In [212…

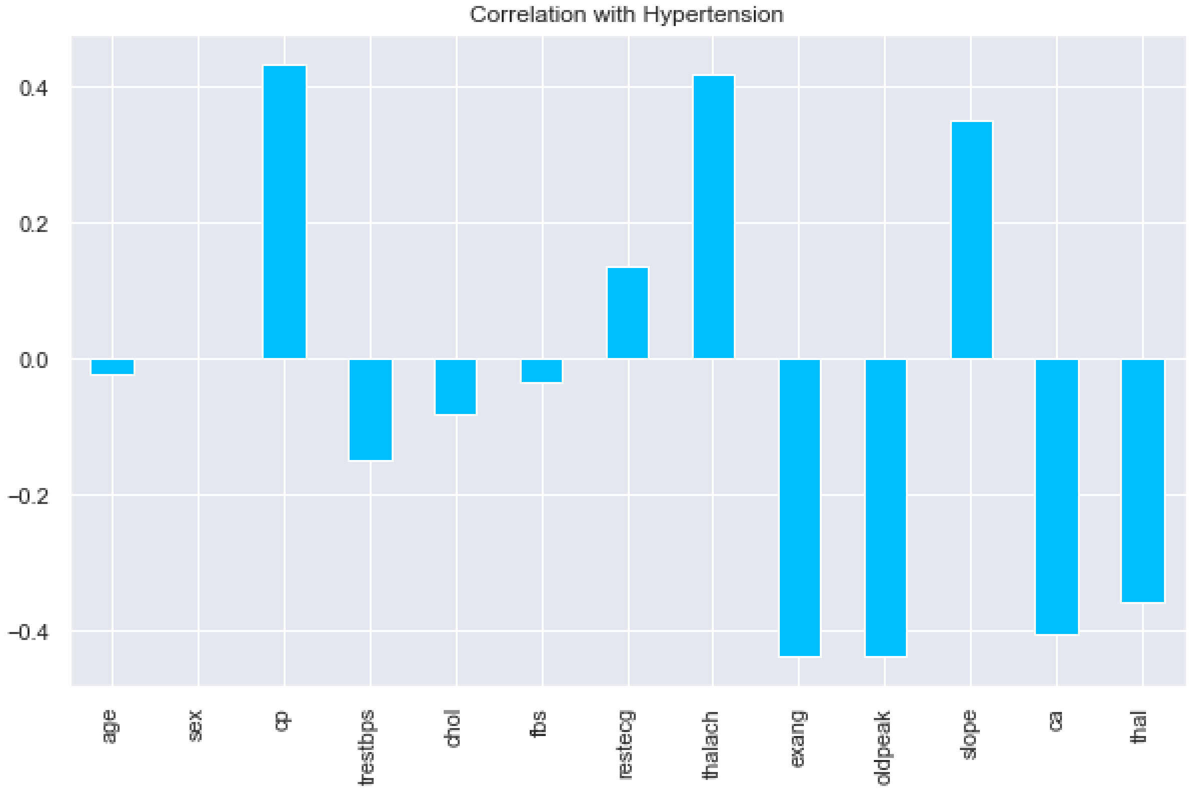
```
import numpy as np
import pandas as pd
from scipy import stats
from sklearn.preprocessing import StandardScaler,MinMaxScaler
from sklearn.neighbors import KNeighborsRegressor, KNeighborsClassifier
from sklearn.linear_model import LogisticRegressionCV, LogisticRegression
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import GridSearchCV, train_test_split, cross_val_score
from sklearn.metrics import confusion_matrix, accuracy_score, classification_report, ConfusionMatrixDisplay,
from sklearn.naive_bayes import GaussianNB, BernoulliNB, MultinomialNB
from sklearn.svm import SVC, LinearSVC
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier, ExtraTreesClassifier, GradientBoostingClassifier, AdaBo
from sklearn.feature_selection import SelectKBest, chi2
from mlxtend.feature_selection import ExhaustiveFeatureSelector as EFS
from sklearn.preprocessing import QuantileTransformer

hypertesion_data = pd.read_csv('/Users/wiizh/CS249 Final Project/hypertension_data.csv')

hypertesion_data.describe()
```

Out[212]:

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	
count	26083.000000	26058.00000	26083.000000	26083.000000	26083.000000	26083.000000	26083.000000	26083.000000	2608
mean	55.661389	0.50000	0.958594	131.592992	246.246061	0.149753	0.526512	149.655024	
std	15.189768	0.50001	1.023931	17.588809	51.643522	0.356836	0.525641	22.858109	
min	11.000000	0.00000	0.000000	94.000000	126.000000	0.000000	0.000000	71.000000	
25%	44.000000	0.00000	0.000000	120.000000	211.000000	0.000000	0.000000	133.000000	
50%	56.000000	0.50000	1.000000	130.000000	240.000000	0.000000	1.000000	153.000000	
75%	67.000000	1.00000	2.000000	140.000000	275.000000	0.000000	1.000000	166.000000	
max	98.000000	1.00000	3.000000	200.000000	564.000000	1.000000	2.000000	202.000000	

In [196…

```
hypertesion_data.drop('target', axis=1).corrwith(hypertesion_data.target).plot(kind='bar', grid=True, figsize
```



In [197…

```
hypertesion_data_vis = hypertesion_data.copy()
hypertesion_data_vis.slope[hypertesion_data_vis['slope'] == 0] = 'up slope'
hypertesion_data_vis.slope[hypertesion_data_vis['slope'] == 1] = 'flat'
hypertesion_data_vis.slope[hypertesion_data_vis['slope'] == 2] = 'down slope'

hypertesion_data_vis.head(3)
```

```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/2833771360.py:2: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#r
eturning-a-view-versus-a-copy
  hypertesion_data_vis.slope[hypertesion_data_vis['slope'] == 0] = 'up slope'
```

Out[197]:

