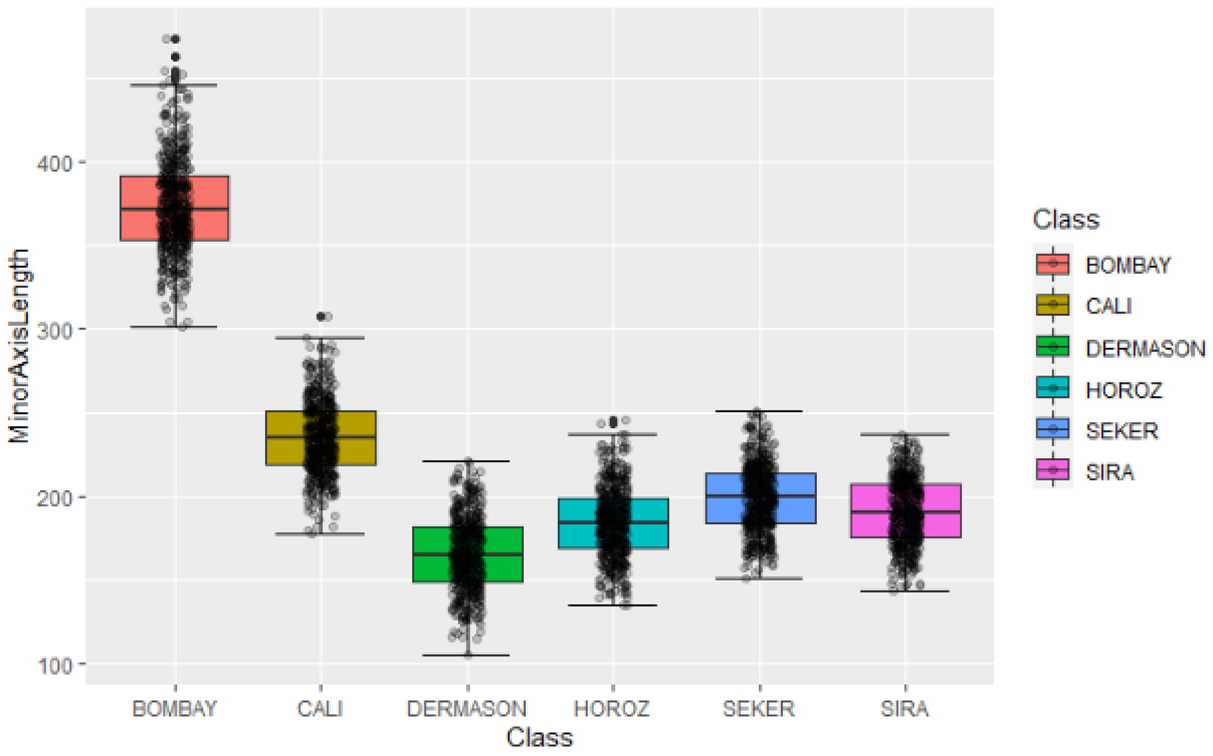

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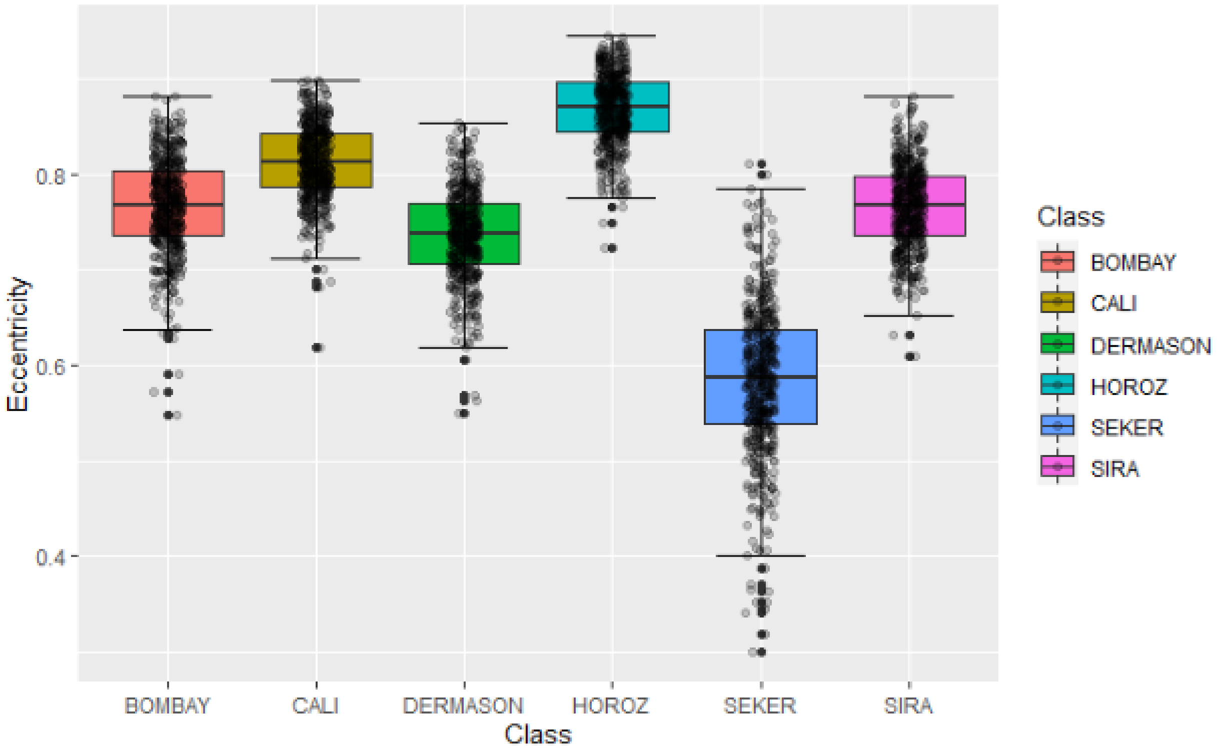

