

ECO395M Homework4

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Q1. Clustering and PCA

We're going to compare PCA and K-means clustering, focusing on which dimensionality reduction technique is more capable of distinguishing the color and quality of wine. We'll focus on two components and clusters to make it easy to compare using plot.

1. PCA

We run PCA with four principal components, which have about 73% of the cumulative variance. It means intuitively that these four components have about 73% information about the original data.

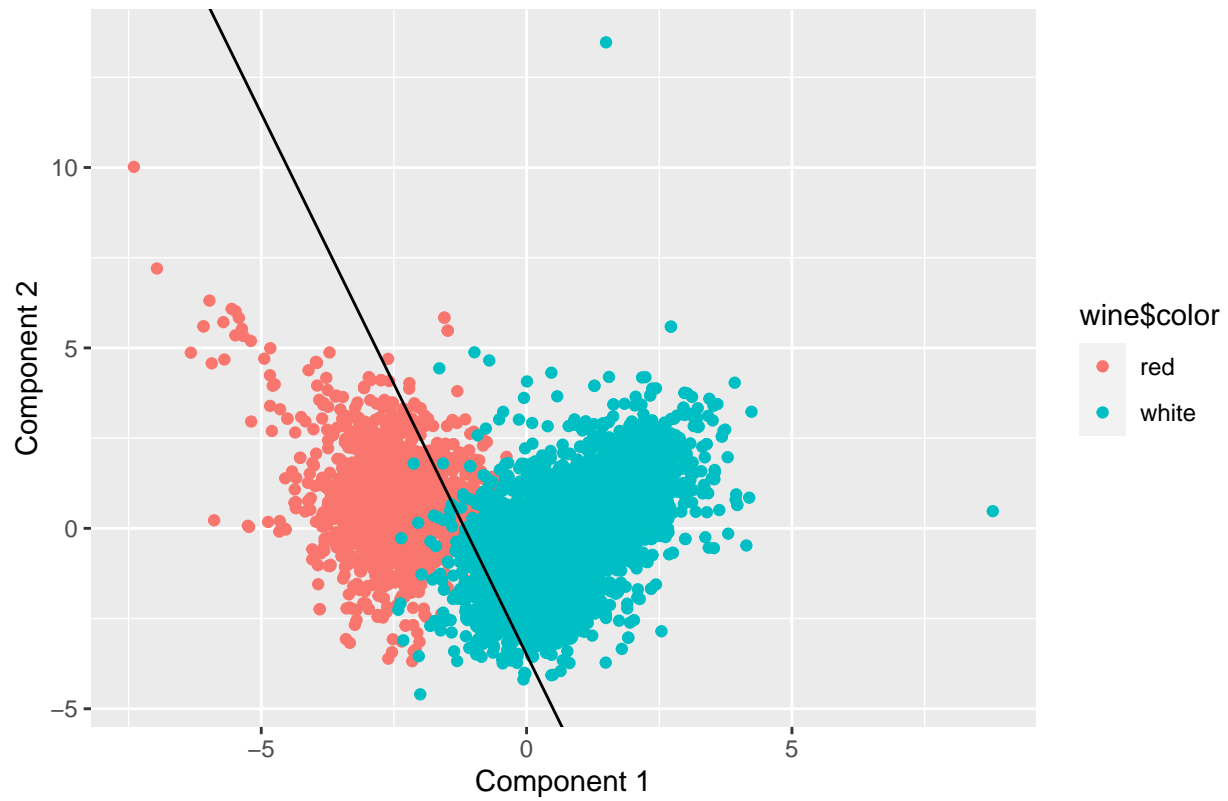
```
## Importance of first k=4 (out of 11) components:
##               PC1    PC2    PC3    PC4
## Standard deviation    1.7407 1.5792 1.2475 0.98517
## Proportion of Variance 0.2754 0.2267 0.1415 0.08823
## Cumulative Proportion 0.2754 0.5021 0.6436 0.73187
```

Also, we can find the loading of the component, and it reflects what the principal components are composed of.

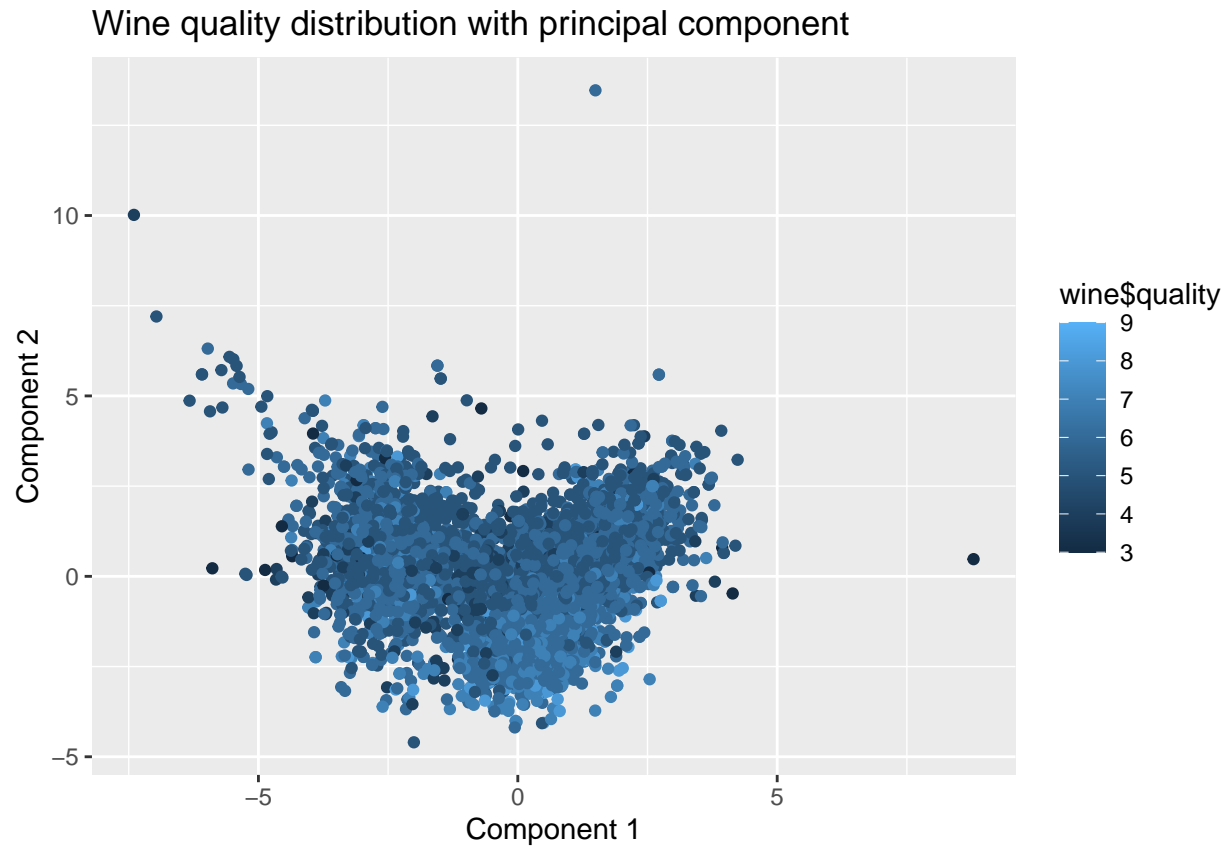
```
##               PC1          PC2          PC3          PC4
## fixed.acidity    -0.23879890  0.33635454 -0.43430130  0.16434621
## volatile.acidity -0.38075750  0.11754972  0.30725942  0.21278489
## citric.acid      0.15238844  0.18329940 -0.59056967 -0.26430031
## residual.sugar   0.34591993  0.32991418  0.16468843  0.16744301
## chlorides        -0.29011259  0.31525799  0.01667910 -0.24474386
## free.sulfur.dioxide 0.43091401  0.07193260  0.13422395 -0.35727894
## total.sulfur.dioxide 0.48741806  0.08726628  0.10746230 -0.20842014
## density          -0.04493664  0.58403734  0.17560555  0.07272496
## pH              -0.21868644 -0.15586900  0.45532412 -0.41455110
## sulphates        -0.29413517  0.19171577 -0.07004248 -0.64053571
## alcohol          -0.10643712 -0.46505769 -0.26110053 -0.10680270
```

