Group_9_Analysis

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Note that some comments appear as both comments in the code (denoted by the symbol #) and text to be included in the knitted pdf file. This is done so that regardless of whether one is looking at the RMarkdown file or the knitted pdf file it is clear what the purpose of a block of code or table/chart is.

Exploratory Data Analysis

Have a look at the summary statistics of the raw data.

Table 1: Summary statistics of continuous variables in the data set.

Variable	Mean	SD	Min.	1st Q.	Median	3rd Q.	Max.
aroma	7.57	0.39	0	7.42	7.58	7.75	8.75
flavor	7.52	0.40	0	7.33	7.58	7.75	8.67
acidity	7.54	0.39	0	7.33	7.50	7.75	8.58
category_two_defects	3.67	5.41	0	0.00	2.00	5.00	55.00
altitude_mean_meters	1850.69	9392.09	1	1100.00	1310.64	1600.00	190164.00
harvested	2013.67	1.81	2010	2012.00	2014.00	2015.00	2018.00

The following table shows the number of batches and the proportion of good quality for each country.

Table 2: Number of batches and proportion of batches that are of good quality for each country

country_of_origin	number_of_batch	Proportion_of_good_quality
Brazil	116	0.47
Burundi	2	0.50
China	14	0.64
Colombia	158	0.80
Costa Rica	41	0.56
Cote d?Ivoire	1	0.00
Ecuador	3	0.33
El Salvador	20	0.70
Ethiopia	38	0.92
Guatemala	152	0.50
Haiti	5	0.20
Hawaii	62	0.55
Honduras	48	0.25
India	10	0.50
Indonesia	16	0.56
Japan	1	1.00
Kenya	24	0.92
Laos	2	0.00
Malawi	11	0.09
Mauritius	1	0.00
Mexico	203	0.27
Myanmar	6	0.00
Nicaragua	23	0.22
Panama	4	0.75
Peru	9	0.56
Philippines	5	0.40
Puerto Rico	3	0.33
Taiwan	62	0.42
Tanzania	32	0.50
Thailand	23	0.70
Uganda	32	0.78
United States	9	0.67
Vietnam	8	0.50
Zambia	1	0.00

The following boxplot is for good quality rates for each country, in which we can check if any countries have unusual high or low good quality rate. It seems like all good quality rates lie in the IQR.

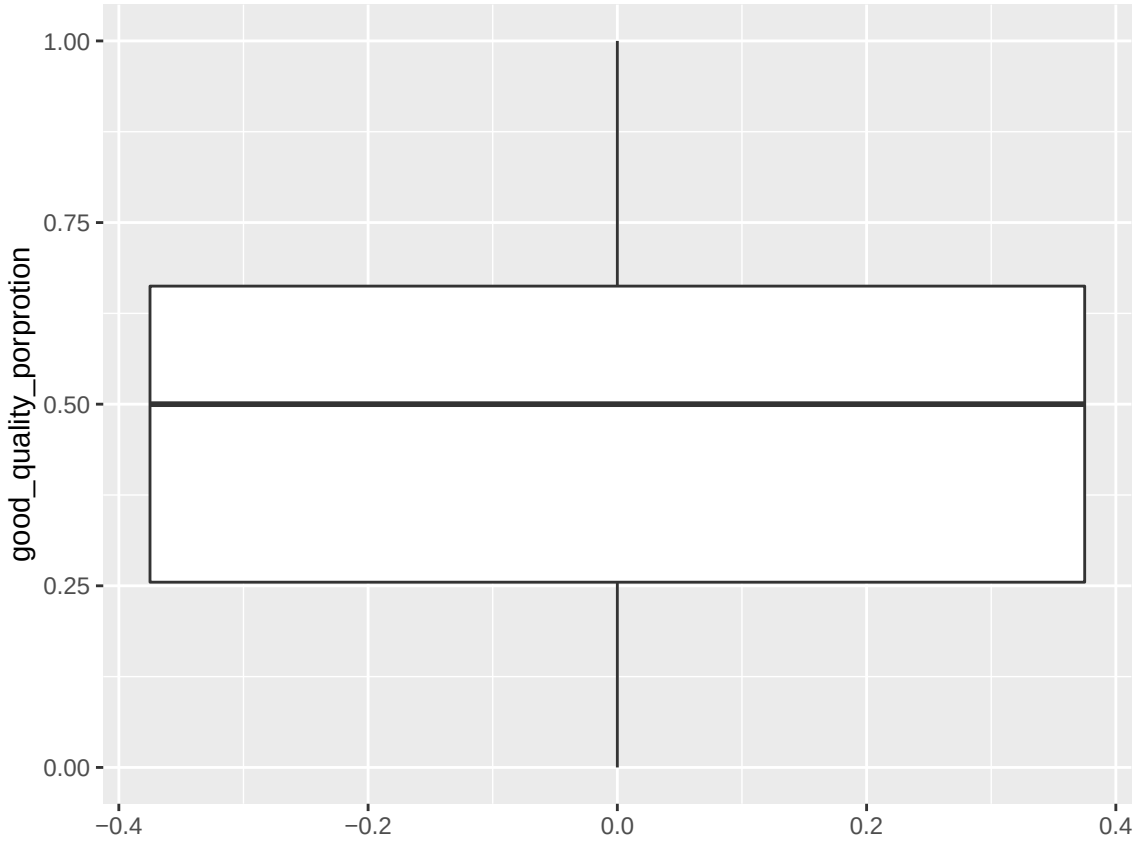


Figure 1: Boxplots of good quality rate for each country.

The following table filter countries and its number of batch with 20% good quality rate before and after, which provides more detailed information than the above boxplot. The number of batch can imply the reliability. For instance, Colombia has a relatively high good quality rate with large number of batch.

