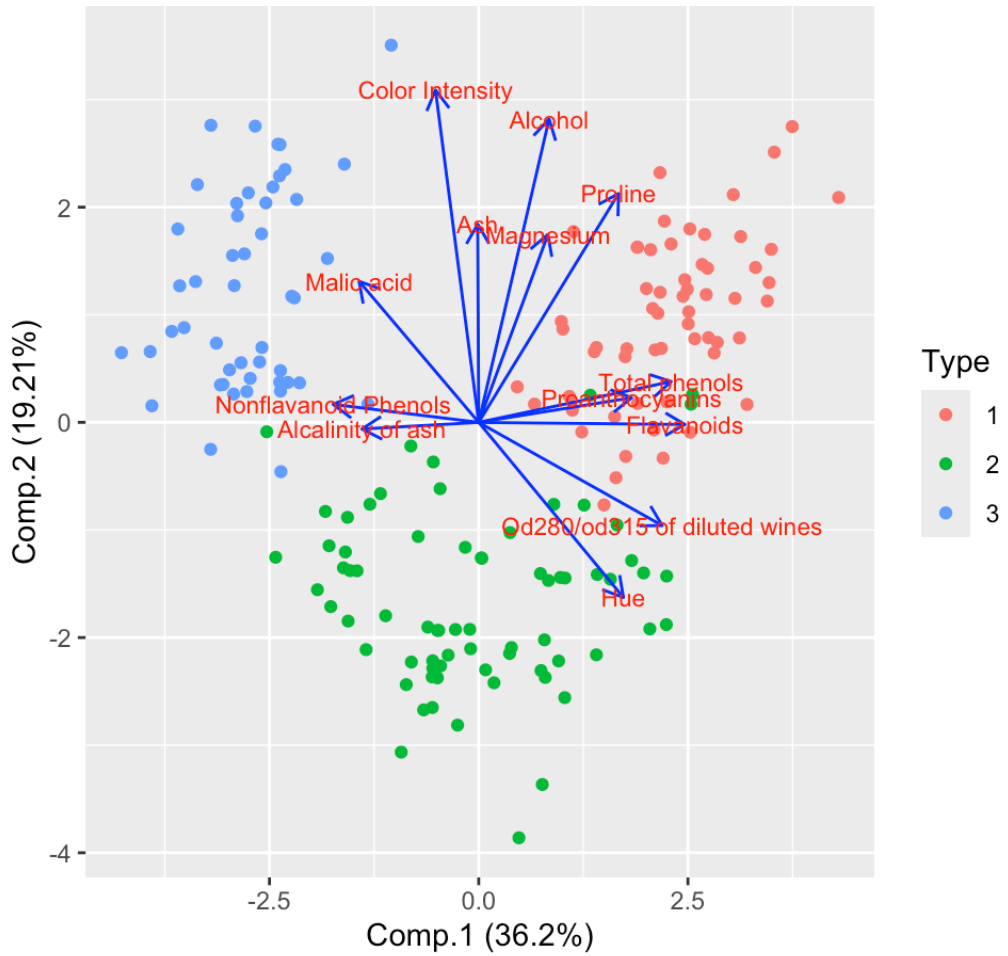
```
> print(principal_components$loadings)

Loadings:
                        Comp.1 Comp.2 Comp.3 Comp.4 Comp.5 Comp.6 Comp.7 Comp.8 Comp.9 Comp.10 Comp.11 Comp.12 Comp.13
Alcohol                  0.144  0.484  0.207         0.266  0.214         0.396  0.509  0.212   0.226   0.266
Malic acid              -0.245  0.225        -0.537         0.537 -0.421                -0.309          -0.122
Ash                             0.316 -0.626  0.214  0.143  0.154  0.149 -0.170 -0.308          0.499          -0.141
Alcalinity of ash       -0.239        -0.612                -0.101  0.287  0.428  0.200          -0.479
Magnesium                0.142  0.300 -0.131  0.352 -0.727         -0.323 -0.156  0.271
Total phenols            0.395        -0.146 -0.198  0.149                -0.406  0.286 -0.320  -0.304   0.304  -0.464
Flavanoids               0.423        -0.151 -0.152  0.109                -0.187         -0.163                  0.832
Nonflavanoid Phenols    -0.299        -0.170  0.203  0.501 -0.259 -0.595 -0.233  0.196  0.216  -0.117           0.114
Proanthocyanins          0.313        -0.149 -0.399 -0.137 -0.534 -0.372  0.368 -0.209  0.134   0.237          -0.117
Color Intensity                 0.530  0.137                -0.419  0.228                -0.291          -0.604
Hue                      0.297 -0.279         0.428  0.174  0.106 -0.232  0.437         -0.522          -0.259
Od280/od315 of diluted wines  0.376 -0.164 -0.166 -0.184  0.101  0.266                 0.137  0.524          -0.601  -0.157
Proline                  0.287  0.365  0.127  0.232  0.158  0.120         0.120 -0.576  0.162  -0.539

               Comp.1 Comp.2 Comp.3 Comp.4 Comp.5 Comp.6 Comp.7 Comp.8 Comp.9 Comp.10 Comp.11 Comp.12 Comp.13
SS loadings     1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000   1.000   1.000   1.000   1.000
Proportion Var  0.077  0.077  0.077  0.077  0.077  0.077  0.077  0.077  0.077   0.077   0.077   0.077   0.077
Cumulative Var  0.077  0.154  0.231  0.308  0.385  0.462  0.538  0.615  0.692   0.769   0.846   0.923   1.000
```



Flavanoids(0.423) and Color Intensity(0.530) contribute the most for 1st PC and 2rd PC respectively.

```
--- Model 1: kNN (k=5) with All 13 Variables ---
> print(tab.all)
         actual
predicted  1  2  3
        1 20  3  0
        2  0 17  0
        3  0  2 12
> cat("Accuracy (All Vars):     ", round(acc_from_tab(tab.all), 4), "\n")
Accuracy (All Vars):      0.9074
> cat("Macro Precision (All Vars):", round(macro_precision(tab.all), 4), "\n")
Macro Precision (All Vars): 0.9089
> cat("Macro Recall (All Vars):   ", round(macro_recall(tab.all), 4), "\n")
Macro Recall (All Vars):    0.9242
> cat("Macro F1 (All Vars):       ", round(macro_f1(tab.all), 4), "\n")
Macro F1 (All Vars):        0.9084
```

```
--- Model 2: kNN (k=5) with First 2 PCs ---
> print(tab.pc)
         actual
predicted  1  2  3
        1 20  1  0
        2  0 21  0
        3  0  0 12
> cat("Accuracy (2 PCs):     ", round(acc_from_tab(tab.pc), 4), "\n")
Accuracy (2 PCs):      0.9815
> cat("Macro Precision (2 PCs):", round(macro_precision(tab.pc), 4), "\n")
Macro Precision (2 PCs): 0.9841
> cat("Macro Recall (2 PCs):   ", round(macro_recall(tab.pc), 4), "\n")
Macro Recall (2 PCs):    0.9848
> cat("Macro F1 (2 PCs):       ", round(macro_f1(tab.pc), 4), "\n")
Macro F1 (2 PCs):        0.9841
```

The model using the first 2 PCs performed significantly better than the model using all 13 variables . The 2-PC model's contingency table shows only one misclassification and achieved a much higher accuracy (0.9815 vs 0.9074) , along with superior macro precision, recall, and F1 scores.