The first two components, which have the biggest variance, seem to distinguish the color of the wine well; they are almost separated; the right upper part of the black line represents white wine, and the left lower part seems to represent red wine.

Wine color distribution with principal component



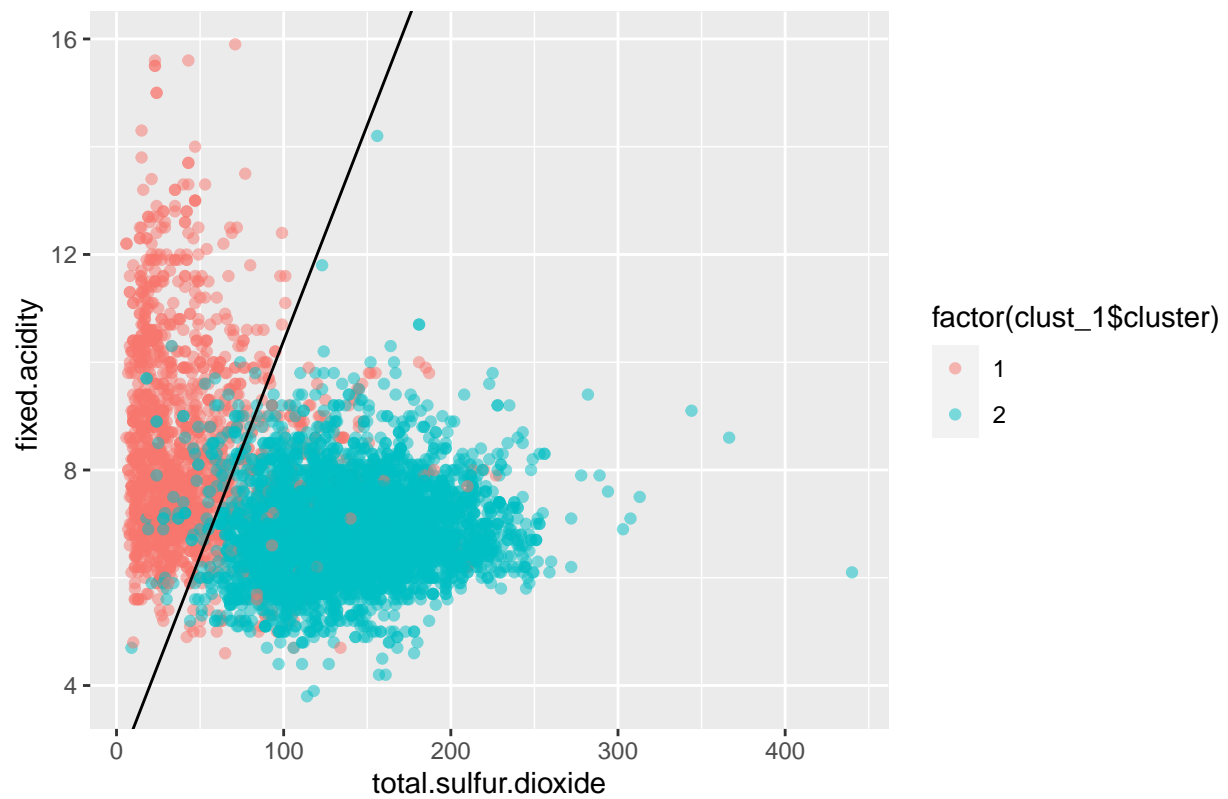
However, it is hard to distinguish wine quality from the principal components. It doesn't show gradation, but various colors—that is, wines of different quality—are scattered around.