Table 3: Origins with twenty percent good quality rate before and after

country_of_origin	good_quality_porprotion	number_of_batch
Cote d?Ivoire	0.00	1
Laos	0.00	2
Mauritius	0.00	1
Myanmar	0.00	6
Zambia	0.00	1
Malawi	0.09	11
Haiti	0.20	5
El Salvador	0.70	20
Thailand	0.70	23
Panama	0.75	4
Uganda	0.78	32
Colombia	0.80	158
Ethiopia	0.92	38
Kenya	0.92	24
Japan	1.00	1

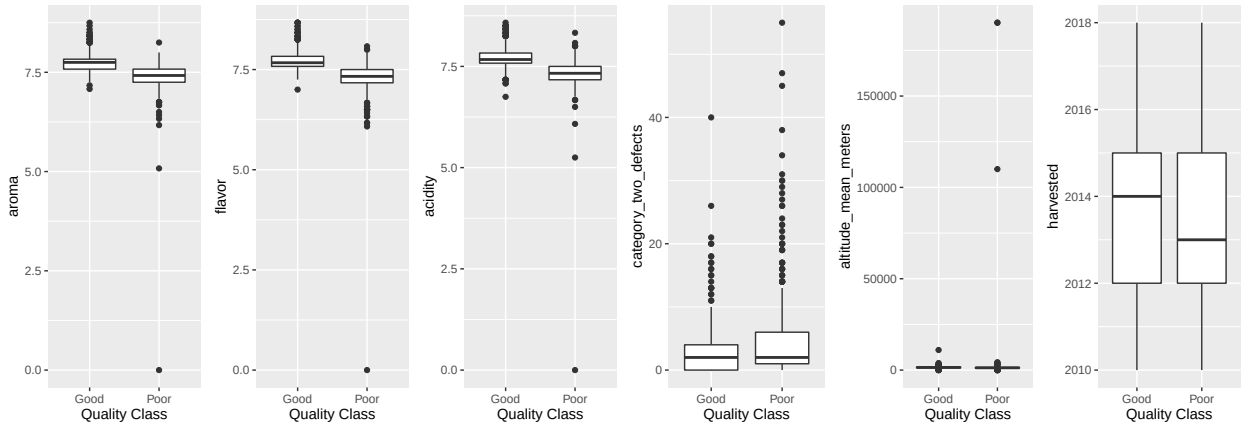


Figure 2: Boxplots2 of countinous features on different quality class.

There are several observations with extremely high altitudes which are impossible. Hence, delete observations which have an altitude higher than Mt. Everest.

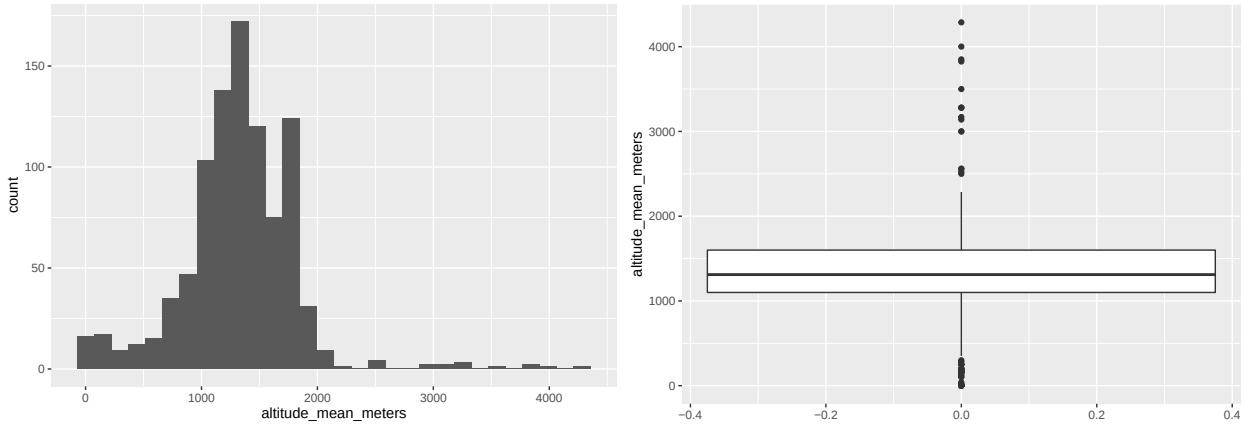


Figure 3: Histogram and boxplot for altitude after removing implausuble observations.

The following two histograms compare the distributions of altitude before and after removing implausible observations.

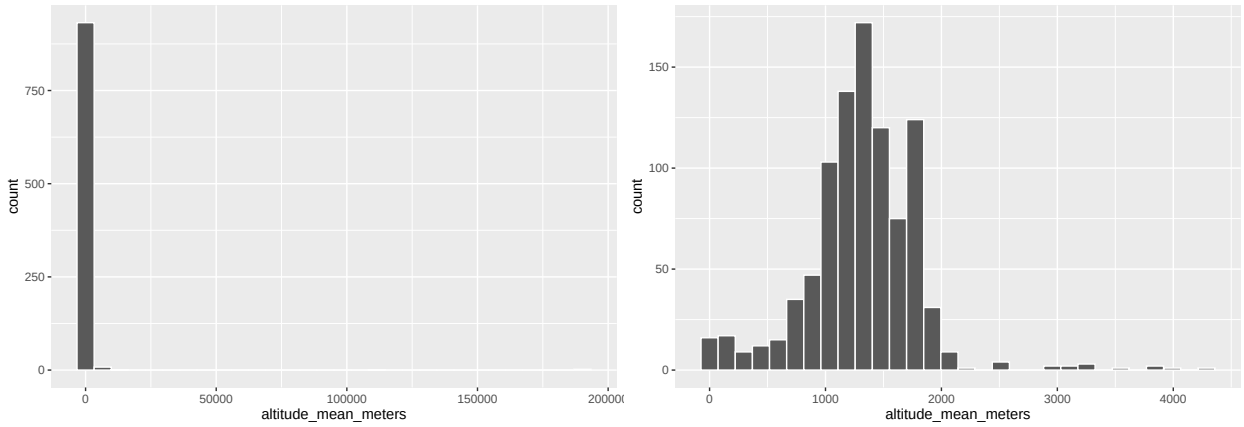


Figure 4: Histogram for altitude befor and after removing implausuble observations.

The following table compares the distribution of features between good and poor coffee. We can check if there are obvious differences in some features between good and poor coffee after data cleaning.