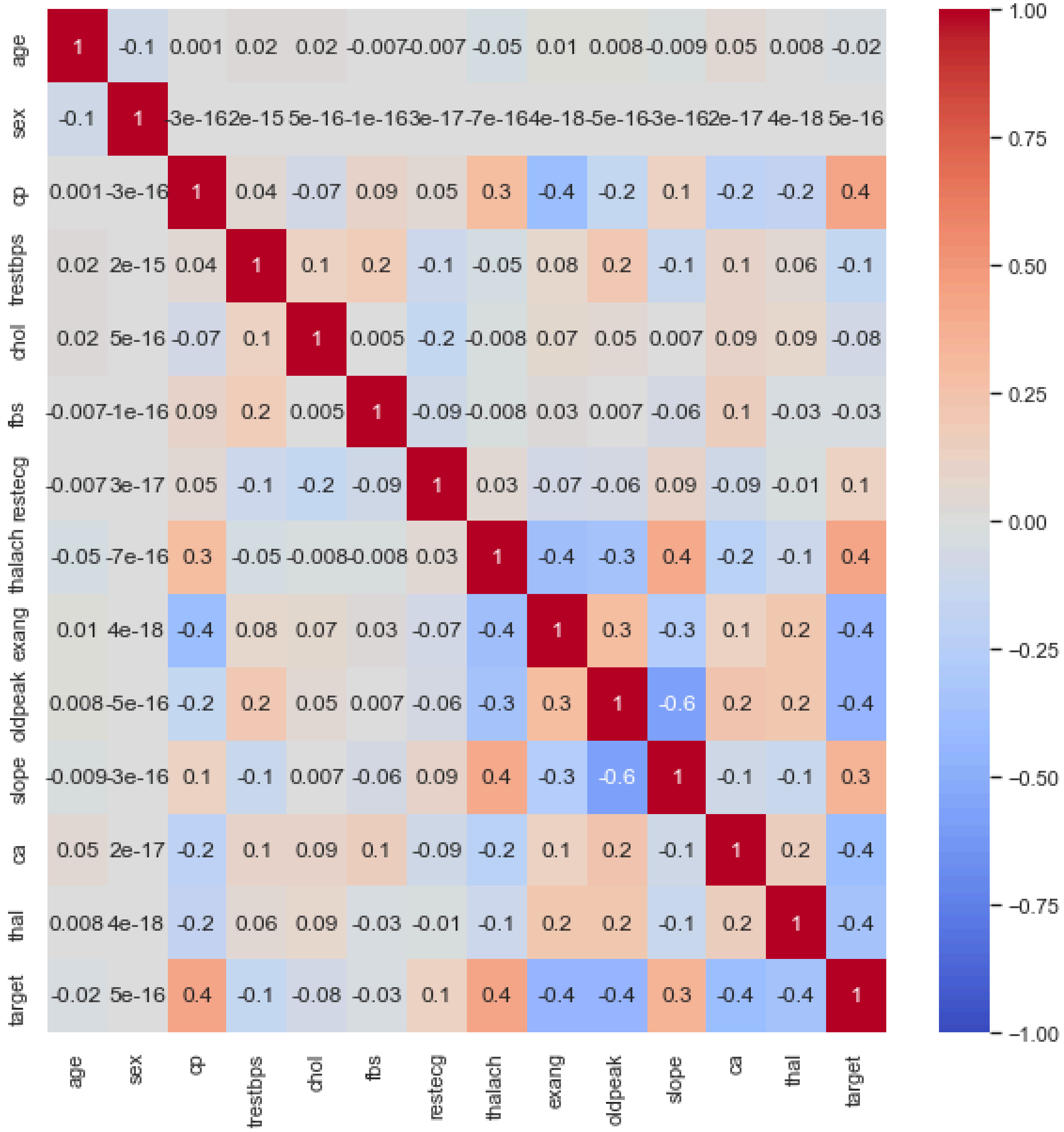
	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slope	ca	thal	target
0	57.0	1.0	3	145	233	1	0	150	0	2.3	up slope	0	1	1
1	64.0	0.0	2	130	250	0	1	187	0	3.5	up slope	0	2	1
2	52.0	1.0	1	130	204	0	0	172	0	1.4	down slope	0	2	1

In [198…

```python
sns.set(rc = {'figure.figsize':(10,10)})
sns.heatmap(hypertesion_data.corr(),vmin=-1, vmax=1, annot = True, fmt='.1g',cmap= 'coolwarm')
```

Out[198]:

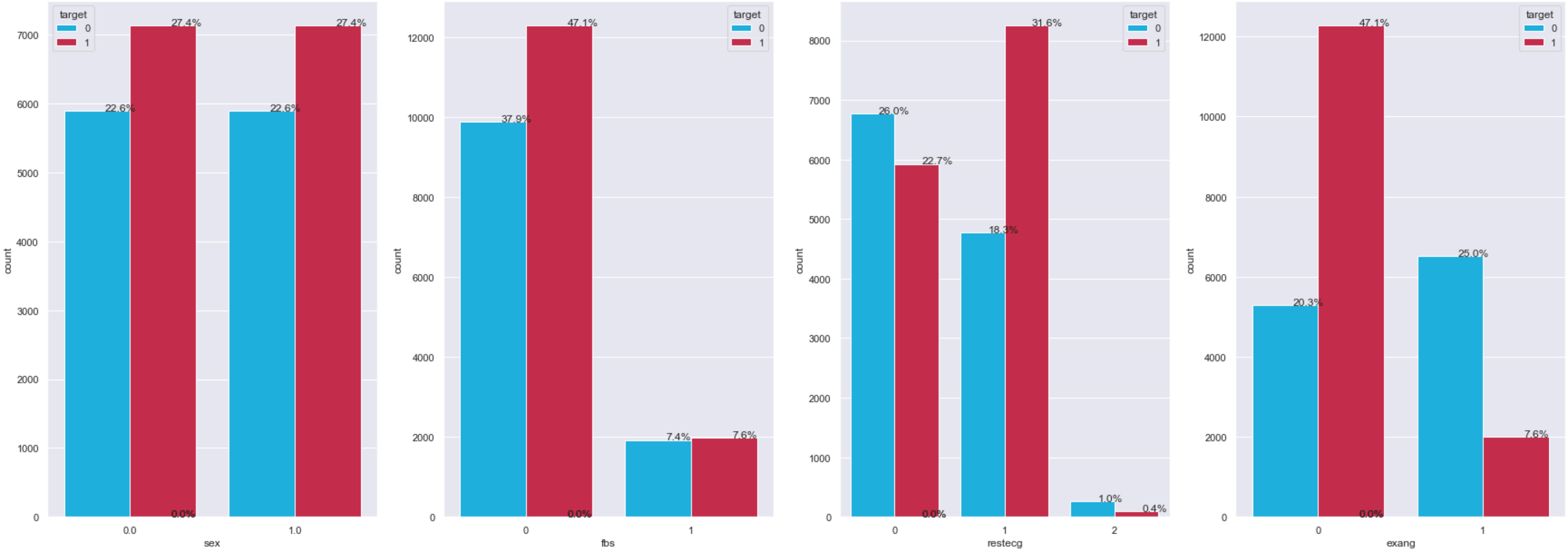
```
<AxesSubplot:>
```



In [199…

```
features = [x for x in hypertesion_data.columns if x in ['sex', 'restecg', 'fbs', 'exang']]
plt.figure(figsize = (30,23))
plt.suptitle('Hypertension by categorical features')
#subplots
for i, feature in enumerate(features):
    plt.subplot(2,4, i+1)
    x = sns.countplot(x=feature ,hue='target', data=hypertesion_data, palette = ['deepskyblue','crimson'])
    for z in x.patches:
      x.annotate('{:.1f}'.format((z.get_height()/hypertesion_data.shape[0])*100)+'%',(z.get_x()+0.25, z.get_
```