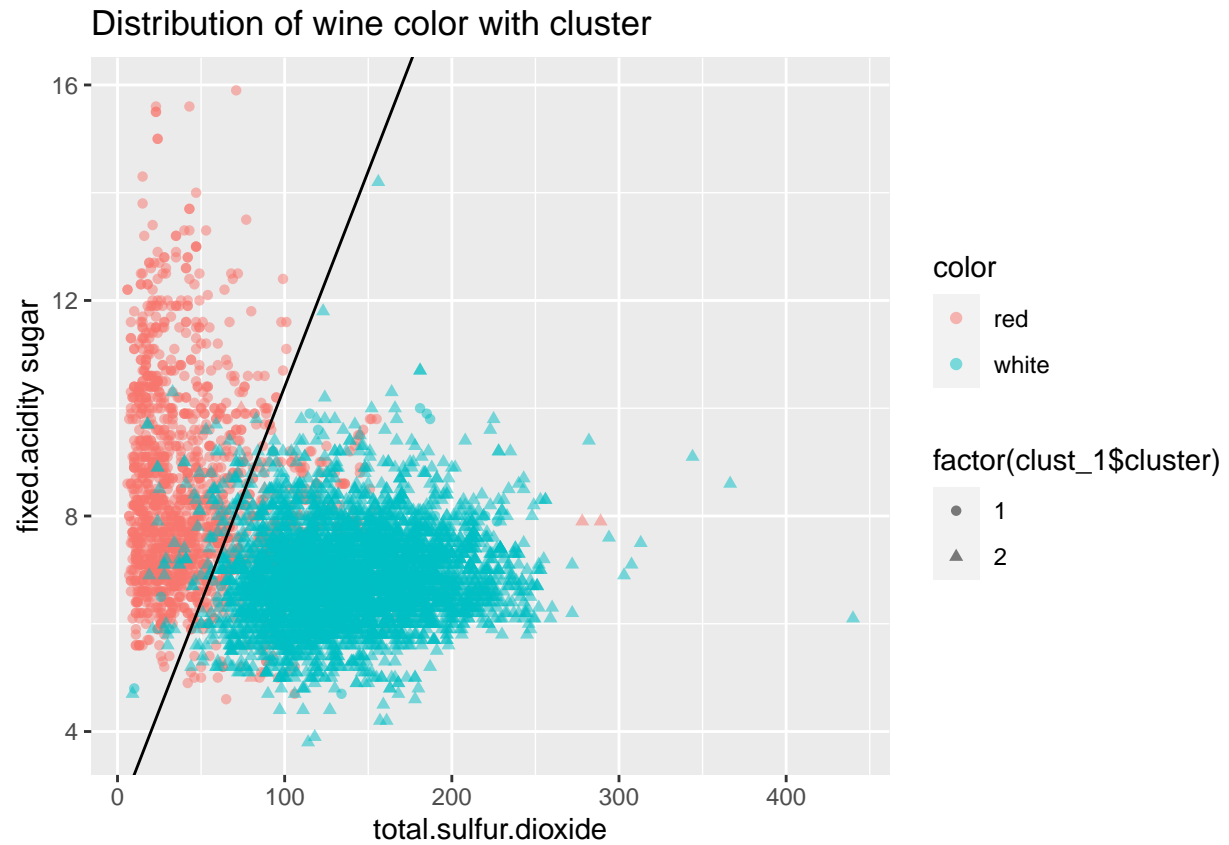
2. K-means clustering

We checked some combinations of chemicals, and found that “total sulfur dioxide” and “fixed acidity” might be largely reflected to the clusters that we make. Even though we do not know what the clusters are, wines are well-distinguished by the clusters on the plot with this two chemicals. The figure below represents that cluster 1 is mainly spread horizontally on x-axis, and cluster 2 is vertically situated.

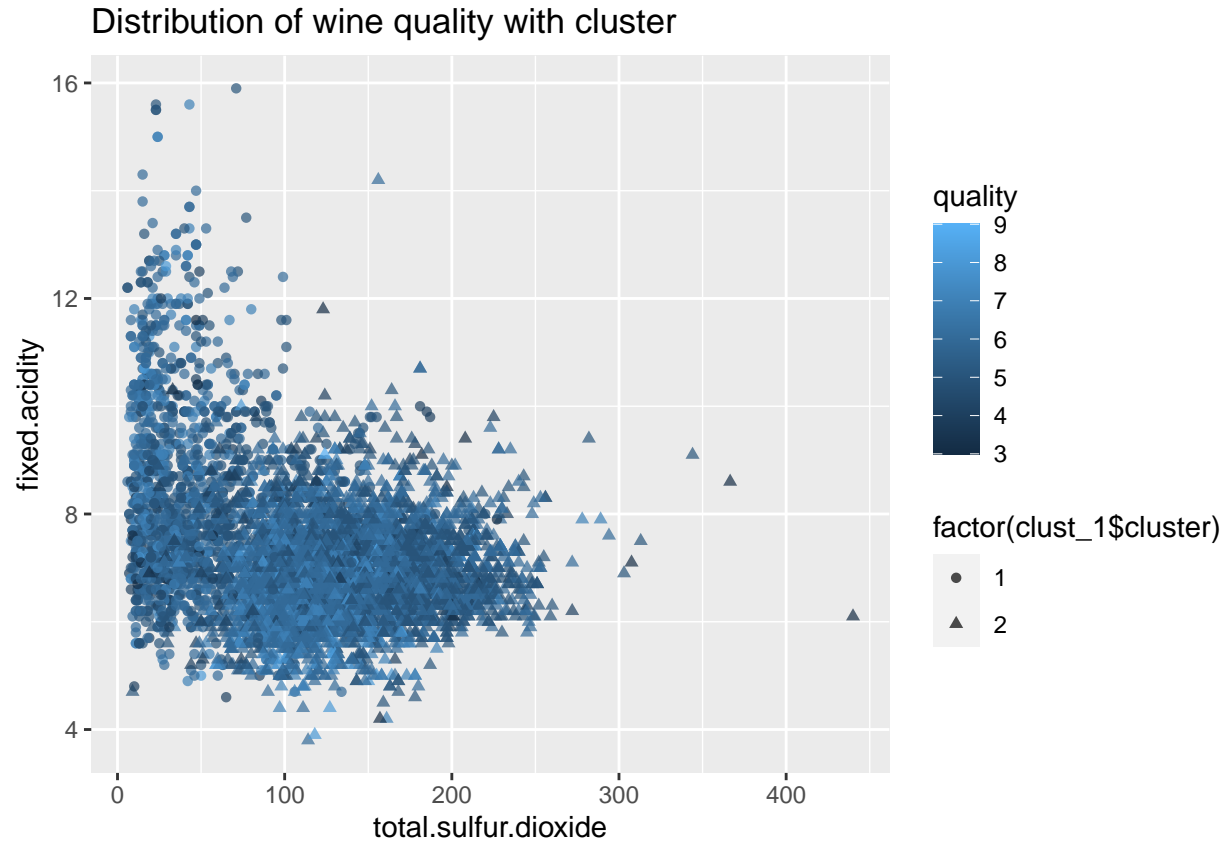
Cluster distribution with total sulfur dioxide and fixed acidity



According to the figure below, the color of wine is well-distinguished by these two clusters, and red is close to cluster 2 and white is similar to cluster 1. Therefore, it seems K-means clustering is capable of distinguishing the color of wine.



The plot below shows the distribution of wine quality, and it is so difficult to find any direction of color change that it is hard to distinguish the quality of wine.



As a result, PCA is better at distinguishing the color of wine since it separates wines more clearly and with less overlap than k-means clustering. However, k-means is not bad at separating, so we can guess that the color of wine is closely related to the chemicals in the data. On the other hand, both PCA and K-men clustering are not capable of distinguishing the quality of wine.