Table 4: Summary statistics of features of good and poor coffee

Variable	Qualityclass	n	Mean	SD	Min	Median	Max	IQR
aroma	Good	477	7.76	0.23	7.17	7.75	8.75	0.08
aroma	Poor	463	7.38	0.43	0.00	7.42	8.25	0.16
flavor	Good	477	7.74	0.22	7.25	7.67	8.67	0.16
flavor	Poor	463	7.30	0.43	0.00	7.33	8.08	0.17
acidity	Good	477	7.72	0.24	7.08	7.67	8.58	0.16
acidity	Poor	463	7.33	0.43	0.00	7.33	8.33	0.17
category_two_defects	Good	477	2.83	3.84	0.00	2.00	40.00	2.00
category_two_defects	Poor	463	4.43	6.43	0.00	2.00	47.00	4.00
altitude_mean_meters	Good	477	1410.98	451.40	1.00	1450.00	3850.00	250.00
altitude_mean_meters	Poor	463	1236.91	500.90	1.00	1250.00	4287.00	200.00
harvested	Good	477	2013.76	1.90	2010.00	2014.00	2018.00	1.00
harvested	Poor	463	2013.63	1.72	2010.00	2013.00	2018.00	2.00

Here is 6 box-plots comparing features distribution between good and poor coffee after data cleaning.

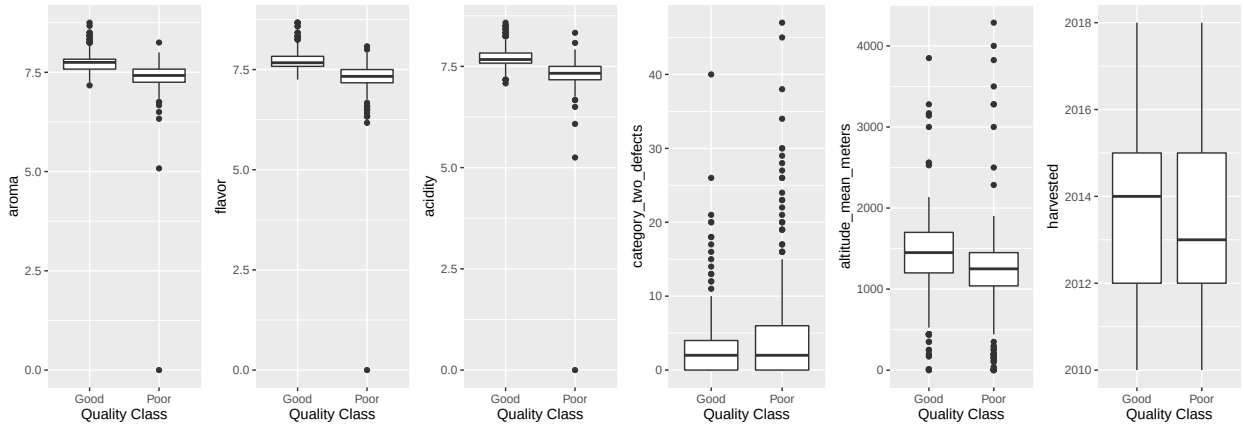


Figure 5: Boxplots of countinous features on different quality class after data cleaning.

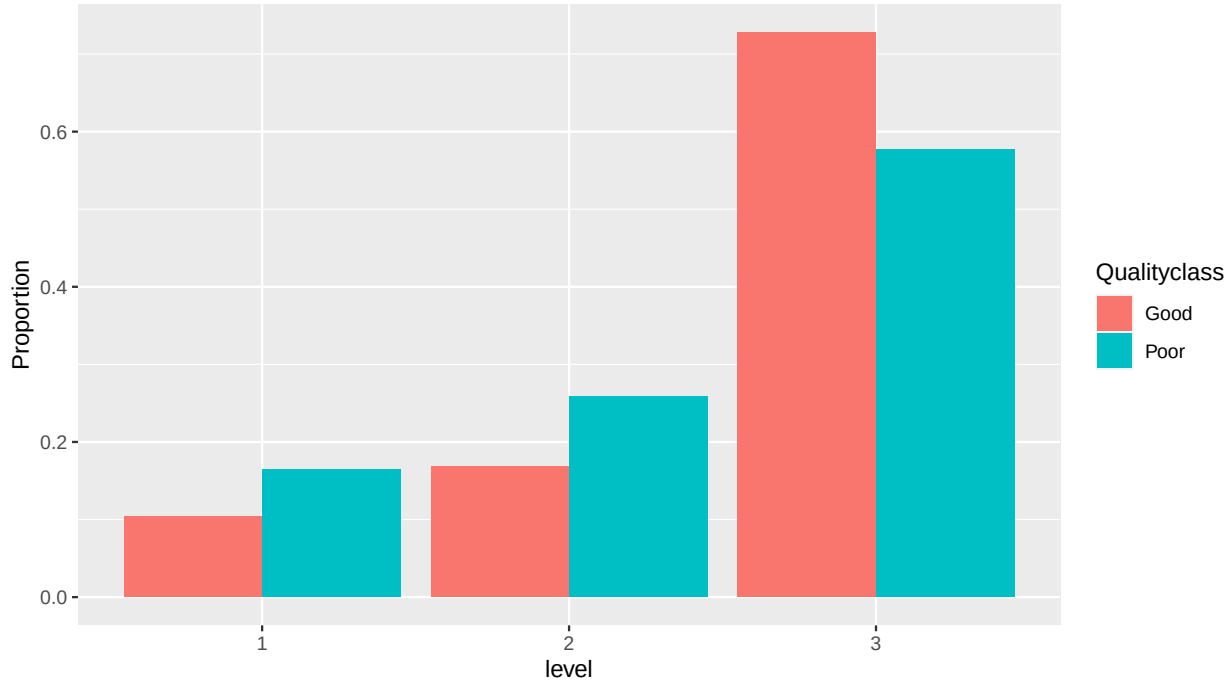


Figure 6: The good and poor quality rates for each altitude level.