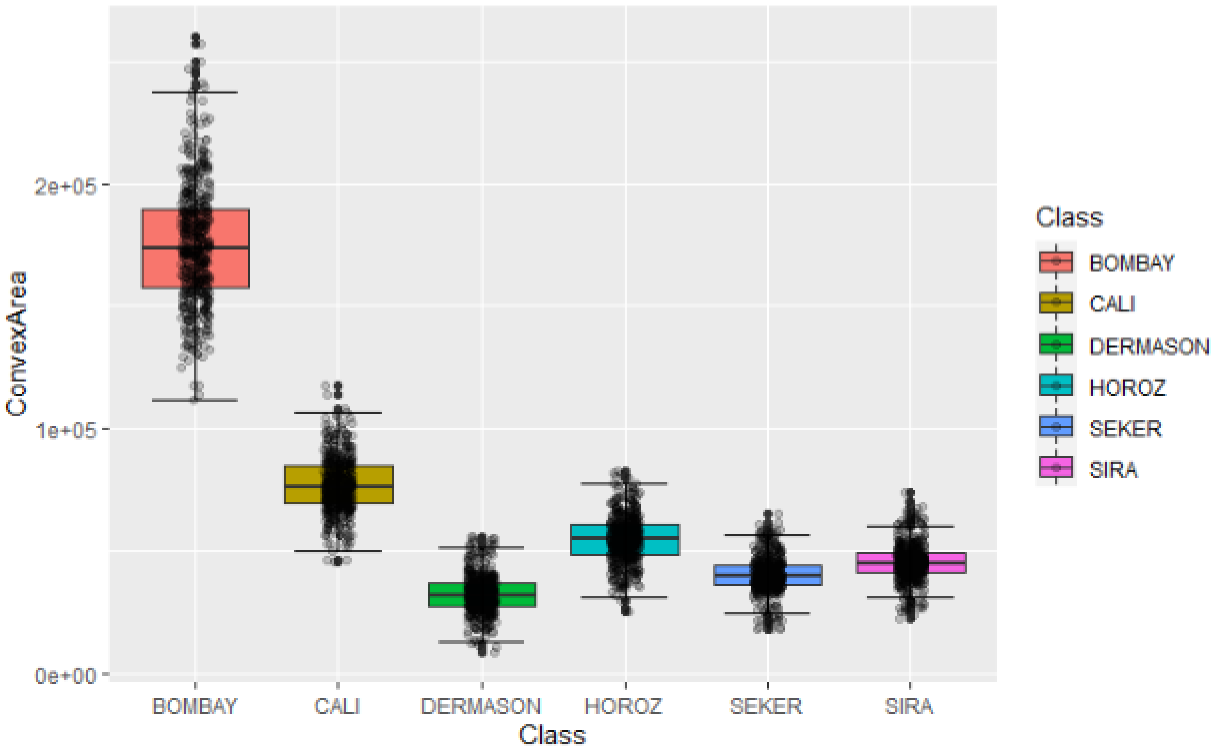

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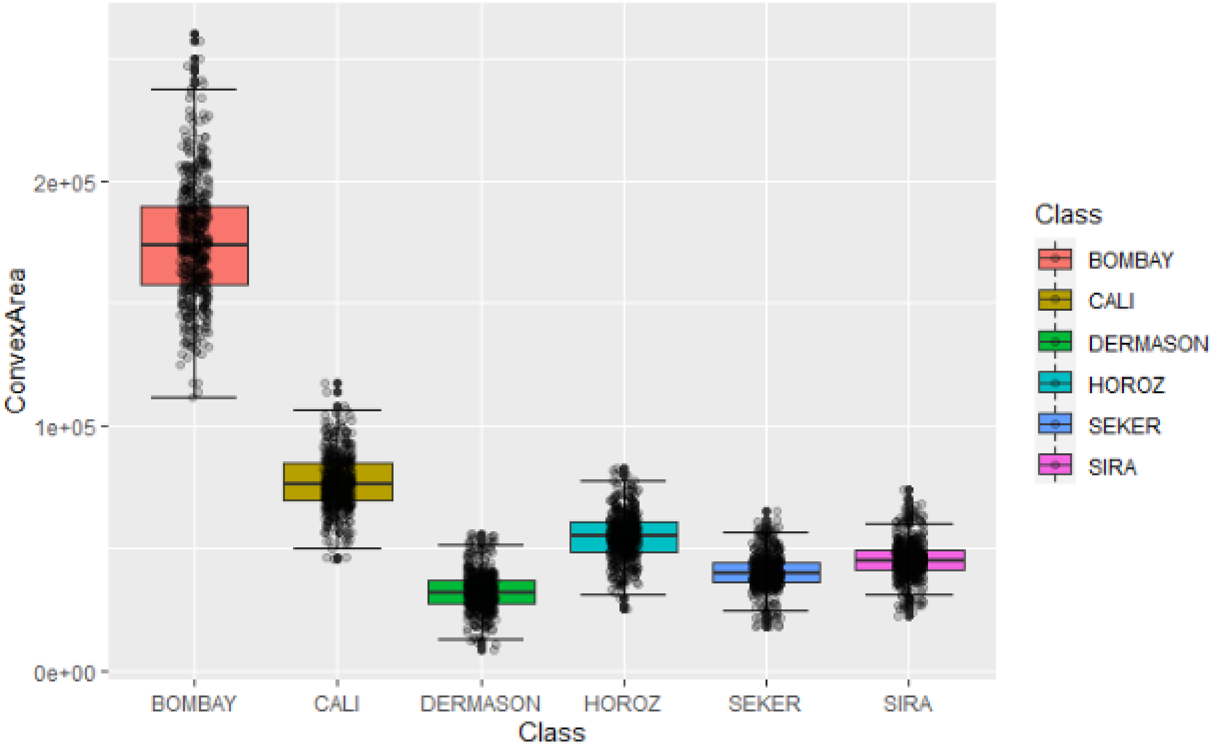