Q2: Market segmentation

Step 1: Data Preprocessing:

We remove records flagged as “spam”, “adult”, or “uncategorized”

```
## 'data.frame': 3331 obs. of 33 variables:
## $ chatter : num -0.929 0.541 -0.929 0.541 0.247 ...
## $ current_events : num 2.783 1.989 0.401 0.401 0.401 ...
## $ travel : num 0.221 0.221 2.458 -0.673 1.116 ...
## $ photo_sharing : num -0.184 1.788 -0.578 -0.578 0.605 ...
## $ tv_film : num 0.066 0.066 0.066 -0.645 2.911 ...
## $ sports_fandom : num -0.741 -0.279 -0.279 -0.741 3.421 ...
## $ politics : num -0.279 -0.604 2.971 -0.604 -0.279 ...
## $ food : num -0.762 0.375 -0.193 0.375 2.08 ...
## $ family : num 0.118 0.118 -0.768 1.003 2.775 ...
## $ home_and_garden : num -0.68 0.737 -0.68 0.737 -0.68 ...
## $ music : num -0.664 0.46 -0.664 0.46 0.46 ...
## $ news : num -0.571 -0.571 -0.103 -0.571 -0.571 ...
## $ online_gaming : num -0.4562 -0.4562 -0.4562 0.34 -0.0581 ...
```

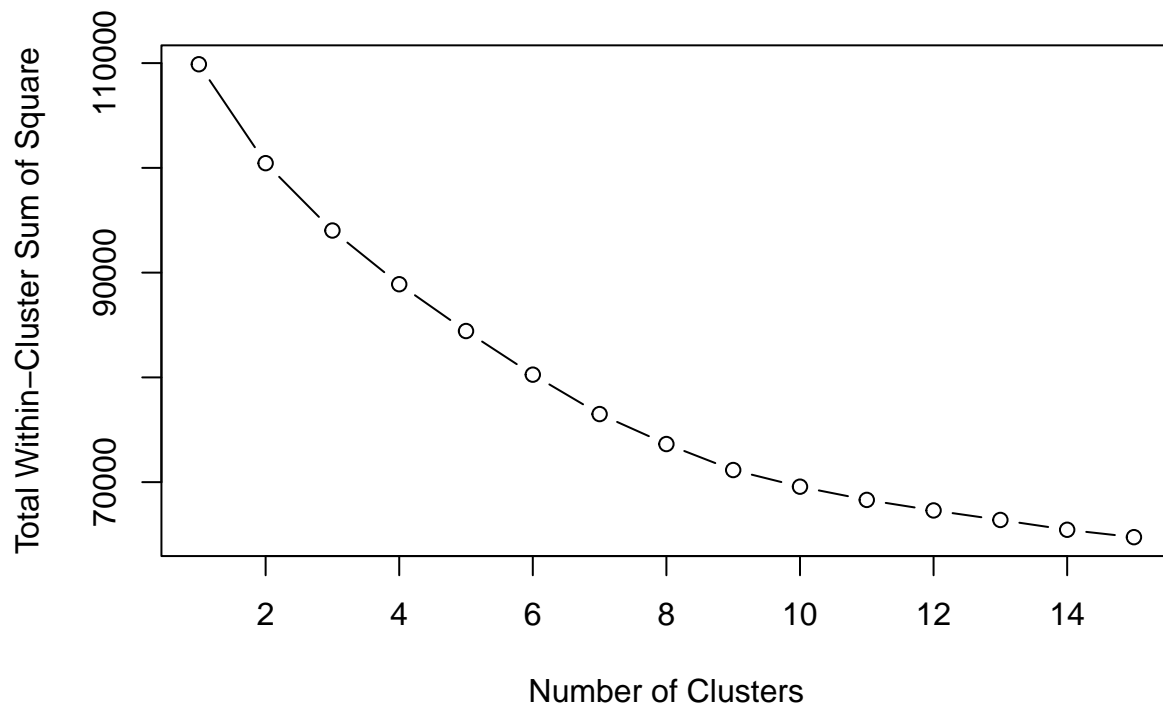
```

## $ shopping      : num -0.752 2.131 -0.176 -0.752 -0.752 ...
## $ health_nutrition: num -0.55 -0.55 -0.312 4.684 1.116 ...
## $ college_uni    : num -0.138 -0.513 -0.138 -0.138 0.987 ...
## $ sports_playing : num -0.643 -0.643 0.446 -0.643 0.446 ...
## $ cooking        : num -0.588 -0.588 -0.216 1.269 0.898 ...
## $ eco            : num -0.636 -0.636 -0.636 2.085 0.724 ...
## $ computers       : num -0.542 0.322 0.322 0.322 1.186 ...
## $ business       : num 0.949 0.949 4.034 0.949 -0.594 ...
## $ outdoors       : num -0.635 -0.635 0.282 2.115 -0.635 ...
## $ crafts         : num 3.277 -0.595 -0.595 -0.595 -0.595 ...
## $ automotive     : num -0.596 0.13 -0.596 -0.596 2.311 ...
## $ art            : num 1.035 -0.44 0.297 0.297 -0.44 ...
## $ religion        : num -0.5592 -0.5592 -0.0324 -0.5592 6.2889 ...
## $ beauty         : num 0.402 -0.515 -0.515 4.069 0.402 ...
## $ parenting      : num -0.606 -0.606 -0.606 -0.606 1.381 ...
## $ dating         : num -0.439 -0.439 -0.439 -0.439 -0.439 ...
## $ school         : num -0.607 -0.607 -0.607 0.248 1.958 ...
## $ personal_fitness: num -0.591 -0.591 -0.591 4.814 0.31 ...
## $ fashion        : num -0.529 -0.529 -0.529 1.467 0.136 ...
## $ small_business : num -0.515 -0.515 -0.515 1.26 -0.515 ...

```

Step 2:

Clustering - Perform a clustering analysis to identify distinct market segments, with K-means Determine the optimal number of clusters k using the Elbow method



In this plot, the elbow seems to be not very pronounced, but we can observe a subtle change in the slope after $k=3$.

Step 3:

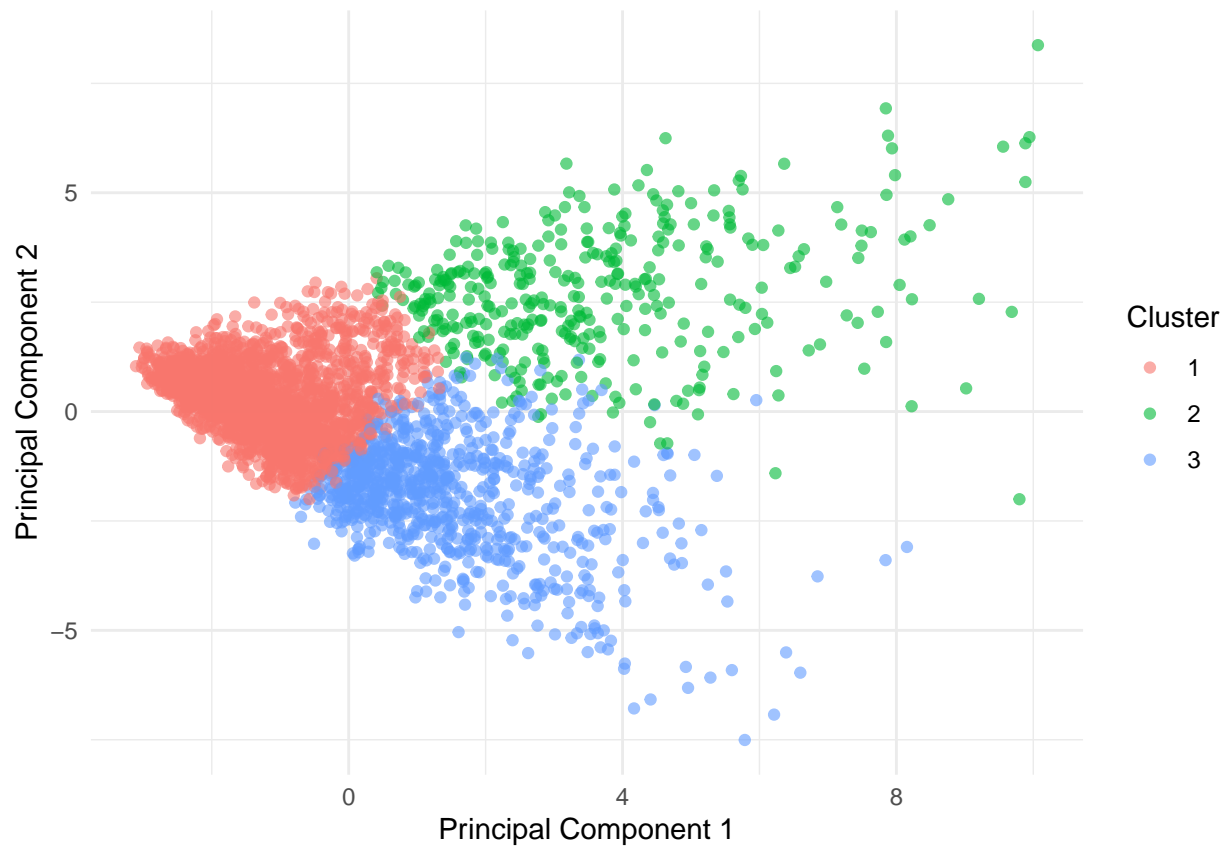
Attach the cluster labels to the original data

```
##      chatter current_events      travel photo_sharing      tv_film sports_fandom
## 1 -0.2087243      -0.1280222 -0.15371356  -0.26697385 -0.13174205      -0.2805639
## 2 -0.1499125       0.1220283 -0.02856598  -0.06897829 -0.01196642       1.8792286
## 3  0.5934117       0.2709939  0.40145429   0.70567081  0.33863255      -0.1064758
##      politics      food      family home_and_garden      music      news
## 1 -0.1660190 -0.33315335 -0.27038265      -0.1365421 -0.17417893 -0.15832896
## 2 -0.1621930  1.77811105  1.37960273      0.2208213  0.09381415 -0.05899605
## 3  0.4906629  0.07056368  0.08485538      0.2496293  0.40007410  0.42635825
##      online_gaming shopping health_nutrition college_uni sports_playing
## 1  -0.09329286 -0.2194907      -0.2314208 -0.10789923      -0.1502637
## 2   0.03353593 -0.0902315      -0.1442512 -0.01461813      0.1505177
## 3   0.22154764  0.5947281      0.6483957  0.27943975      0.3149067
##      cooking      eco computers      business      outdoors      crafts
## 1 -0.2842992 -0.21269405 -0.2044454 -0.1806136 -0.22496555 -0.2122706
## 2 -0.0525809  0.05322218  0.1634802  0.1581506 -0.02682957  0.7063966
## 3  0.7423953  0.51519222  0.4464057  0.3884042  0.58103519  0.2303006
##      automotive      art religion      beauty parenting      dating
## 1 -0.1474706 -0.14532572 -0.3099297 -0.2467260 -0.3024846 -0.1490671
## 2  0.1165529  0.08520921  2.1352929  0.3993153  2.0075847  0.1052732
## 3  0.3225961  0.33078705 -0.1434182  0.4509398 -0.1067692  0.3315379
##      school personal_fitness      fashion small_business
## 1 -0.30459997      -0.2482595 -0.24311598      -0.1640251
## 2  1.67674454      -0.1221209  0.09811419      0.1368287
## 3  0.04234259      0.6813974  0.57268201      0.3556845

##      cluster X chatter current_events      travel photo_sharing      tv_film
## 1          1 NA 3.449200      1.334431 1.161336      1.788335 0.7220132
## 2          2 NA 3.649315      1.649315 1.441096      2.290411 0.8904110
## 3          3 NA 6.178571      1.836905 2.402381      4.254762 1.3833333
##      sports_fandom politics      food      family home_and_garden      music
## 1      0.9962371 1.347131 0.7539981 0.5620884      0.3833490 0.4355597
## 2      5.6657534 1.358904 4.4684932 2.4246575      0.6356164 0.6739726
## 3      1.3726190 3.367857 1.4642857 0.9630952      0.6559524 0.9464286
##      news online_gaming shopping health_nutrition college_uni sports_playing
## 1 0.8809972      0.911571 0.9238006      1.337723      1.079962      0.4524929
## 2 1.0931507      1.230137 1.1479452      1.704110      1.328767      0.7287671
## 3 2.1297619      1.702381 2.3357143      5.035714      2.113095      0.8797619
##      cooking      eco computers      business      outdoors      crafts automotive
## 1 0.8170273 0.3113829 0.3904045 0.2681091 0.4468485 0.2963311 0.6175917
## 2 1.4410959 0.5068493 0.8164384 0.4876712 0.6630137 1.0082192 0.9808219
## 3 3.5821429 0.8464286 1.1440476 0.6369048 1.3261905 0.6392857 1.2642857
##      art religion      beauty parenting      dating      school personal_fitness
## 1 0.3998119 0.4731891 0.2925682 0.4581373 0.3443086 0.3537159      0.7610536
## 2 0.7123288 5.1150685 0.9972603 3.9452055 0.6465753 2.6712329      1.0410959
## 3 1.0452381 0.7892857 1.0535714 0.7535714 0.9154762 0.7595238      2.8250000
##      fashion small_business
```



```
## 1 0.4294450      0.1975541
## 2 0.9424658      0.3671233
## 3 1.6559524      0.4904762
```



```
## cluster X chatter current_events travel photo_sharing tv_film
## 1 1 NA 3.449200 1.334431 1.161336 1.788335 0.7220132
## 2 2 NA 3.649315 1.649315 1.441096 2.290411 0.8904110
## 3 3 NA 6.178571 1.836905 2.402381 4.254762 1.3833333
## sports_fandom politics food family home_and_garden music
## 1 0.9962371 1.347131 0.7539981 0.5620884 0.3833490 0.4355597
## 2 5.6657534 1.358904 4.4684932 2.4246575 0.6356164 0.6739726
## 3 1.3726190 3.367857 1.4642857 0.9630952 0.6559524 0.9464286
## news online_gaming shopping health_nutrition college_uni sports_playing
## 1 0.8809972 0.911571 0.9238006 1.337723 1.079962 0.4524929
## 2 1.0931507 1.230137 1.1479452 1.704110 1.328767 0.7287671
## 3 2.1297619 1.702381 2.3357143 5.035714 2.113095 0.8797619
## cooking eco computers business outdoors crafts automotive
## 1 0.8170273 0.3113829 0.3904045 0.2681091 0.4468485 0.2963311 0.6175917
## 2 1.4410959 0.5068493 0.8164384 0.4876712 0.6630137 1.0082192 0.9808219
## 3 3.5821429 0.8464286 1.1440476 0.6369048 1.3261905 0.6392857 1.2642857
## art religion beauty parenting dating school personal_fitness
## 1 0.3998119 0.4731891 0.2925682 0.4581373 0.3443086 0.3537159 0.7610536
## 2 0.7123288 5.1150685 0.9972603 3.9452055 0.6465753 2.6712329 1.0410959
## 3 1.0452381 0.7892857 1.0535714 0.7535714 0.9154762 0.7595238 2.8250000
## fashion small_business cluster PC1
## 1 0.4294450 0.1975541 1 -1.199759
```

```
## 2 0.9424658      0.3671233      2 3.624491
## 3 1.6559524      0.4904762      3 1.461604
```