Hypertension by categorical features



In [200…

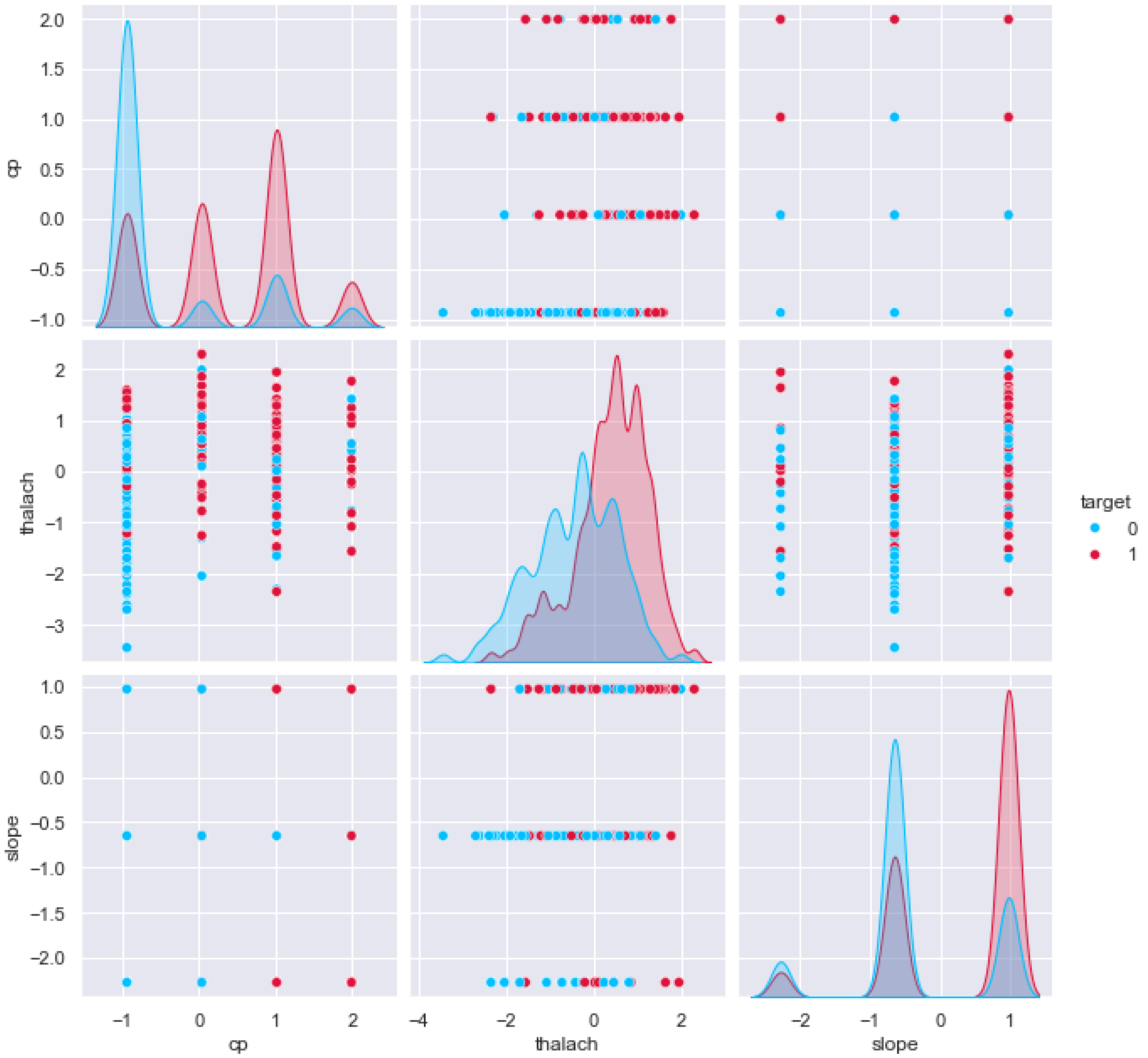
```
#scale the data before pairplot
data_pairplot = hypertesion_data
float_columns = [x for x in hypertesion_data.columns if x in ['slope','cp','thalach']]

sc = StandardScaler()
data_pairplot[float_columns] = sc.fit_transform(data_pairplot[float_columns])
data_pairplot.head(4)
```

Out[200]:

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slope	ca	thal	target
0	57.0	1.0	1.993733	145	233	1	0	0.015092	0	2.3	-2.271363	0	1	1
1	64.0	0.0	1.017086	130	250	0	1	1.633805	0	3.5	-2.271363	0	2	1
2	52.0	1.0	0.040439	130	204	0	0	0.977570	0	1.4	0.972748	0	2	1
3	56.0	0.0	0.040439	120	236	0	1	1.240064	0	0.8	0.972748	0	2	1

In [201…

```
float_columns = [x for x in data_pairplot.columns if x in ['slope','cp','thalach']]
sns.set_context('notebook')
sns.pairplot(data_pairplot[float_columns + ['target']],
             hue='target',
             hue_order=[0,1],
             height=3,
             palette={0:'deepskyblue',1:'crimson'});
```



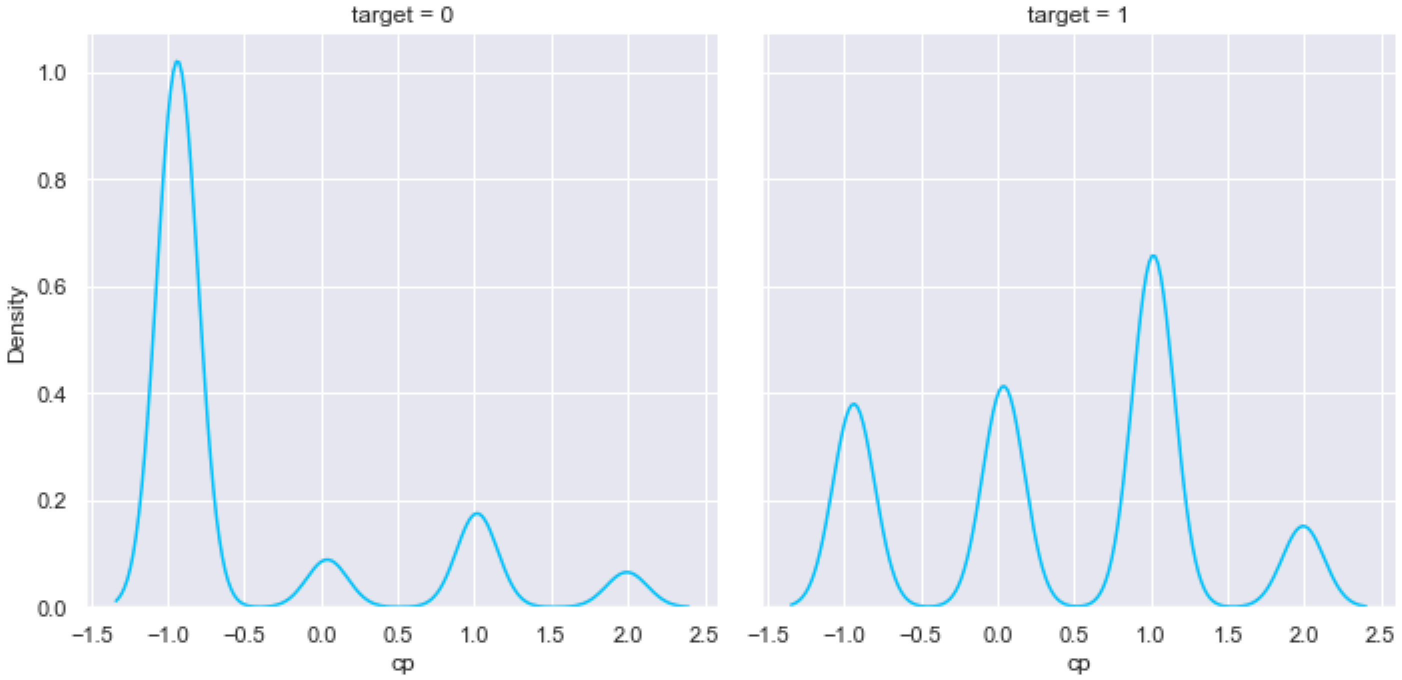
In [202…

```
plt.figure(figsize=(12,5))
sns.displot(x='cp', col='target' , data = hypertesion_data, kind="kde" ,color = 'deepskyblue');

cp = pd.cut( hypertesion_data['cp'],bins=[-1.5,-0.5,0.5,1.5,2.5],labels=['asymptomatic','typical angina','aty
cp_temp = pd.crosstab(hypertesion_data['target'],cp,rownames=['target'])
cp_temp = cp_temp.astype(float)
cp_temp
```

Out[202]:

cp target	asymptomatic	typical angina	atypical angina	non-anginal pain
0	8930.0	776.0	1532.0	571.0
1	3384.0	3680.0	5860.0	1350.0