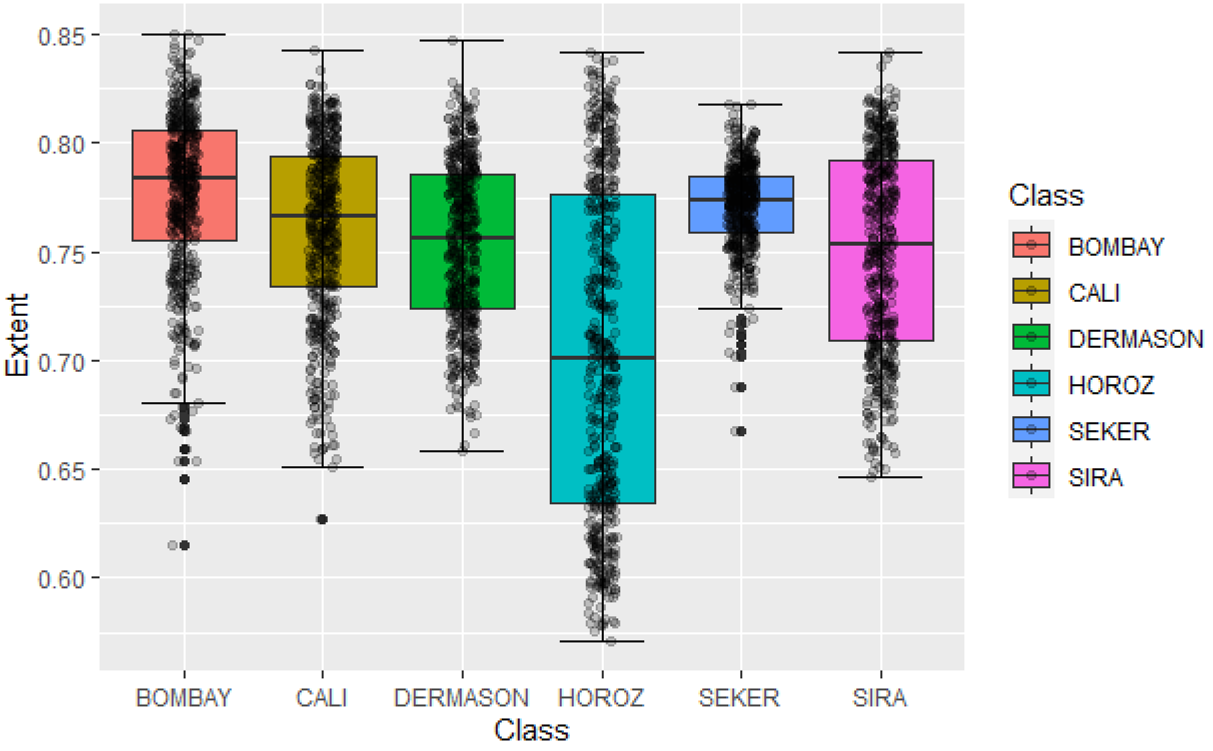

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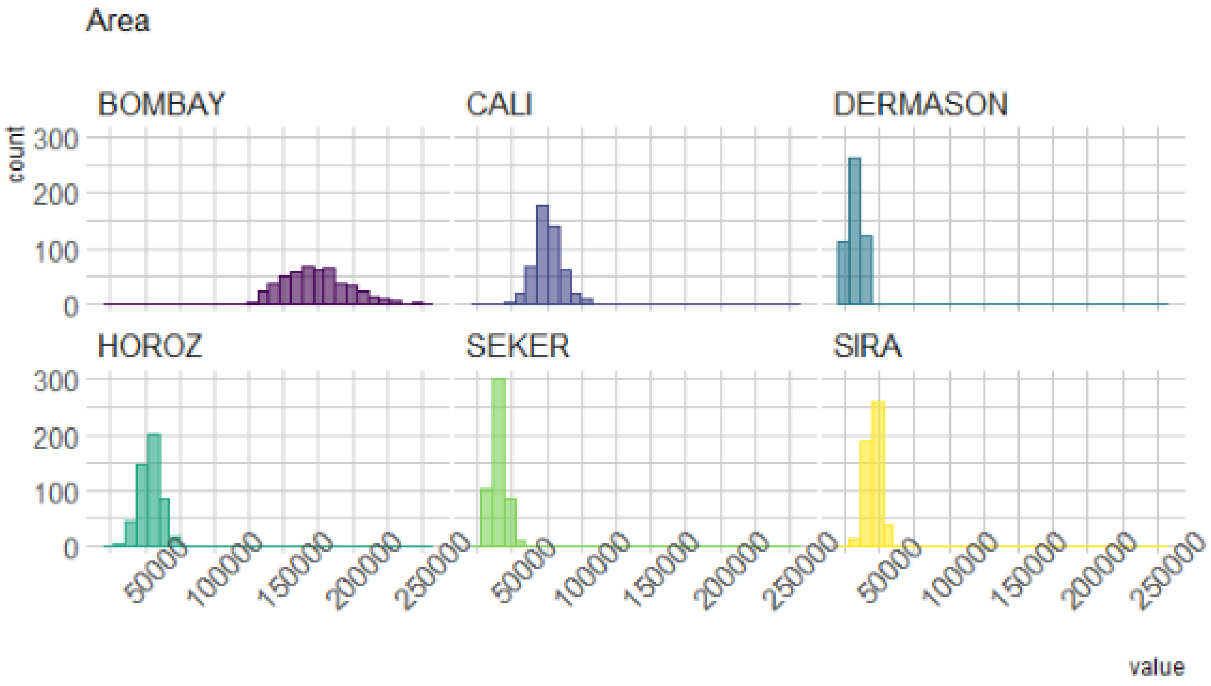