Formal Analysis Using Logistic Regression

Firstly we fit a model using altitude levels as the only explanatory variable.

```
Call:
glm(formula = Qualityclass ~ level - 1, family = binomial(link = "logit"),
    data = coffee_final)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
```

```
-1.286  -1.286   1.073   1.073   1.369

Coefficients:
       Estimate Std. Error z value Pr(>|z|)
level1 -0.43891    0.18321  -2.396  0.01659 *
level2 -0.40968    0.14513  -2.823  0.00476 **
level3  0.25131    0.08175   3.074  0.00211 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.6  on 931  degrees of freedom
Residual deviance: 1267.1  on 928  degrees of freedom
AIC: 1273.1

Number of Fisher Scoring iterations: 4
```

Table 5: confidence interval of estimated parameters

	Estimate	Std error	P_value	Lower_ci	Upper_ci
level1	-0.44	0.18	0.02	-0.80	-0.08
level2	-0.41	0.15	0.00	-0.70	-0.13
level3	0.25	0.08	0.00	0.09	0.41

If the level of altitude is the only explanatory variable in the model, the effect of three levels are all statistically significant. In detail, high altitude has a positive influence on the quality of coffee.

Secondly, we fit a model using harvested year as the only explanatory variable.

```
Call:
glm(formula = Qualityclass ~ year - 1, family = binomial(link = "logit"),
    data = coffee_final)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.7125  -1.1774   0.7244   1.1146   1.3683

Coefficients:
           Estimate Std. Error z value Pr(>|z|)
year2010  1.204e+00  4.655e-01   2.587 0.009694 **
year2011  1.012e+00  4.129e-01   2.450 0.014277 *
year2012 -4.383e-01  1.283e-01  -3.417 0.000634 ***
year2013  1.495e-01  1.733e-01   0.863 0.388102
year2014  2.742e-15  1.436e-01   0.000 1.000000
year2015  1.699e-01  1.848e-01   0.919 0.357851
year2016  2.144e-01  1.982e-01   1.082 0.279346
year2017 -1.133e-01  2.752e-01  -0.412 0.680441
year2018  9.555e-01  5.262e-01   1.816 0.069408 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.6  on 931  degrees of freedom
Residual deviance: 1257.3  on 922  degrees of freedom
AIC: 1275.3

Number of Fisher Scoring iterations: 4
```

Table 6: confidence interval of estimated parameters

	Estimate	Std error	P_value	Lower_ci	Upper_ci
year2010	1.20	0.47	0.01	0.35	2.21
year2011	1.01	0.41	0.01	0.24	1.88
year2012	-0.44	0.13	0.00	-0.69	-0.19

If harvested year is the only explanatory variable in the model, the effects of year 2010, 2011 and 2012 are statistically significant. Coffee harvested in year 2012 has a higher odds ratio. Coffee harvested in year 2010 and 2011 has a lower odds ratio.

Then, we fit a model using country of region as the only explanatory variable.

```
Call:
glm(formula = Qualityclass ~ country_of_origin - 1, family = binomial(link = "logit"),
    data = coffee_final)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-2.14597  -1.01655   0.00036   1.08424   2.18993

Coefficients:
                              Estimate Std. Error z value Pr(>|z|)
country_of_originBrazil       6.596e-02  2.098e-01   0.314  0.75320
country_of_originBurundi      0.000e+00  1.414e+00   0.000  1.00000
country_of_originChina        5.878e-01  5.578e-01   1.054  0.29197
country_of_originColombia     1.563e+00  2.345e-01   6.666 2.64e-11 ***
country_of_originCosta Rica   2.231e-01  3.354e-01   0.665  0.50587
country_of_originCote d?Ivoire -1.657e+01  2.400e+03  -0.007  0.99449
country_of_originEcuador      -1.570e-16  1.414e+00   0.000  1.00000
country_of_originEl Salvador  9.555e-01  5.262e-01   1.816  0.06941 .
country_of_originEthiopia     1.657e+01  5.003e+02   0.033  0.97359
country_of_originGuatemala    7.878e-02  1.776e-01   0.444  0.65736
country_of_originHaiti        -1.386e+00  1.118e+00  -1.240  0.21500
country_of_originHawaii       1.657e+01  2.400e+03   0.007  0.99449
country_of_originHonduras     -1.070e+00  3.345e-01  -3.200  0.00137 **
country_of_originIndia        0.000e+00  6.325e-01   0.000  1.00000
country_of_originIndonesia    2.877e-01  5.401e-01   0.533  0.59425
country_of_originKenya        2.197e+00  7.454e-01   2.948  0.00320 **
country_of_originLaos         -1.657e+01  1.697e+03  -0.010  0.99221
country_of_originMalawi       -2.303e+00  1.049e+00  -2.195  0.02813 *
country_of_originMauritius    -1.657e+01  2.400e+03  -0.007  0.99449
country_of_originMexico       -1.046e+00  1.612e-01  -6.488 8.68e-11 ***
country_of_originMyanmar      -1.657e+01  9.796e+02  -0.017  0.98651
```

```
country_of_originNicaragua     -1.204e+00  6.583e-01  -1.829  0.06740 .
country_of_originPanama         1.099e+00  1.155e+00   0.951  0.34139
country_of_originPeru          -1.657e+01  2.400e+03  -0.007  0.99449
country_of_originPhilippines   -4.055e-01  9.129e-01  -0.444  0.65692
country_of_originPuerto Rico   -6.931e-01  1.225e+00  -0.566  0.57143
country_of_originTaiwan        -3.909e-01  2.700e-01  -1.448  0.14769
country_of_originTanzania      -6.899e-02  3.716e-01  -0.186  0.85271
country_of_originThailand       2.877e-01  5.401e-01   0.533  0.59425
country_of_originUganda         1.190e+00  4.317e-01   2.756  0.00585 **
country_of_originUnited States  6.931e-01  7.071e-01   0.980  0.32696
country_of_originVietnam        2.877e-01  7.638e-01   0.377  0.70642
country_of_originZambia        -1.657e+01  2.400e+03  -0.007  0.99449
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.6  on 931  degrees of freedom
Residual deviance: 1072.7  on 898  degrees of freedom
AIC: 1138.7

Number of Fisher Scoring iterations: 15
```

Table 7: confidence interval of estimated parameters

	Estimate	Std error	P_value	Lower_ci	Upper_ci
country_of_originColombia	1.56	0.23	0.00	1.12	2.05
country_of_originHonduras	-1.07	0.33	0.00	-1.77	-0.44
country_of_originKenya	2.20	0.75	0.00	0.95	4.04
country_of_originMalawi	-2.30	1.05	0.03	-5.21	-0.65
country_of_originMexico	-1.05	0.16	0.00	-1.37	-0.74
country_of_originUganda	1.19	0.43	0.01	0.39	2.11

If the country of origin is the only explanatory variable, Colombia, Mexico, Honduras, Kenya, Malawi, Uganda have statistically significant effect on the odds ratio.