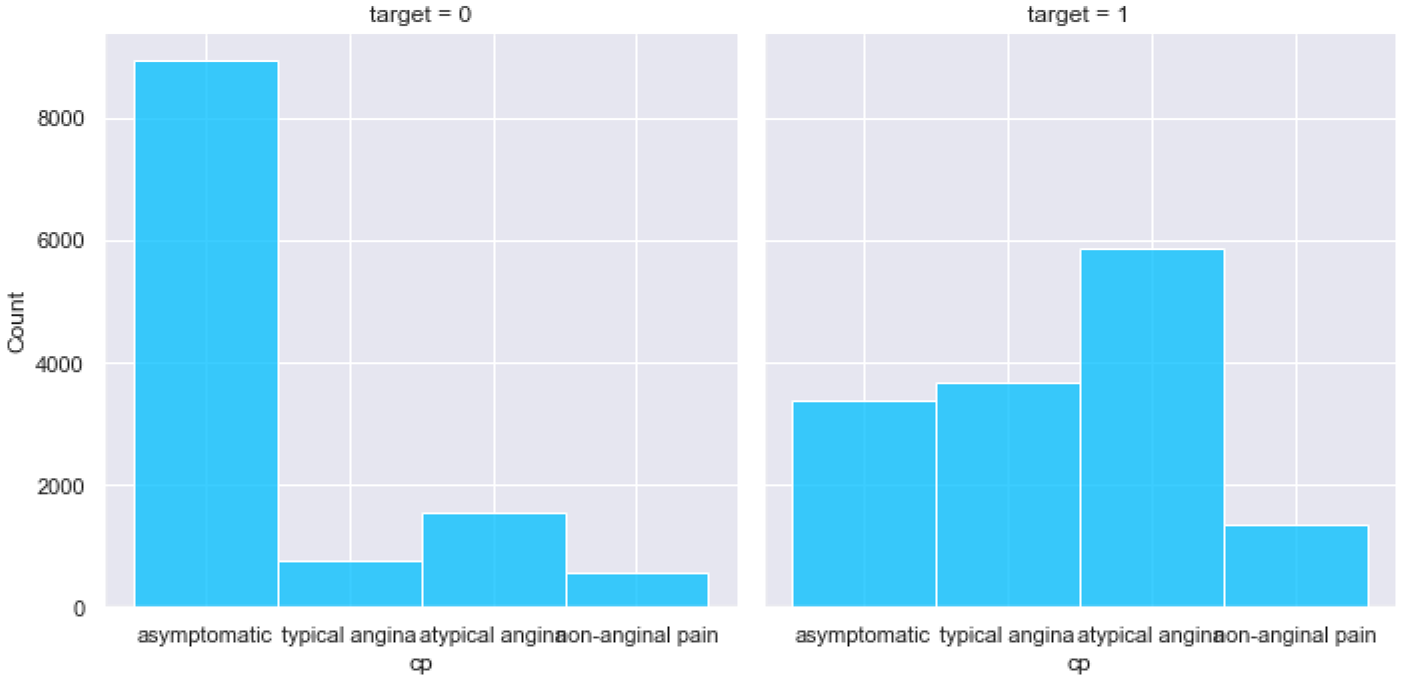
```
<Figure size 864x360 with 0 Axes>
```



In [203…

```
#
cp_temp_sum_lst=list(cp_temp.transpose().sum().values)
for idx in range(cp_temp.values.shape[0]):
    cp_temp.values[idx]= cp_temp.values[idx]/cp_temp_sum_lst[idx]*100

cp_temp

plt.figure(figsize=(12,20))
sns.displot(data=hypertesion_data,col='target',x=cp,color='deepskyblue');
```

```
<Figure size 864x1440 with 0 Axes>
```



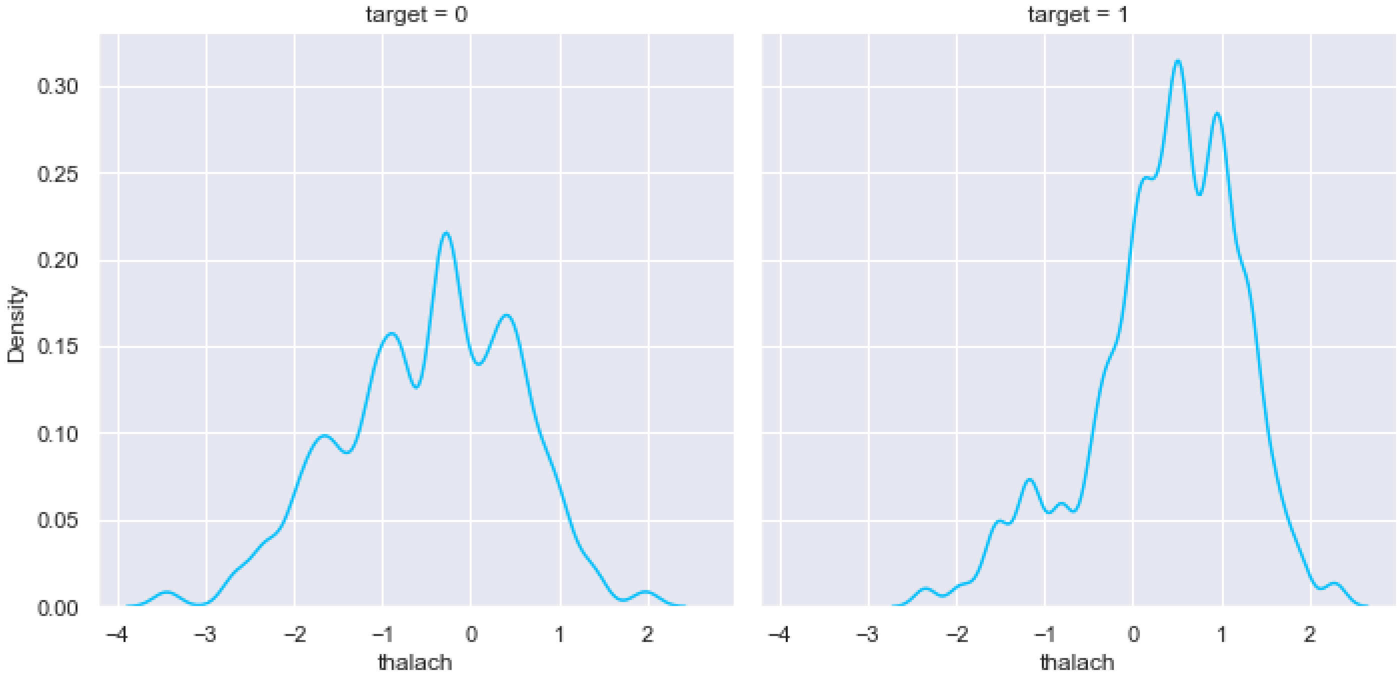
In [204…

```
plt.figure(figsize=(12,5))
sns.displot(x='thalach', col='target' , data = hypertesion_data, kind="kde" ,color = 'deepskyblue');

thalach = pd.cut( hypertesion_data['thalach'],bins=[-4,-3,-2,-1,0,1,2,2.5],labels=['71-90.65','90.65-103.75'
'116.85-129.95','129.95-143.05','143.05-156.15','156.15-202.00'])
thalach_temp = pd.crosstab(hypertesion_data['target'],thalach,rownames=['target'])
thalach_temp = thalach_temp.astype(float)
thalach_temp
```

Out[204]:

thalach	71-90.65	90.65-103.75	103.75-116.85	116.85-129.95	129.95-143.05	143.05-156.15	156.15-202.00
target							
0	82.0	692.0	2730.0	4082.0	3569.0	654.0	0.0
1	0.0	84.0	1216.0	2448.0	7186.0	3232.0	108.0