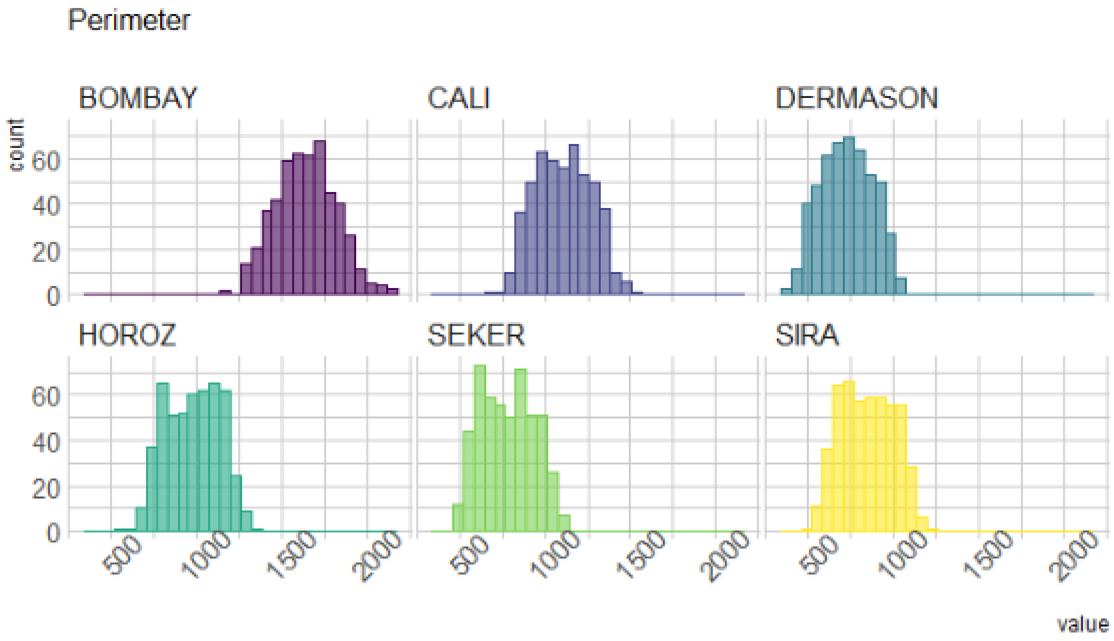

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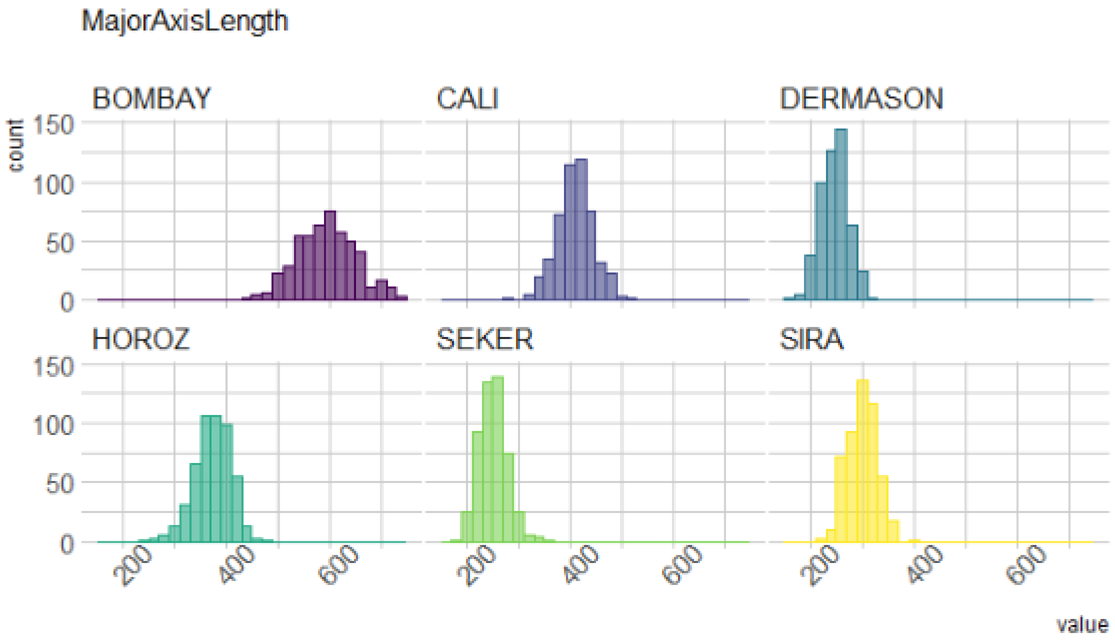