Step 4:

Labeling Clusters - Market Segmentation

How they might position their brand to maximally appeal to each market segment: Customer segmentation advice:

1:Community-Focused Cluster: Cluster 1 High on PC1, Low on PC2: This cluster would be characterized by users with strong community and family values who are less engaged in activities like sharing photos, cooking, or personal fitness. We chose to label this cluster “Community & Family-Focused.” This segment values community and traditional activities. “NutrientH20” could position their brand as a traditional, family-friendly product. Marketing campaigns could feature family gatherings, communal events, and emphasize the brand’s role in nurturing these relationships. Sponsorships or partnerships with community organizations, faith-based groups, and local sports teams could also resonate well with this segment. AS this appears to be the majority of their consumers with 2126 consumers in it, it may be important to focus on these consumers.

2: Health-Conscious Cluster:

Cluster 2 is high on PC1, and high on PC2: These users appear to be interested in health and lifestyle as suggested by the positive values of “food” and “sports_fandom” and “family” on PC2. These individuals appear to value both their health and their community. NutrientH20 might focus on highlighting the health benefits of their drinks, such as hydration, natural ingredients, or fitness recovery aspects to indulge the sports fanatics. They could also show their brand as a supporter of community health initiatives, such as local sports events, wellness programs, or outdoor activities that promote a healthy lifestyle. However, this is the smallest of the clusters with only 365 members so maybe not the most important folkd to target.

3: Active Lifestyle Enthusiasts Cluster:

Cluster 3 is low on PC1 and high on PC2. These users focused on photo sharing and fitness. This group is engaged in modern lifestyle activities such as fitness and sharing their experiences online. NutrientH20 can showcase their product within the context of an active lifestyle, focusing on the convenience, design, and how the product fits into an on-the-go, wellness-oriented life. Collaborating with fitness influencers, participating in fitness challenges, and creating visually appealing content for social media that encourages sharing could appeal to this segment.

Q3: Association rules for grocery purchases

```
## Apriori
##
## Parameter specification:
## confidence minval smax arem aval originalSupport maxtime support minlen
##          0.1    0.1    1 none FALSE                TRUE     5   0.005    4
## maxlen target  ext
##          10  rules TRUE
##
## Algorithmic control:
```

```

## filter tree heap memopt load sort verbose
## 0.1 TRUE TRUE FALSE TRUE 2 TRUE
##
## Absolute minimum support count: 49
##
## set item appearances ...[0 item(s)] done [0.00s].
## set transactions ...[169 item(s), 9835 transaction(s)] done [0.00s].
## sorting and recoding items ... [120 item(s)] done [0.00s].
## creating transaction tree ... done [0.00s].
## checking subsets of size 1 2 3 4 done [0.00s].
## writing ... [48 rule(s)] done [0.00s].
## creating S4 object ... done [0.00s].

```

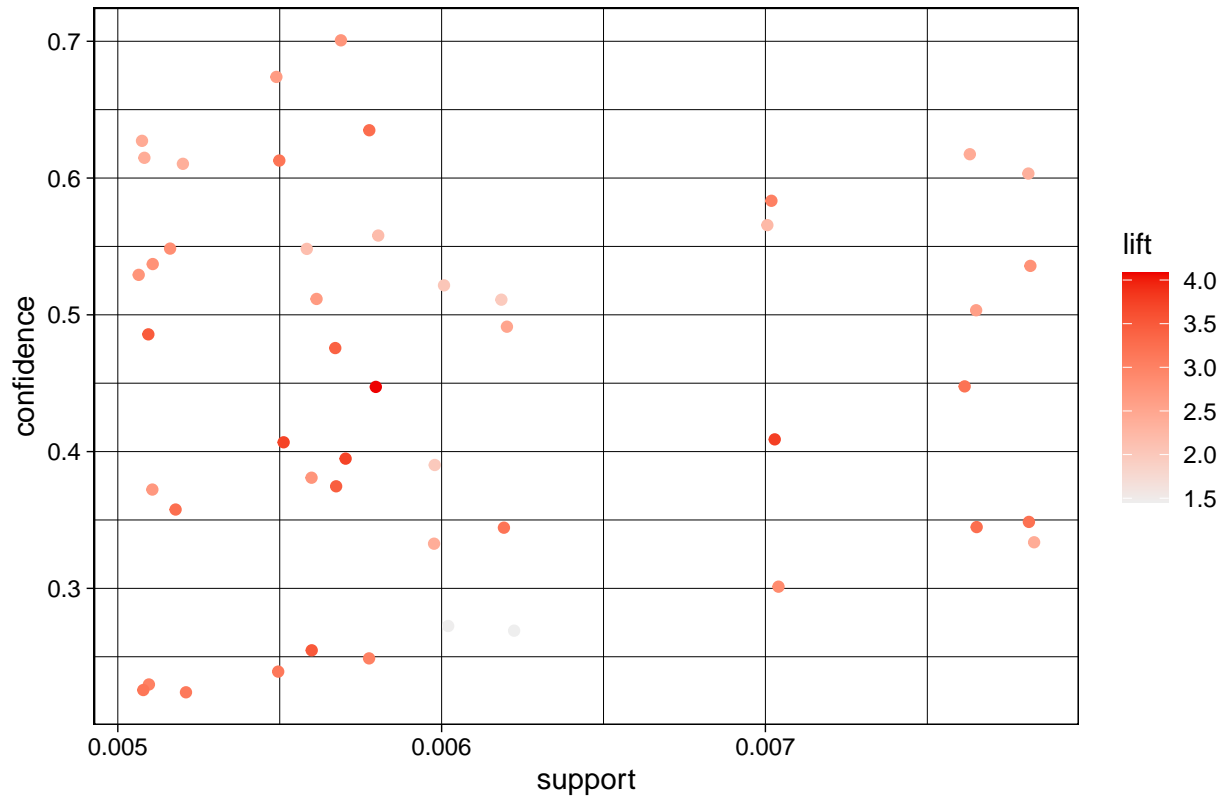
Thresholds for lift and confidence: A support threshold of 0.005 means we're interested in itemsets that appear in at least 0.5% of all transactions. This value is chosen to ensure that the rules are not based on very rare item combinations, which might be of less practical significance. It's low enough to capture infrequent but potentially interesting associations, yet high enough to ignore rules that could occur simply by chance due to very low occurrence.