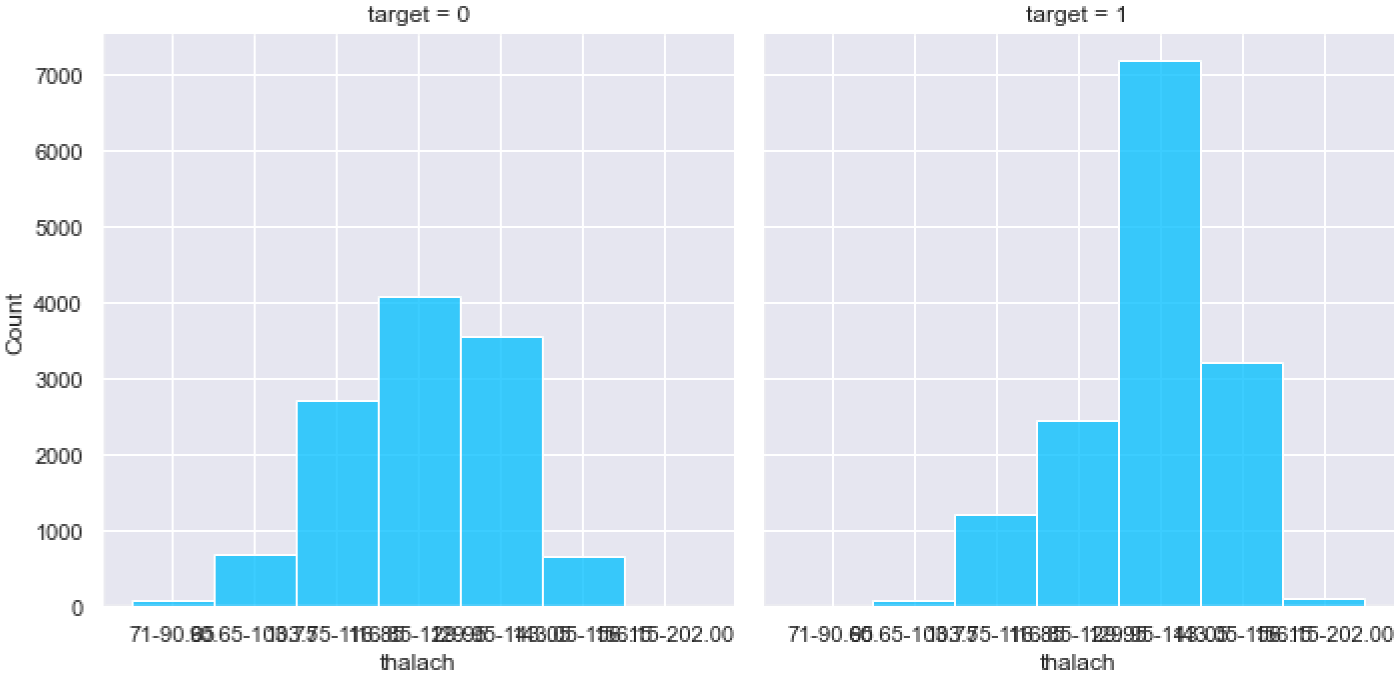
```
<Figure size 864x360 with 0 Axes>
```



In [205…

```
plt.figure(figsize=(12,20))
sns.displot(data=hypertesion_data,col='target',x=thalach,color='deepskyblue');
```

```
<Figure size 864x1440 with 0 Axes>
```



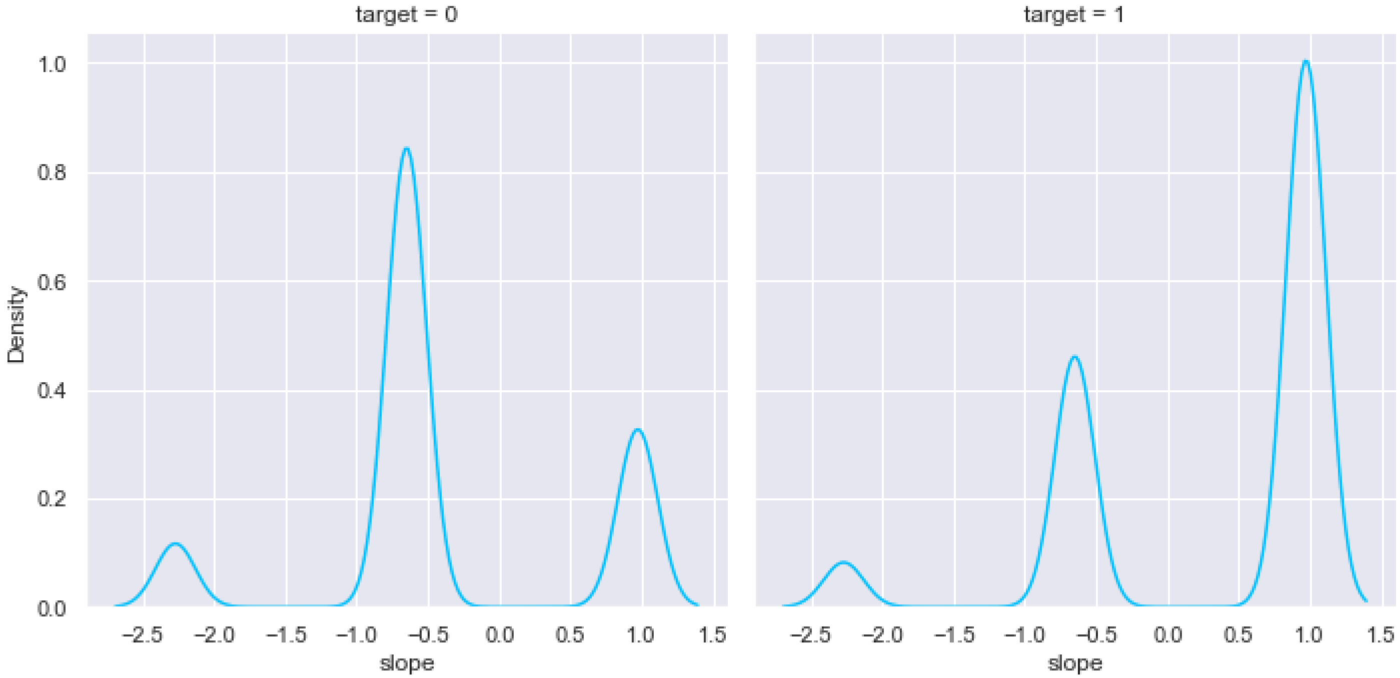
In [206…

```
plt.figure(figsize=(12,5))
sns.displot(x='slope', col='target' , data = hypertesion_data, kind="kde" ,color = 'deepskyblue');

slope = pd.cut( hypertesion_data['slope'],bins=[-2.75,-1.5,0,1.5],labels=['upsloping','flat','downsloping'])
slope_temp = pd.crosstab(hypertesion_data['target'],slope,rownames=['target'])
slope_temp = slope_temp.astype(float)
slope_temp
```

Out[206]:

slope	upsloping	flat	downsloping
target			
0	1070.0	7742.0	2997.0
1	756.0	4248.0	9270.0