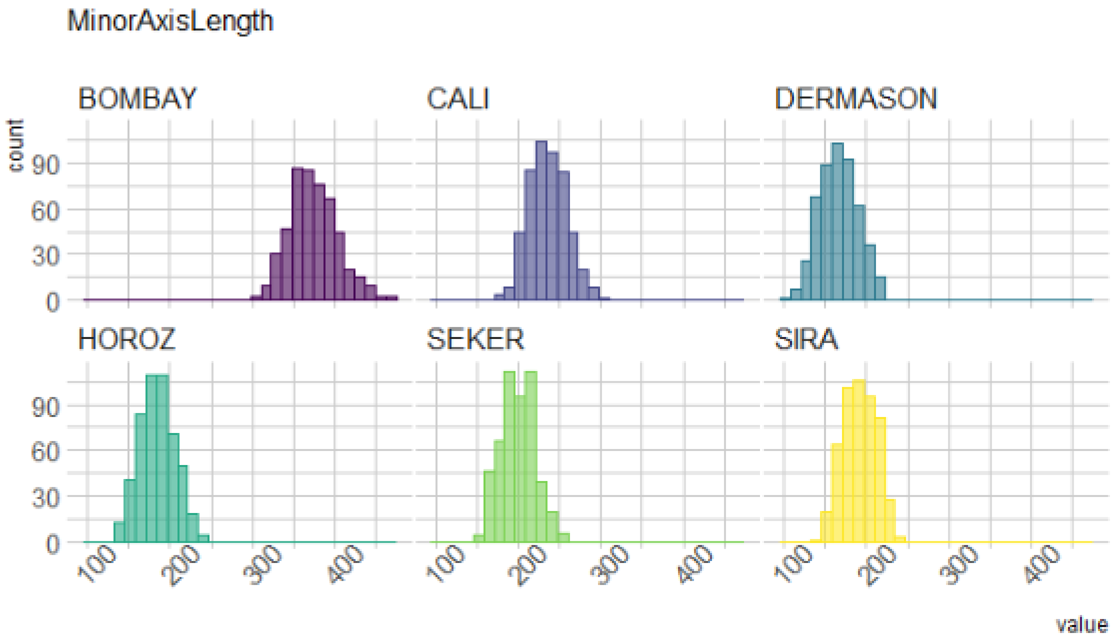

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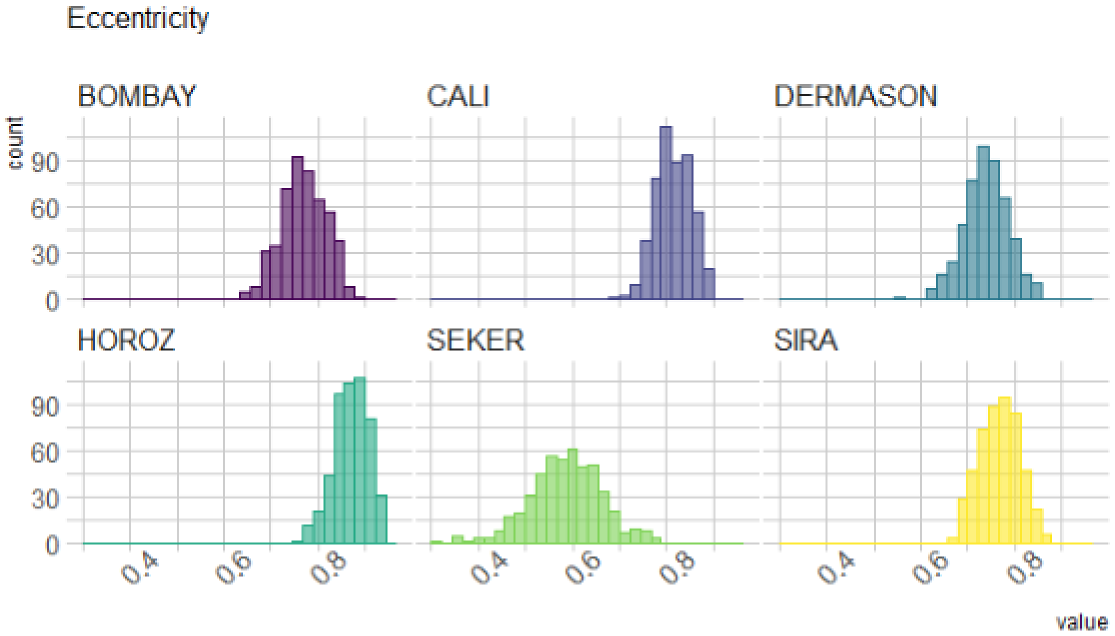