A confidence threshold of 0.2 is chosen to ensure that at least 20% of the time, the items on the left-hand side of the rule are accompanied by the items on the right-hand side. This is a relatively low threshold for confidence, allowing for the discovery of rules that might not be very strong but could still provide interesting insights. Higher confidence levels could be used to focus on more reliable rules but might miss out on less obvious patterns.

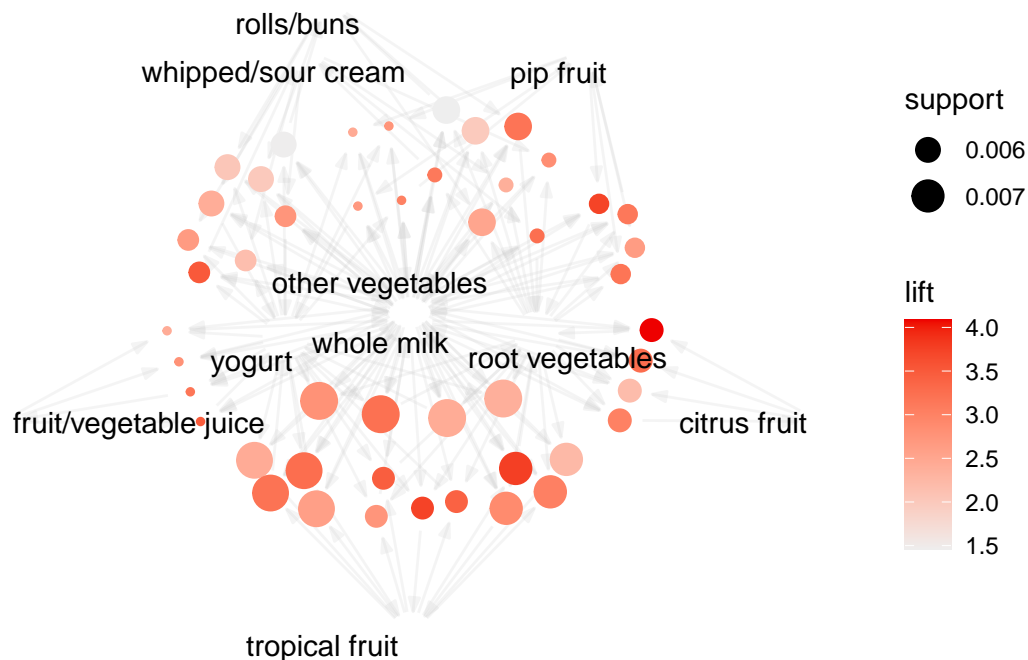
Setting minlen to 2 ensures that the rules consist of at least two items. This is the smallest possible rule and ensures that you are looking at associations between items, not just the frequency of single items.

```
## To reduce overplotting, jitter is added! Use jitter = 0 to prevent jitter.
```

Scatter plot for 48 rules



```
## Available control parameters (with default values):
## layout      = stress
## circular    = FALSE
## ggraphdots  = NULL
## edges       = <environment>
## nodes       = <environment>
## nodetext    = <environment>
## colors      = c("#EE0000FF", "#EEEEEEFF")
## engine      = ggplot2
## max         = 100
## verbose     = FALSE
```



	lhs	rhs	support	confidence	coverage	lift	cor
## [1]	{citrus fruit, other vegetables, whole milk}	=> {root vegetables}	0.005795628	0.4453125	0.013014743	4.085493	
## [2]	{other vegetables, tropical fruit, whole milk}	=> {root vegetables}	0.007015760	0.4107143	0.017081851	3.768074	
## [3]	{root vegetables, whole milk, yogurt}	=> {tropical fruit}	0.005693950	0.3916084	0.014539908	3.732043	
## [4]	{other vegetables, pip fruit, whole milk}	=> {root vegetables}	0.005490595	0.4060150	0.013523132	3.724961	
## [5]	{other vegetables, whole milk, yogurt}	=> {whipped/sour cream}	0.005592272	0.2511416	0.022267412	3.503514	
## [6]	{fruit/vegetable juice, other vegetables, whole milk}	=> {yogurt}	0.005083884	0.4854369	0.010472801	3.479790	
## [7]	{tropical fruit, whole milk, yogurt}	=> {root vegetables}	0.005693950	0.3758389	0.015149975	3.448112	
## [8]	{root vegetables, tropical fruit, whole milk}	=> {yogurt}	0.005693950	0.4745763	0.011997966	3.401937	
## [9]	{citrus fruit,						

```
##      root vegetables,
##      whole milk}          => {other vegetables}    0.005795628  0.6333333 0.009150991 3.273165
## [10] {other vegetables,
##      whole milk,
##      yogurt}             => {tropical fruit}      0.007625826  0.3424658 0.022267412 3.263712
```

Support and Confidence Levels:

Graph 01:

The scatter plot indicates that most rules have a support between 0.005 and 0.0075. This is consistent with the minimum support level defined, meaning we've captured the itemsets that appear in at least 0.5% of the transactions.

Graph 02:

The graph visualization clusters items like 'whole milk', 'yogurt', 'other vegetables', 'rolls/buns', and 'tropical fruit' with high lift values, suggesting that these combinations are more common than expected. This finding is logical as items such as 'whole milk' and 'bread' are staples in many households, and 'yogurt' often pairs with 'fruit' as a common breakfast or snack choice. The presence of 'whole milk' in several rules could signify it as a potential 'connector' item, which is frequently bought with various other items.

Q4: Image classification with neural networks

The following figures are the output of the "ECO395MHomework4Q4" Jupyter Source File located in the same directory as this R Markdown file. The code uses a 80/20 train test split of the EuroSAT_RGB photographs, and using the color values in RGB notation, classifies each test photo into one of 11 categories (e.g. industrial, crops, rivers, forest, etc.). We had it run through 10 Epochs, or 10 runs through the whole set. We list below the neural network model with a learning rate of 0.001 and loss function output decreasing as we move through the Epochs.

```
SataliteNN (conv1): Conv2d(3, 16, kernel_size=(5, 5), stride=(1, 1))
(pool): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
(conv2): Conv2d(16, 32, kernel_size=(5, 5), stride=(1, 1))
(fc1): Linear(in_features=800, out_features=120, bias=True)
(fc2): Linear(in_features=120, out_features=84, bias=True)
(fc3): Linear(in_features=84, out_features=10, bias=True)
Epoch 1, Loss: 1.2811198836427045
Epoch 2, Loss: 0.9210050483367026
Epoch 3, Loss: 0.8127668705654624
Epoch 4, Loss: 0.7332519596057978
Epoch 5, Loss: 0.6718016320998194
Epoch 6, Loss: 0.6176651422231548
Epoch 7, Loss: 0.5799342335957098
Epoch 8, Loss: 0.5500946855521976
```

Epoch 9, Loss: 0.5310325839008201

Epoch 10, Loss: 0.507780645660004

After this runs, we simply calculate the overall test-set accuracy of the network on test images by the number if got correct over the total images in the test set and got an out of sample accuracy of 79 %. Below are a few examples of the test set images after being rescales.