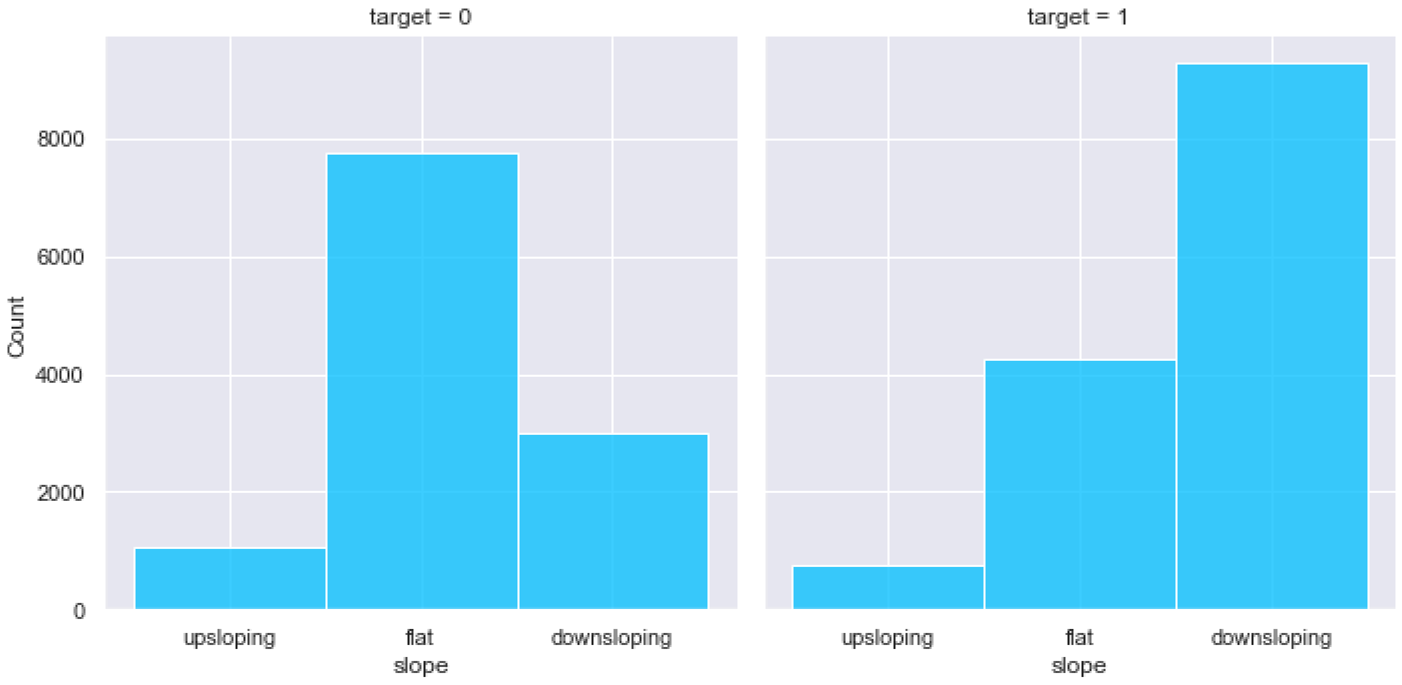
```
<Figure size 864x360 with 0 Axes>
```



In [207…

```
plt.figure(figsize=(12,20))
sns.displot(data=hypertesion_data,col='target',x=slope,color='deepskyblue');
```

```
<Figure size 864x1440 with 0 Axes>
```



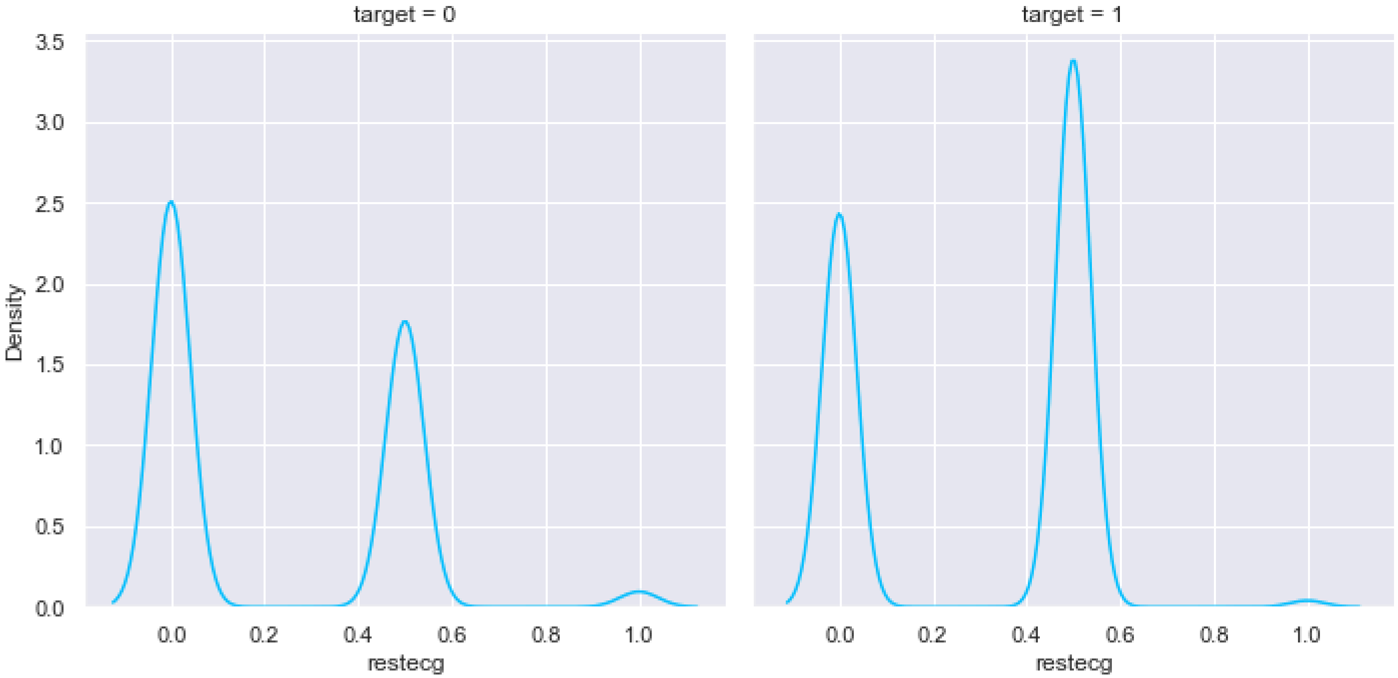
In [292…

```
plt.figure(figsize=(12,5))
sns.displot(x='restecg', col='target' , data = hypertesion_data, kind="kde" ,color = 'deepskyblue');

restecg = pd.cut(hypertesion_data['restecg'],bins=[-0.75,0.5,1.5,2.6],labels=['normal','ST-T wave abnormality
restecg_temp = pd.crosstab(hypertesion_data['target'],restecg,rownames=['target'])
restecg_temp = restecg_temp.astype(float)
restecg_temp
```

Out[292]:

restecg	normal	ST-T wave abnormality
target		
0	6776.0	5033.0
1	5926.0	8348.0

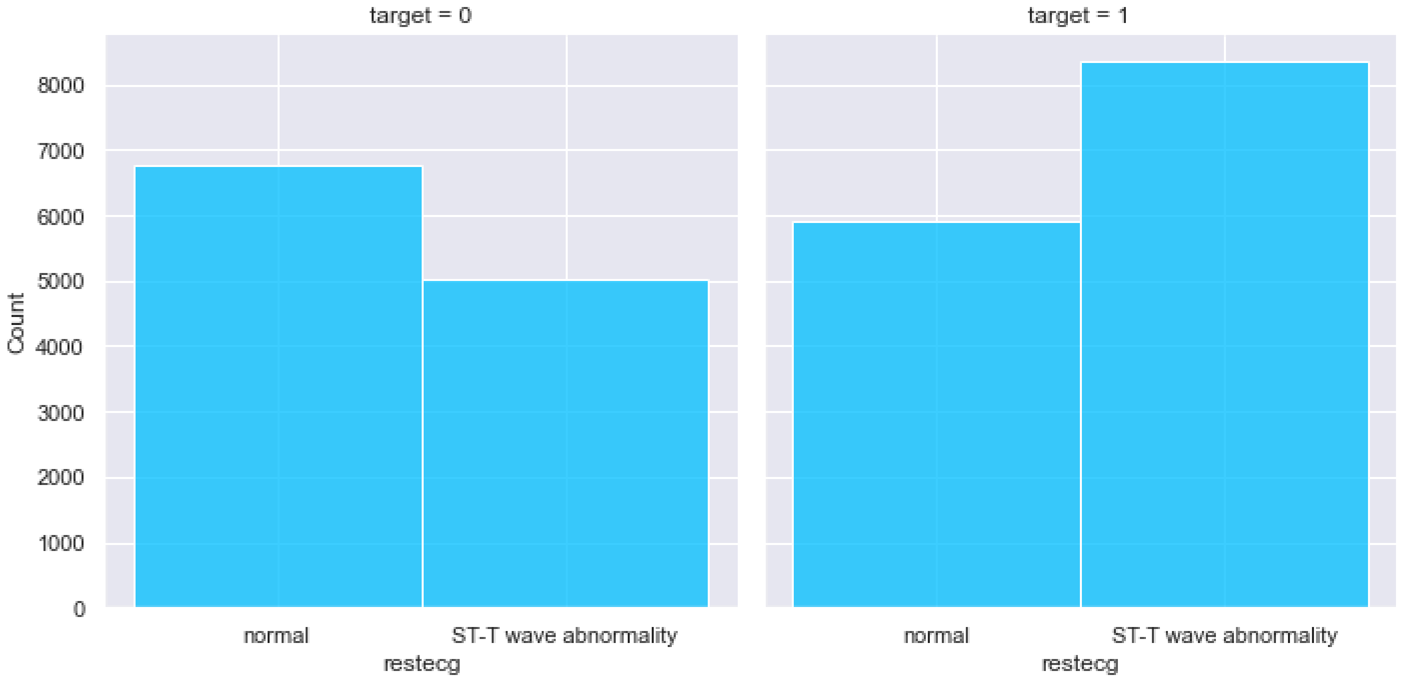
```
<Figure size 864x360 with 0 Axes>
```