All variables which are significant above are considered to be potential explanatory variables. They are all three altitude levels, year 2010, 2011 and 2012 and countries of Colombia, Mexico, Honduras, Kenya, Malawi and Uganda.

The following model use all potential explanatory variables. And use step AIC to select variables again.

```
Call:
glm(formula = Qualityclass ~ aroma + flavor + acidity + Colombia +
    Mexico + Honduras + Kenya + Malawi + Uganda + category_two_defects +
    level + year2010 + year2011 + year2012, family = binomial(link = "logit"),
    data = coffee_final)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.2233  -0.3110   0.0010   0.3332   3.4913
```

```
Coefficients:
                       Estimate Std. Error z value Pr(>|z|)
(Intercept)          -124.52106    9.39969 -13.247  < 2e-16 ***
aroma                   4.42037    0.73018   6.054 1.41e-09 ***
flavor                  7.21914    0.87975   8.206 2.29e-16 ***
acidity                 4.80821    0.72879   6.598 4.18e-11 ***
Colombia                1.77971    0.39212   4.539 5.66e-06 ***
Mexico                 -0.82994    0.34382  -2.414   0.0158 *
Honduras               -0.58919    0.53161  -1.108   0.2677
Kenya                   0.99751    1.34387   0.742   0.4579
Malawi                 -1.26603    1.15543  -1.096   0.2732
Uganda                 -1.29548    0.62048  -2.088   0.0368 *
category_two_defects    0.05244    0.02894   1.812   0.0700 .
level2                  0.13831    0.39437   0.351   0.7258
level3                  0.39276    0.33774   1.163   0.2449
year2010               -0.40857    0.86051  -0.475   0.6349
year2011               -0.47132    0.65362  -0.721   0.4708
year2012               -0.22952    0.31593  -0.726   0.4675
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.6  on 930  degrees of freedom
Residual deviance:  499.0  on 915  degrees of freedom
AIC: 531

Number of Fisher Scoring iterations: 7


Start:  AIC=531
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Honduras + Kenya + Malawi + Uganda + category_two_defects +
    level + year2010 + year2011 + year2012

                       Df Deviance    AIC
- level                 2   500.68 528.68
- year2010              1   499.22 529.22
- year2011              1   499.51 529.51
- year2012              1   499.53 529.53
- Kenya                 1   499.62 529.62
- Honduras              1   500.28 530.28
- Malawi                1   500.51 530.51
<none>                      499.00 531.00
- category_two_defects  1   502.16 532.16
- Uganda                1   503.06 533.06
- Mexico                1   504.93 534.93
- Colombia              1   522.71 552.71
- aroma                 1   550.65 580.65
- acidity               1   552.26 582.26
- flavor                1   589.47 619.47

Step:  AIC=528.68
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Honduras + Kenya + Malawi + Uganda + category_two_defects +
```

```
    year2010 + year2011 + year2012

                       Df Deviance    AIC
- year2010              1   500.81 526.81
- year2011              1   501.21 527.21
- year2012              1   501.31 527.31
- Honduras              1   501.45 527.45
- Kenya                 1   501.46 527.46
- Malawi                1   502.00 528.00
<none>                      500.68 528.68
- category_two_defects  1   504.11 530.11
- Uganda                1   504.17 530.17
+ level                 2   499.00 531.00
- Mexico                1   506.09 532.09
- Colombia              1   528.97 554.97
- aroma                 1   554.14 580.14
- acidity               1   556.27 582.27
- flavor                1   589.52 615.52

Step:  AIC=526.81
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Honduras + Kenya + Malawi + Uganda + category_two_defects +
    year2011 + year2012

                       Df Deviance    AIC
- year2011              1   501.31 525.31
- year2012              1   501.40 525.40
- Honduras              1   501.56 525.56
- Kenya                 1   501.60 525.60
- Malawi                1   502.12 526.12
<none>                      500.81 526.81
- Uganda                1   504.25 528.25
- category_two_defects  1   504.30 528.30
+ year2010              1   500.68 528.68
+ level                 2   499.22 529.22
- Mexico                1   506.23 530.23
- Colombia              1   529.18 553.18
- aroma                 1   554.21 578.21
- acidity               1   556.49 580.49
- flavor                1   589.60 613.60

Step:  AIC=525.31
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Honduras + Kenya + Malawi + Uganda + category_two_defects +
    year2012

                       Df Deviance    AIC
- year2012              1   501.78 523.78
- Honduras              1   502.01 524.01
- Kenya                 1   502.12 524.12
- Malawi                1   502.58 524.58
<none>                      501.31 525.31
- Uganda                1   504.68 526.68
- category_two_defects  1   504.80 526.80
```

```
+ year2011              1   500.81 526.81
+ year2010              1   501.21 527.21
+ level                 2   499.68 527.68
- Mexico                1   506.85 528.85
- Colombia              1   529.36 551.36
- aroma                 1   555.00 577.00
- acidity               1   556.77 578.77
- flavor                1   589.70 611.70

Step:  AIC=523.78
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Honduras + Kenya + Malawi + Uganda + category_two_defects

                      Df Deviance    AIC
- Honduras             1   502.38 522.38
- Kenya                1   502.61 522.61
- Malawi               1   503.00 523.00
<none>                     501.78 523.78
- Uganda               1   505.00 525.00
- category_two_defects  1   505.00 525.00
+ year2012             1   501.31 525.31
+ year2011             1   501.40 525.40
+ year2010             1   501.71 525.71
+ level                2   500.04 526.04
- Mexico               1   511.24 531.24
- Colombia             1   529.38 549.38
- aroma                1   555.13 575.13
- acidity              1   557.73 577.73
- flavor               1   590.18 610.18

Step:  AIC=522.38
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Kenya + Malawi + Uganda + category_two_defects

                      Df Deviance    AIC
- Kenya                1   503.26 521.26
- Malawi               1   503.52 521.52
<none>                     502.38 522.38
- Uganda               1   505.47 523.47
- category_two_defects  1   505.49 523.49
+ Honduras             1   501.78 523.78
+ year2012             1   502.01 524.01
+ year2011             1   502.03 524.03
+ year2010             1   502.32 524.32
+ level                2   501.13 525.13
- Mexico               1   511.31 529.31
- Colombia             1   531.79 549.79
- aroma                1   556.16 574.16
- acidity              1   559.22 577.22
- flavor               1   591.11 609.11

Step:  AIC=521.26
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Malawi + Uganda + category_two_defects
```

```
                       Df Deviance    AIC
- Malawi                1   504.42 520.42
<none>                      503.26 521.26
+ Kenya                 1   502.38 522.38
- Uganda                1   506.40 522.40
- category_two_defects  1   506.40 522.40
+ Honduras              1   502.61 522.61
+ year2012              1   502.89 522.89
+ year2011              1   502.89 522.89
+ year2010              1   503.20 523.20
+ level                 2   501.87 523.87
- Mexico                1   512.59 528.59
- Colombia              1   532.34 548.34
- aroma                 1   556.51 572.51
- acidity               1   561.04 577.04
- flavor                1   593.35 609.35

Step:  AIC=520.42
Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Uganda + category_two_defects

                       Df Deviance    AIC
<none>                      504.42 520.42
+ Malawi                1   503.26 521.26
- Uganda                1   507.44 521.44
+ Kenya                 1   503.52 521.52
+ Honduras              1   503.85 521.85
- category_two_defects  1   507.92 521.92
+ year2011              1   504.06 522.06
+ year2012              1   504.09 522.09
+ year2010              1   504.36 522.36
+ level                 2   503.14 523.14
- Mexico                1   513.43 527.43
- Colombia              1   534.72 548.72
- aroma                 1   557.63 571.63
- acidity               1   562.84 576.84
- flavor                1   596.95 610.95

Call:
glm(formula = Qualityclass ~ aroma + flavor + acidity + Colombia +
    Mexico + Uganda + category_two_defects, family = binomial(link = "logit"),
    data = coffee_final)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.1969  -0.3208   0.0010   0.3370   3.4697

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)          -125.42332    9.27395 -13.524  < 2e-16 ***
aroma                   4.44405    0.71829   6.187 6.13e-10 ***
flavor                  7.16176    0.86051   8.323  < 2e-16 ***
acidity                 4.98081    0.72085   6.910 4.86e-12 ***
```

```
Colombia                1.83828    0.36232   5.074 3.90e-07 ***
Mexico                 -0.87447    0.29601  -2.954  0.00313 **
Uganda                 -1.09151    0.60860  -1.793  0.07290 .
category_two_defects    0.05394    0.02831   1.905  0.05672 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.55  on 930  degrees of freedom
Residual deviance:  504.42  on 923  degrees of freedom
AIC: 520.42

Number of Fisher Scoring iterations: 7
```