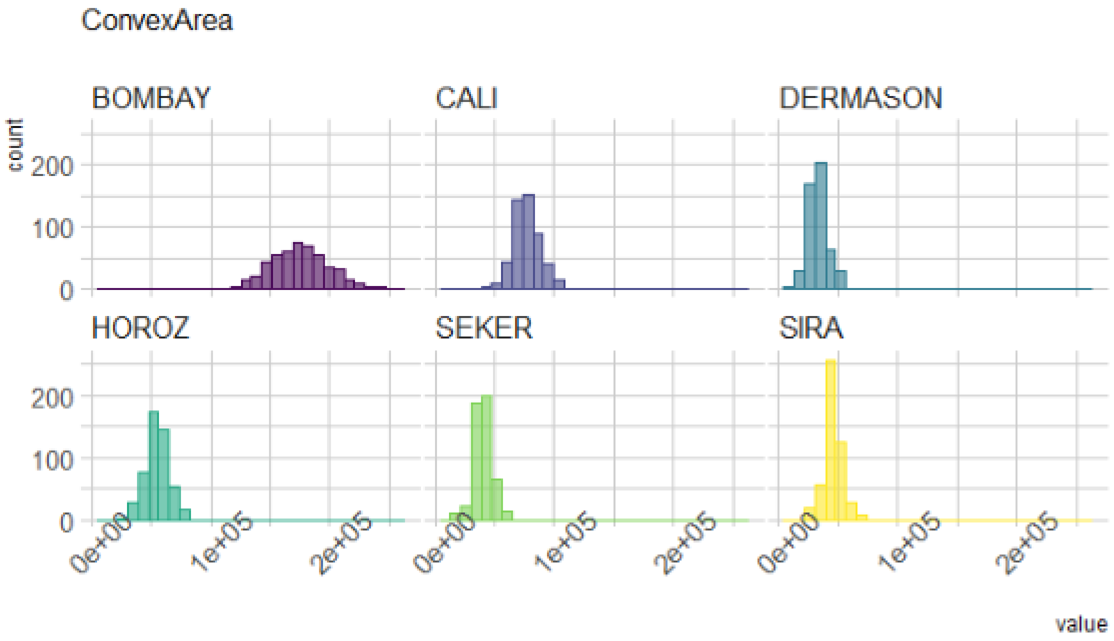

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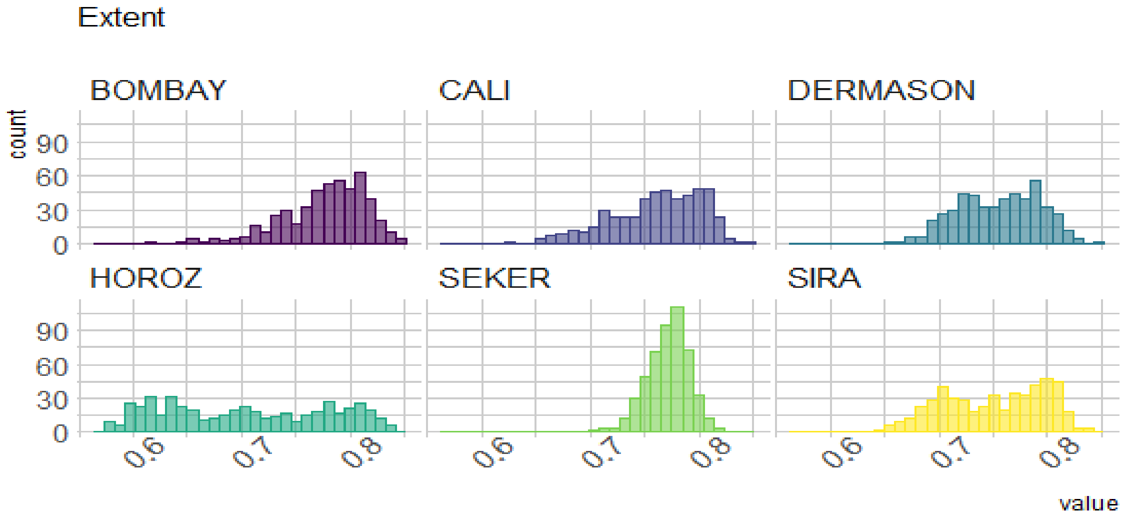
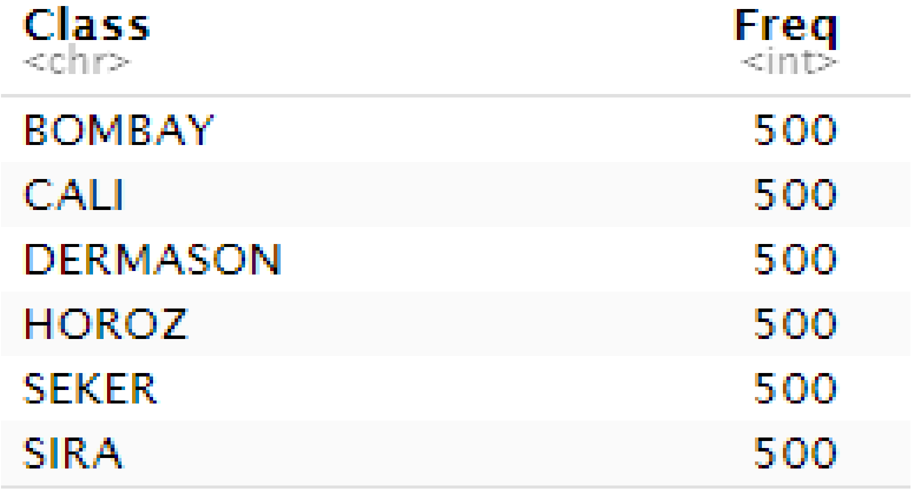