In [293…

```
plt.figure(figsize=(12,20))
sns.displot(data=hypertesion_data,col='target',x=restecg,color='deepskyblue');
```

```
<Figure size 864x1440 with 0 Axes>
```

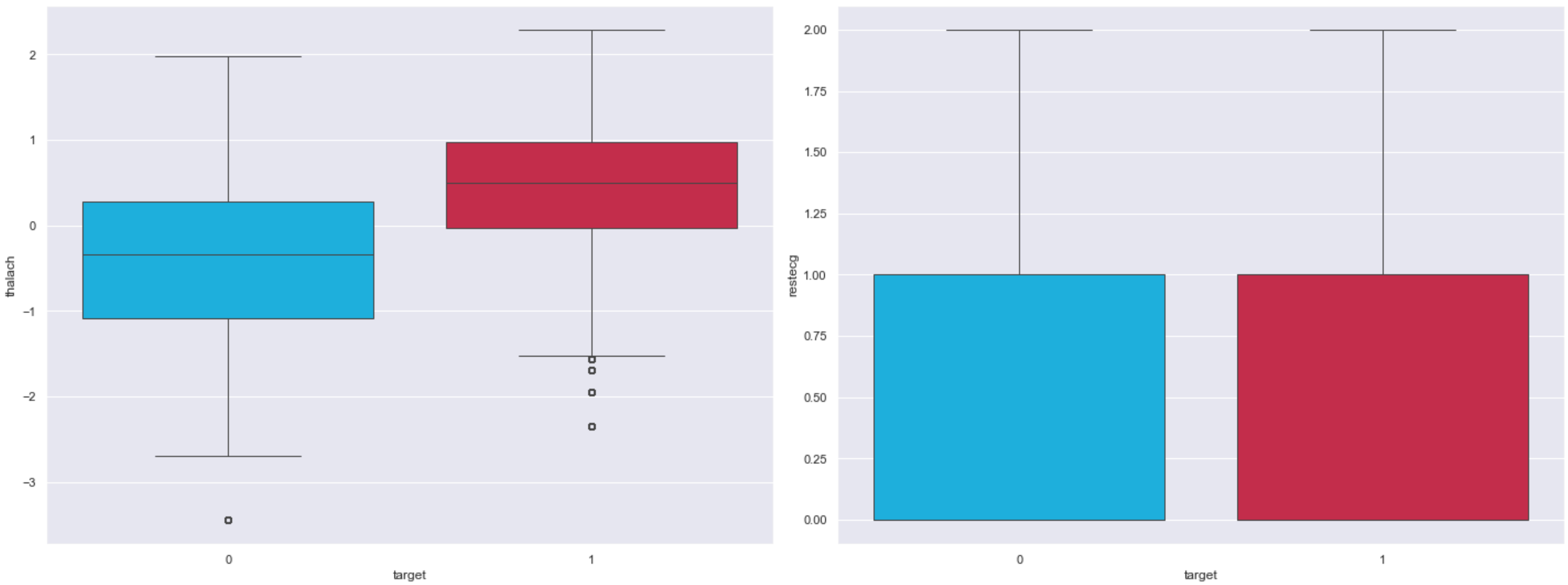


In [209…

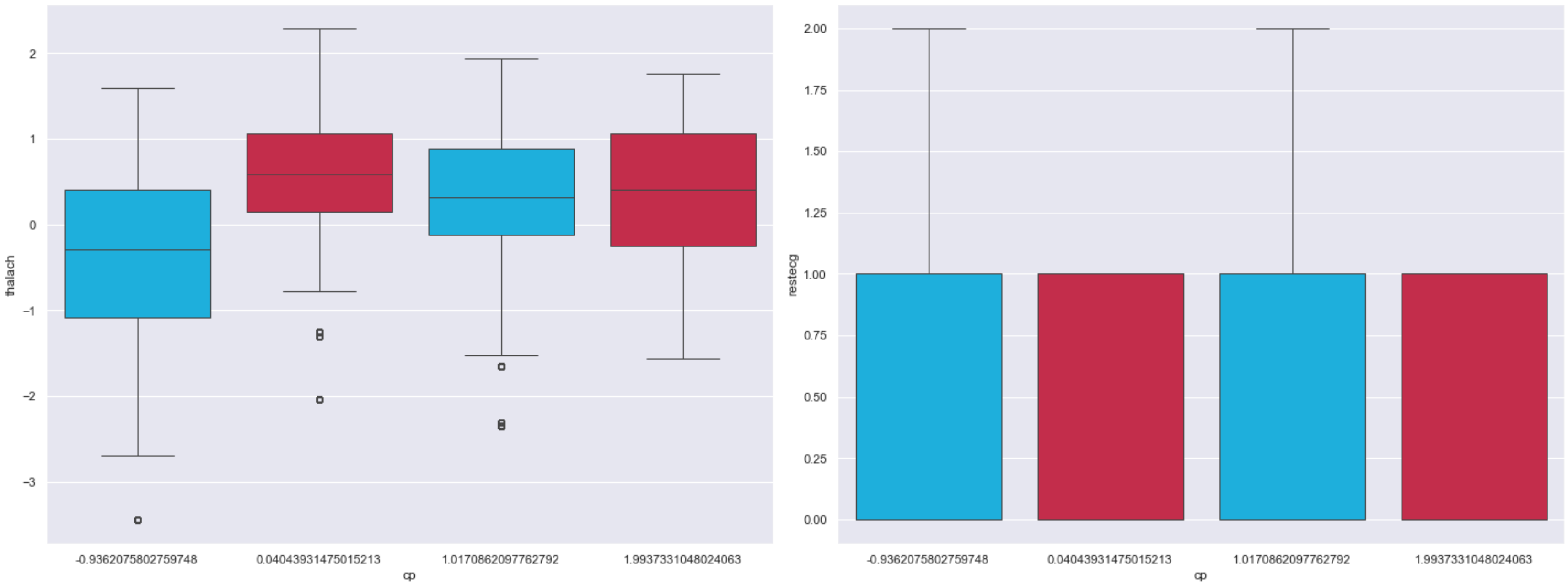
```
features = ['target','cp']
for i in enumerate(features):
  box_cols = ['thalach','restecg']
  fig, axes = plt.subplots(nrows=1, ncols=2, figsize=(20,8))
  fig.suptitle('Distribution of Continuous Features by '+i[1], y = 1.05);
  for col, ax in zip(box_cols, axes.ravel()):
      sns.boxplot(data=hypertesion_data, x=i[1], y=col ,palette = ['deepskyblue','crimson'], ax=ax)
  plt.tight_layout()
```

```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1315614673.py:7: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variab
le to `hue` and set `legend=False` for the same effect.

  sns.boxplot(data=hypertesion_data, x=i[1], y=col ,palette = ['deepskyblue','crimson'], ax=ax)
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1315614673.py:7: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variab
le to `hue` and set `legend=False` for the same effect.

  sns.boxplot(data=hypertesion_data, x=i[1], y=col ,palette = ['deepskyblue','crimson'], ax=ax)
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1315614673.py:7: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variab
le to `hue` and set `legend=False` for the same effect.

  sns.boxplot(data=hypertesion_data, x=i[1], y=col ,palette = ['deepskyblue','crimson'], ax=ax)
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1315614673.py:7: UserWarning:
The palette list has fewer values (2) than needed (4) and will cycle, which may produce an uninterpretable pl
ot.
  sns.boxplot(data=hypertesion_data, x=i[1], y=col ,palette = ['deepskyblue','crimson'], ax=ax)
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1315614673.py:7: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variab
le to `hue` and set `legend=False` for the same effect.

  sns.boxplot(data=hypertesion_data, x=i[1], y=col ,palette = ['deepskyblue','crimson'], ax=ax)
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1315614673.py:7: UserWarning:
The palette list has fewer values (2) than needed (4) and will cycle, which may produce an uninterpretable pl
ot.
  sns.boxplot(data=hypertesion_data, x=i[1], y=col ,palette = ['deepskyblue','crimson'], ax=ax)
```