In the selected model, two terms are not significant. Then, we try to delete term Uganda which has the highest p-value.

After deleting Uganda, category_two_defects is still not significant. Hence, it was deleted. And we use anova to compare three models. There isn't a statistically significant difference among them. Hence, it is reasonable to delete them and get a simple model.

```
Call:
glm(formula = Qualityclass ~ aroma + flavor + acidity + Colombia +
    Mexico + category_two_defects, family = binomial(link = "logit"),
    data = coffee_final)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.1273  -0.3217   0.0012   0.3439   3.4487

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)         -122.68887    9.00647 -13.622  < 2e-16 ***
aroma                  4.16837    0.69442   6.003 1.94e-09 ***
flavor                 7.11890    0.85662   8.310  < 2e-16 ***
acidity                4.93107    0.71480   6.899 5.25e-12 ***
Colombia               1.89169    0.35907   5.268 1.38e-07 ***
Mexico                -0.81385    0.29179  -2.789  0.00528 **
category_two_defects   0.05398    0.02817   1.916  0.05534 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.55  on 930  degrees of freedom
Residual deviance:  507.44  on 924  degrees of freedom
AIC: 521.44

Number of Fisher Scoring iterations: 7

Call:
glm(formula = Qualityclass ~ aroma + flavor + acidity + Colombia +
    Mexico, family = binomial(link = "logit"), data = coffee_final)
```

```
Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.1419  -0.3215   0.0013   0.3473   3.3870

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -121.1845     8.8906 -13.631  < 2e-16 ***
aroma          4.1755     0.6982   5.980 2.23e-09 ***
flavor         7.0057     0.8582   8.163 3.27e-16 ***
acidity        4.8571     0.7118   6.824 8.86e-12 ***
Colombia       1.8308     0.3557   5.147 2.64e-07 ***
Mexico        -0.6596     0.2780  -2.372   0.0177 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.55  on 930  degrees of freedom
Residual deviance:  510.96  on 925  degrees of freedom
AIC: 522.96

Number of Fisher Scoring iterations: 7

Analysis of Deviance Table

Model 1: Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    Uganda + category_two_defects
Model 2: Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico +
    category_two_defects
Model 3: Qualityclass ~ aroma + flavor + acidity + Colombia + Mexico
  Resid. Df Resid. Dev Df Deviance
1       923     504.42
2       924     507.44 -1  -3.0223
3       925     510.96 -1  -3.5196

[1] 3.841459
```

Final Model

```
Call:
glm(formula = Qualityclass ~ aroma + flavor + acidity + Colombia +
    Mexico, family = binomial(link = "logit"), data = coffee_final)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.1419  -0.3215   0.0013   0.3473   3.3870

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -121.1845     8.8906 -13.631  < 2e-16 ***
aroma          4.1755     0.6982   5.980 2.23e-09 ***
flavor         7.0057     0.8582   8.163 3.27e-16 ***
```

```
acidity        4.8571     0.7118   6.824 8.86e-12 ***
Colombia       1.8308     0.3557   5.147 2.64e-07 ***
Mexico        -0.6596     0.2780  -2.372   0.0177 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1290.55  on 930  degrees of freedom
Residual deviance:  510.96  on 925  degrees of freedom
AIC: 522.96

Number of Fisher Scoring iterations: 7
```