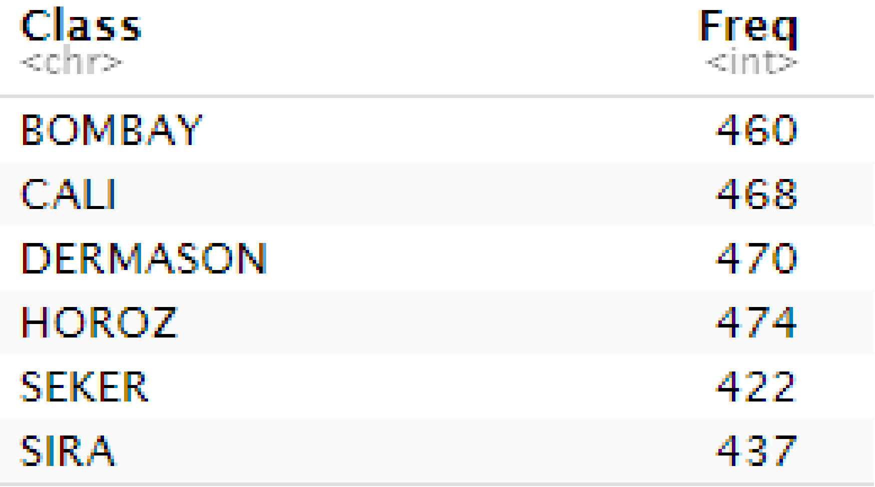


Class	Freq
<chr>	<int>
BOMBAY	500
CALI	500
DERMASON	500
HOROZ	500
SEKER	500
SIRA	500

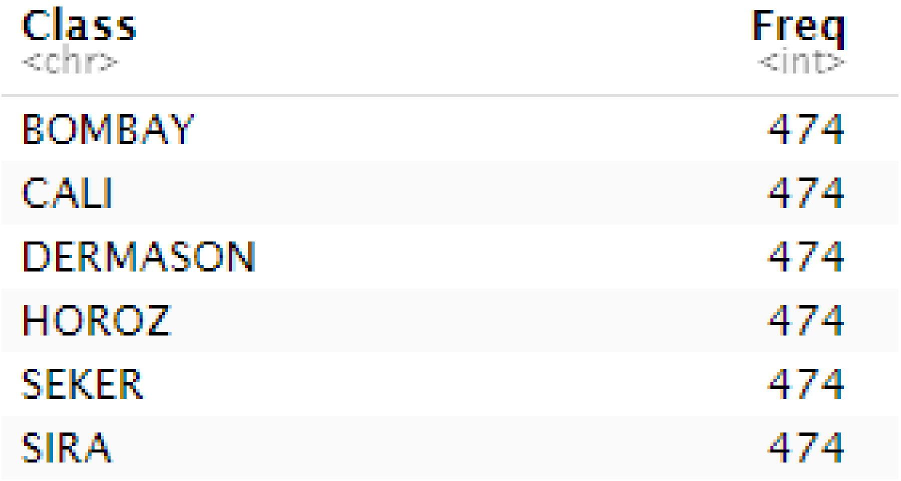
- Results:
  - Most of the data is normally distributed with the least normally distributed variable being Extent
  - The dataset has many outliers as revealed by the boxplots. These will be removed in order optimize the predictive models.

Exploratory Analysis

- Results After Outlier Removal
  - Dataset was reduced from 3000 observations to 2731 but bolstered back to 3000 via oversampling minority datasets:



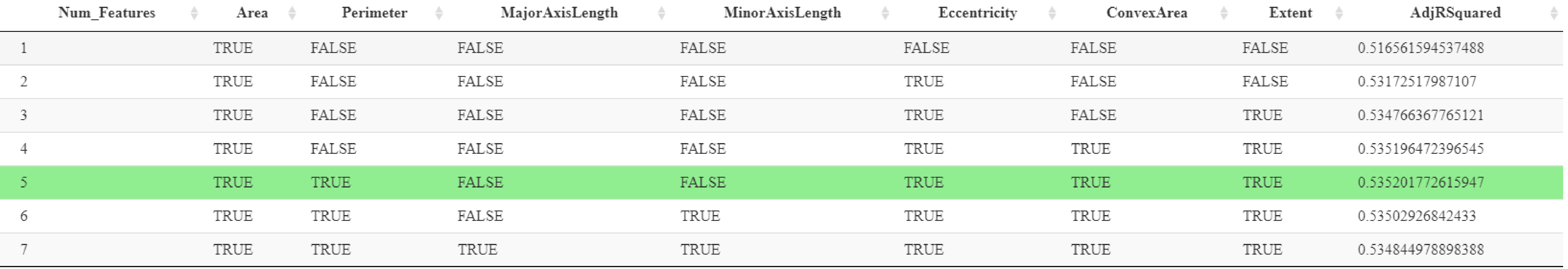
Class	Freq
<chr>	<int>
BOMBAY	460
CALI	468
DERMASON	470
HOROZ	474
SEKER	422
SIRA	437



Class	Freq
<chr>	<int>
BOMBAY	474
CALI	474
DERMASON	474
HOROZ	474
SEKER	474
SIRA	474

Predictive Analysis

- Best Subset Selection results:
  - For each possible count of features, 1 thru 7, each were iteratively tested for their ability to accurately predict bean classes
  - The set with 5 features was chosen as it had the highest adjusted R^2 score