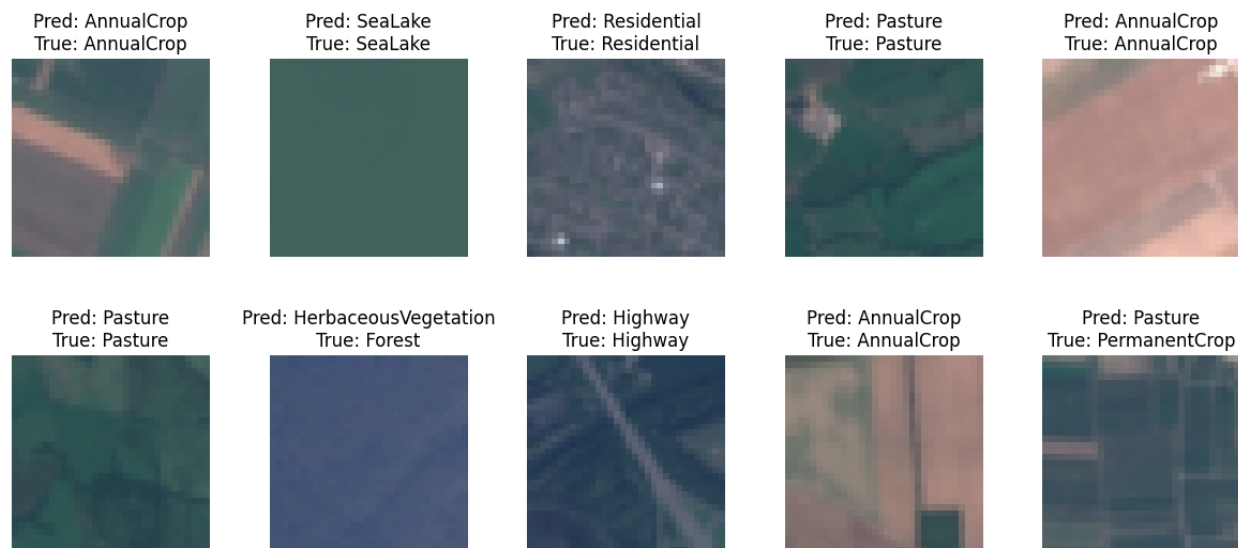


Figure 1: Sample Predictions

We see that the the categories the model is the least accurate discerning are the vegetation and permanent cropland categories. We provide the confusion matrix below showing of the actual category pictures (y-axis), how many of those categories were predicted to be in each category (x-axis). We see that by far most pictures are accurately placed in the correct category solely based on the RGB values of a scaled version of the picture. This example provides evidence for the robustness of the nerual network as a model to make predictions.

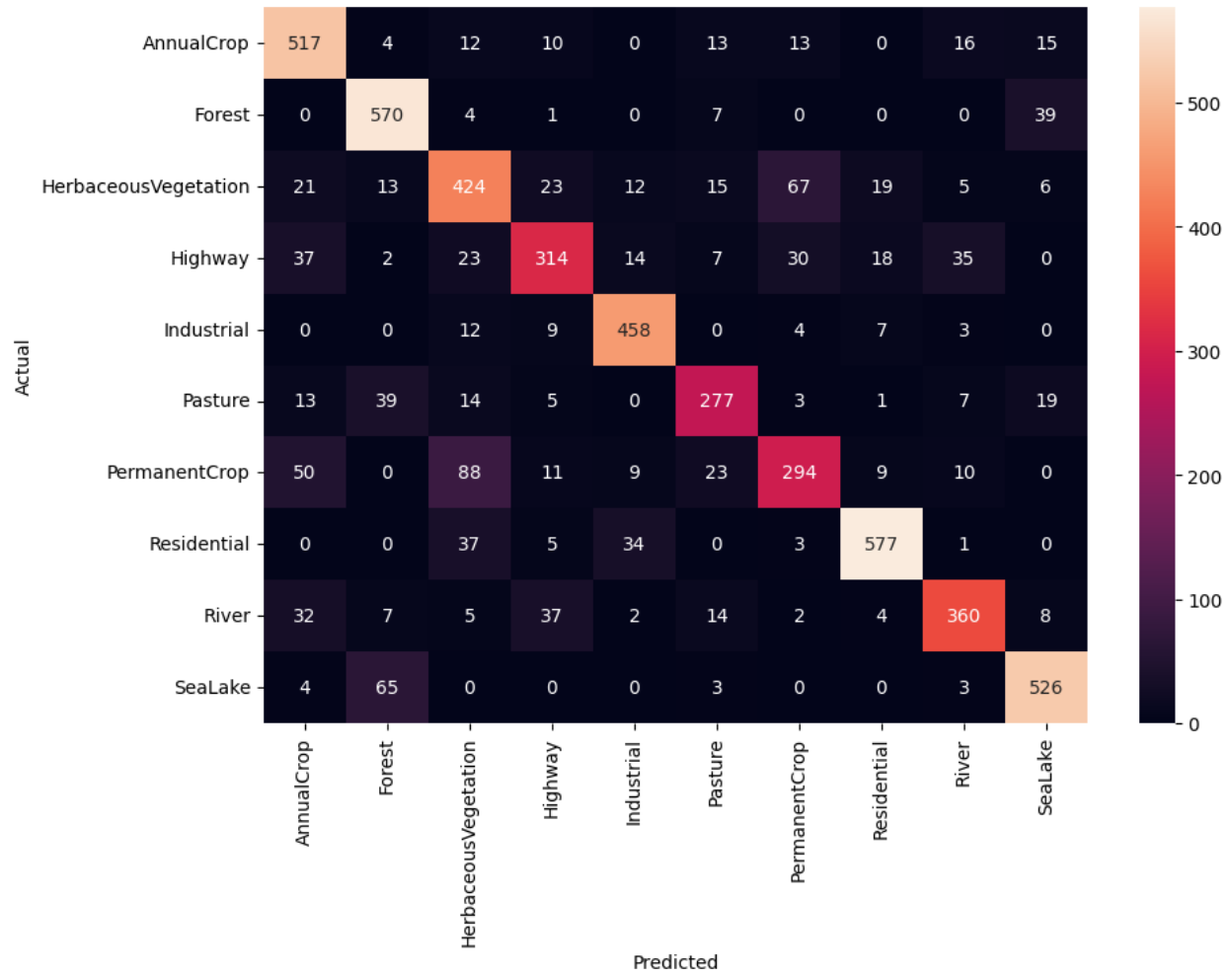


Figure 2: Confusion Matrix