Create regression equations for use in the presentation.

$$Qualityclass \sim Harvested_{\text{year}} - 1$$

$$Qualityclass \sim Altitude_{\text{level}} - 1$$

$$Qualityclass \sim Origin_{\text{country}} - 1$$

$$\ln(\frac{p_i}{1-p_i}) = \alpha + \beta_1 \cdot aroma_i + \beta_2 \cdot flavor_i + \beta_3 \cdot acidity_i + \beta_4 \cdot \mathbb{I}_{\text{Colombia}}(x) + \beta_5 \cdot \mathbb{I}_{\text{Mexico}}(x)$$

$$\mathbb{I}_{\text{Colombia}}(x) = \begin{cases} 1 & \text{if Country of region of } x\text{th observation is Colombia,} \\ 0 & \text{Otherwise.} \end{cases}$$

$$\mathbb{I}_{\text{Mexico}}(x) = \begin{cases} 1 & \text{if Country of region of } x\text{th observation is Mexico,} \\ 0 & \text{Otherwise.} \end{cases}$$

The following is the fitted model.

$$\ln(\frac{p_i}{1-p_i}) = -121.18 + 4.18 \cdot aroma_i + 7.01 \cdot flavor_i + 4.86 \cdot acidity_i + 1.83 \cdot \mathbb{I}_{\text{Colombia}}(x) - 0.66 \cdot \mathbb{I}_{\text{Mexico}}(x)$$

Generate a summary table containing confidence intervals of estimated parameters of final model.

Table 8: confidence interval of estimated parameters

	Estimate	Std error	P value	Lower_ci	Upper_ci
(Intercept)	-121.18	8.89	0.00	-139.59	-104.68
aroma	4.18	0.70	0.00	2.85	5.58
flavor	7.01	0.86	0.00	5.38	8.75
acidity	4.86	0.71	0.00	3.49	6.29
Colombia	1.83	0.36	0.00	1.16	2.56
Mexico	-0.66	0.28	0.02	-1.21	-0.12

Table 9: confidence interval of odds

	Exp_lower_ci	Exp_upper_ci
(Intercept)	0.00	0.00
aroma	17.34	266.06
flavor	217.66	6332.18
acidity	32.91	538.71
Colombia	3.18	12.89
Mexico	0.30	0.89

Based on the model we built, we try to use 10-fold cross validation to test the validity of our final model. In the validation we assess three criteria: accuracy, sensitivity and specificity.

```
[1] 0.8839625
```

```
[1] 0.8931425
```

```
[1] 0.8766441
```

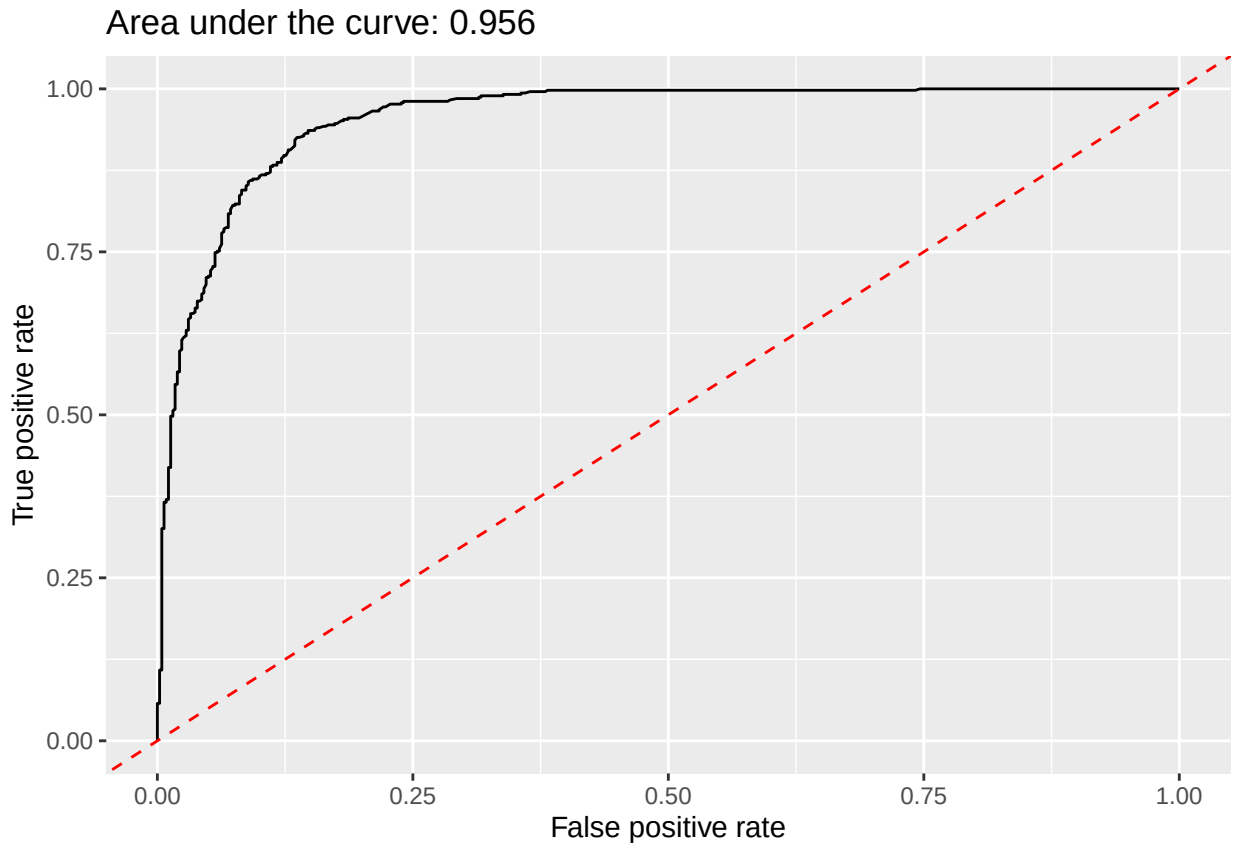
The accuracy of our final model is 0.88. The sensitivity of our final model is 0.89. The specificity of our final model is 0.88.

```
Hosmer and Lemeshow Goodness-of-Fit Test

Call:
glm(formula = Qualityclass ~ aroma + flavor + acidity + Colombia +
    Mexico, family = binomial(link = "logit"), data = coffee_final)
 ChiSquare df      P_value
  46.03677  8 2.339035e-07
```

However, the model has good predicting performance, it failed in Hosmer-Lemeshow Goodness of Fit Test.