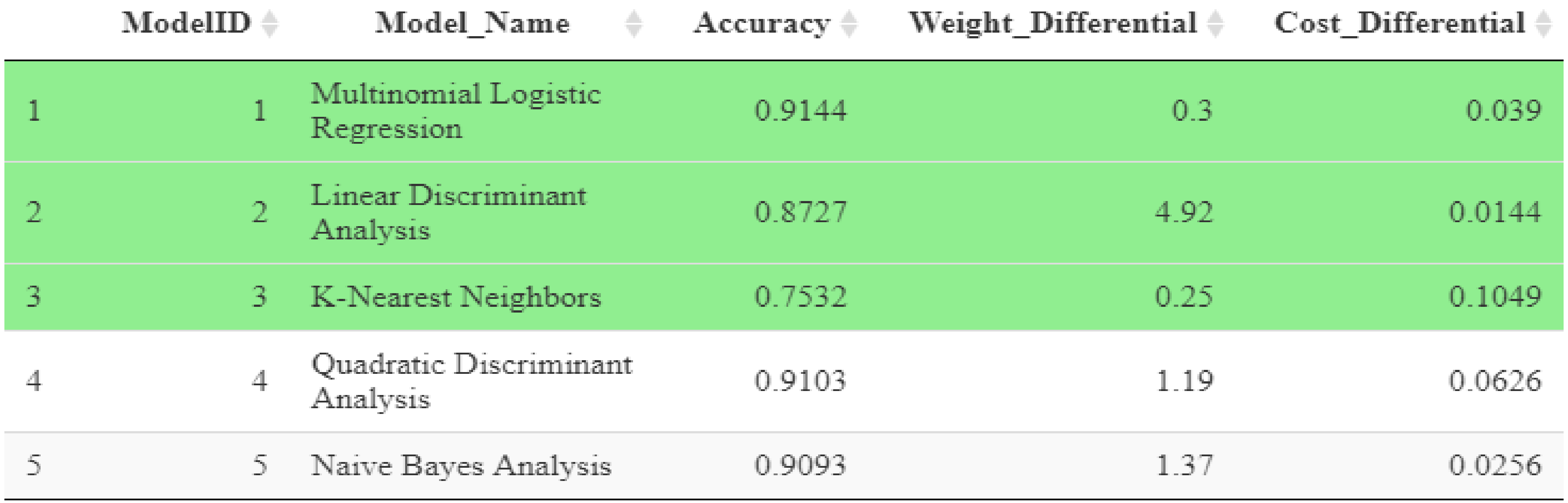


Num_Features	Area	Perimeter	MajorAxisLength	MinorAxisLength	Eccentricity	ConvexArea	Extent	AdjRSquared
1	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	0.516561594537488
2	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	0.53172517987107
3	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	0.534766367765121
4	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	0.535196472396545
5	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE	0.535201772615947
6	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE	TRUE	0.53502926842433
7	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	0.534844978898388

**This chart shows the results of Best Subset Selection. Number of features is shown on the left, with the selected features being represented by their respective names and whether they were present in the results of each test. This was completed in an attempt to maximize adjusted R^2. 5 features allowed for the optimal(maximum) result.*

Results Analysis

- Leave-One-Out Cross Validation Results and chosen models:

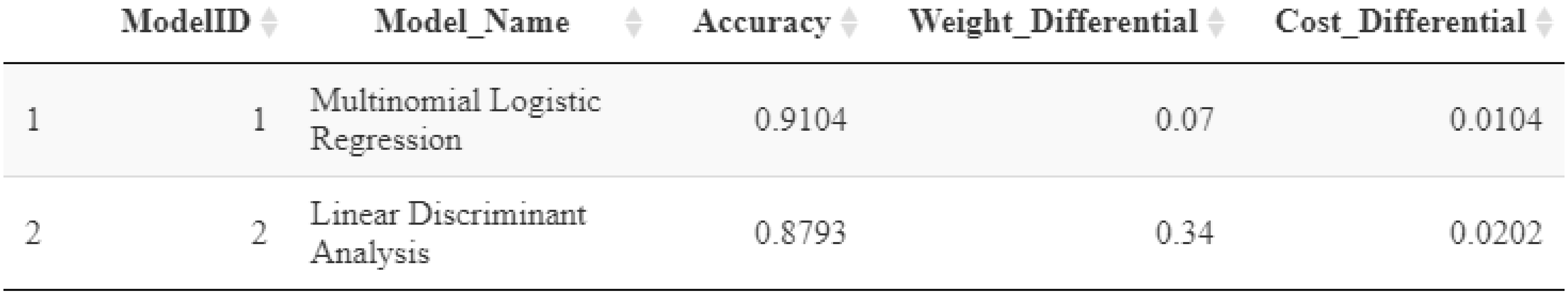


	ModelID	Model_Name	Accuracy	Weight_Differential	Cost_Differential
1	1	Multinomial Logistic Regression	0.9144	0.3	0.039
2	2	Linear Discriminant Analysis	0.8727	4.92	0.0144
3	3	K-Nearest Neighbors	0.7532	0.25	0.1049
4	4	Quadratic Discriminant Analysis	0.9103	1.19	0.0626
5	5	Naive Bayes Analysis	0.9093	1.37	0.0256

- 3 models were optimal but for different categories.
- Multinomial Logistic Regression and Linear Discriminant Analysis were chosen due to their higher accuracy rates and due to having a lower cost differential, which is being prioritized over weight differential.

Results Analysis

- Test dataset results:



	ModelID	Model_Name	Accuracy	Weight_Differential	Cost_Differential
1	1	Multinomial Logistic Regression	0.9104	0.07	0.0104
2	2	Linear Discriminant Analysis	0.8793	0.34	0.0202

- The results on the test dataset indicated strong results on all three measures and by both models.

Conclusions

- Multinomial Logistic Regression and Linear Discriminant Analysis were chosen as the most optimal when making predictions on bean types based on the morphometric measurement features
    - Both had accuracy rates of over 87% on the validation and test datasets, with Multinomial Logistic Regression having an accuracy rate of over 91%
    - Linear Discriminant Analysis had the lowest cost differential when compared to the other models

References

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