Classfication boundry

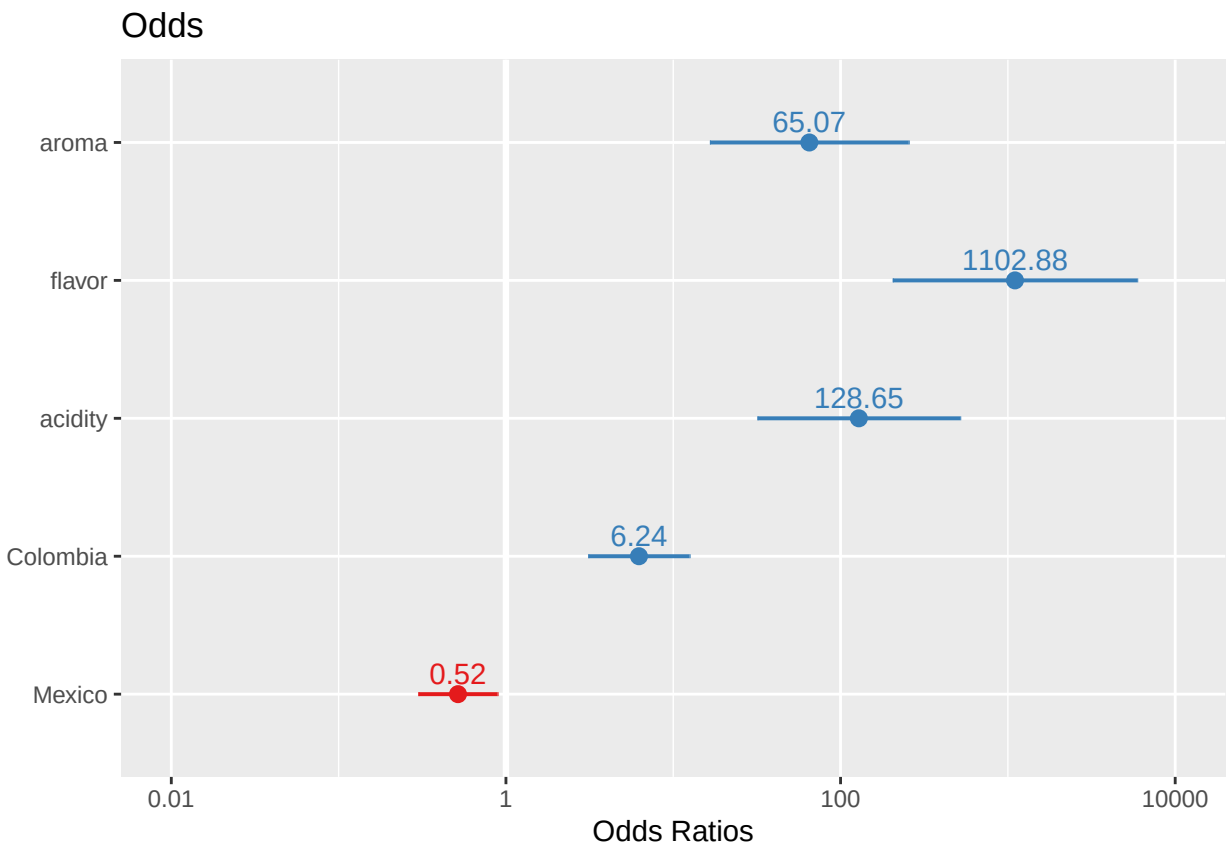



```
(Intercept)       aroma      flavor     acidity    Colombia      Mexico
    -121.18        4.18        7.01        4.86        1.83       -0.66

(Intercept)       aroma      flavor     acidity    Colombia      Mexico
       0.00       65.07     1102.88      128.65        6.24        0.52
```

Table 10: Regression coefficients and exponentiated coefficients.

	(Intercept)	aroma	flavor	acidity	Colombia	Mexico
coefficients	-121.18	4.18	7.01	4.86	1.83	-0.66
exp(coefficients)	0.00	65.07	1102.88	128.65	6.24	0.52




```
[1] 0.8871768
```

```
[1] 0.9177465
```

```
[1] 0.8571202
```

After adjusting the classification boundary. The accuracy of our final model is 0.89. The sensitivity of our final model is 0.92. The specificity of our final model is 0.86.

Sensitivity analysis

In addition, we try the linear mixed model. However, it doesn't improve the performance of predicting.

```
Generalized linear mixed model fit by maximum likelihood (Laplace
  Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: Qualityclass ~ 1 + aroma + flavor + acidity + (1 | country_of_origin)
   Data: coffee_final

     AIC      BIC   logLik deviance df.resid
   528.7    552.9   -259.4    518.7      926

Scaled residuals:
     Min       1Q   Median       3Q      Max
```

```
-101.192   -0.203    0.000    0.240   18.985

Random effects:
 Groups            Name        Variance Std.Dev.
 country_of_origin (Intercept) 0.7949   0.8916
Number of obs: 931, groups:  country_of_origin, 33

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -129.3494     9.9853 -12.954  < 2e-16 ***
aroma          4.5965     0.7491   6.136 8.47e-10 ***
flavor         7.4162     0.9229   8.036 9.31e-16 ***
acidity        5.1280     0.7570   6.774 1.25e-11 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

[1] 0.8721574

[1] 0.8753867

[1] 0.8702345
```

If only use aroma, flavour and acidity grades as explantatory variables. The accuracy of the model is 0.87. The sensitivity of the model is 0.88. The specificity of the model is 0.87.