Distribution of Continuous Features by target



Distribution of Continuous Features by cp



plt.figure(figsize=(8,6)) x = sns.countplot(x='slope' ,hue='target', data=hypertesion_data_vis, palette = ['deepskyblue','crimson']) for z in x.patches: x.annotate('{:.1f}'.format((z.get_height()/hypertesion_data_vis.shape[0])*100)+'%',(z.get_x()+0.25, z.get_height()+0.01))

In [213…

```
hypertesion_data.slope[hypertesion_data['slope'] == 0] = 'up slope'
hypertesion_data.slope[hypertesion_data['slope'] == 1] = 'normal'
hypertesion_data.slope[hypertesion_data['slope'] == 2] = 'down slope'
one_hot_encode_cols = ['slope']  # filtering by string categoricals
# Encode these columns as categoricals so one hot encoding works on split data (if desired)
for col in one_hot_encode_cols:
    hypertesion_data[col] = pd.Categorical(hypertesion_data[col])
# Do the one hot encoding
hypertesion_data = pd.get_dummies(hypertesion_data, columns=one_hot_encode_cols)
hypertesion_data.head()
```

```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1171724562.py:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#r
eturning-a-view-versus-a-copy
  hypertesion_data.slope[hypertesion_data['slope'] == 0] = 'up slope'
```

Out[213]:

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	ca	thal	target	slope_down slope	slope_normal	slope_up slope
0	57.0	1.0	3	145	233	1	0	150	0	2.3	0	1	1	0	0	1
1	64.0	0.0	2	130	250	0	1	187	0	3.5	0	2	1	0	0	1
2	52.0	1.0	1	130	204	0	0	172	0	1.4	0	2	1	1	0	0
3	56.0	0.0	1	120	236	0	1	178	0	0.8	0	2	1	1	0	0
4	66.0	0.0	0	120	354	0	1	163	1	0.6	0	2	1	1	0	0

In [214…

```
#Skewness Checking
data_skew = hypertesion_data[['cp','thalach','restecg','slope_down slope', 'slope_normal','slope_up slope']]
skew = pd.DataFrame(data_skew.skew())
skew.columns = ['skew']
skew['too_skewed'] = skew['skew'] > .75
skew
```

Out[214]:

	skew	too_skewed
cp	0.494495	False
thalach	-0.521341	False
restecg	0.172989	False
slope_down slope	0.118992	False
slope_normal	0.161790	False
slope_up slope	3.370580	True

In [228…

```
qt = QuantileTransformer(n_quantiles=5000, output_distribution='normal')
hypertesion_data[['slope_up slope']] = qt.fit_transform(hypertesion_data[['slope_up slope']])

data_skew = hypertesion_data[['cp','thalach','restecg','slope_down slope', 'slope_normal','slope_up slope']]
skew = pd.DataFrame(data_skew.skew())
skew.columns = ['skew']
skew['too_skewed'] = skew['skew'] > .75
skew
```

Out[228]:

	skew	too_skewed
cp	0.494495	False
thalach	-0.521341	False
restecg	0.172989	False
slope_down slope	0.118992	False
slope_normal	0.161790	False
slope_up slope	3.370580	True

In [229…

```
sc = StandardScaler()
hypertesion_data[['cp']] = sc.fit_transform(hypertesion_data[['cp']])
hypertesion_data[['thalach']] = sc.fit_transform(hypertesion_data[['thalach']])
hypertesion_data[['restecg']] = sc.fit_transform(hypertesion_data[['restecg']])
hypertesion_data[['slope_down slope']] = sc.fit_transform(hypertesion_data[['slope_down slope']])
hypertesion_data[['slope_normal']] = sc.fit_transform(hypertesion_data[['slope_normal']])
hypertesion_data.head()
```

Out[229]:

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	ca	thal	target	slope_down slope	slope_normal	sl
0	57.0	1.0	1.993733	145	233	1	-1.001675	0.015092	0	2.3	0	1	1	-0.942276	-0.922376	5.
1	64.0	0.0	1.017086	130	250	0	0.900800	1.633805	0	3.5	0	2	1	-0.942276	-0.922376	5.
2	52.0	1.0	0.040439	130	204	0	-1.001675	0.977570	0	1.4	0	2	1	1.061260	-0.922376	-5.
3	56.0	0.0	0.040439	120	236	0	0.900800	1.240064	0	0.8	0	2	1	1.061260	-0.922376	-5.
4	66.0	0.0	-0.936208	120	354	0	0.900800	0.583829	1	0.6	0	2	1	1.061260	-0.922376	-5.

In [230…

```
(hypertesion_data[['cp','thalach','restecg','slope_down slope','slope_normal']]).describe()
```

Out[230]:

	cp	thalach	restecg	slope_down slope	slope_normal
count	2.608300e+04	2.608300e+04	2.608300e+04	2.608300e+04	2.608300e+04
mean	8.662830e-17	3.440614e-16	-3.098732e-17	-9.316628e-17	-2.274674e-17
std	1.000019e+00	1.000019e+00	1.000019e+00	1.000019e+00	1.000019e+00
min	-9.362076e-01	-3.441078e+00	-1.001675e+00	-9.422758e-01	-9.223757e-01
25%	-9.362076e-01	-7.286405e-01	-1.001675e+00	-9.422758e-01	-9.223757e-01
50%	4.043931e-02	1.463393e-01	9.008002e-01	-9.422758e-01	-9.223757e-01
75%	1.017086e+00	7.150762e-01	9.008002e-01	1.061260e+00	1.084157e+00
max	1.993733e+00	2.290040e+00	2.803276e+00	1.061260e+00	1.084157e+00

In [231…

```
y = (hypertesion_data['target']).astype(int)
X = hypertesion_data[['cp', 'thalach', 'restecg', 'slope_normal', 'slope_down slope']]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33, random_state=42)

print(y_train.value_counts(normalize=True))
print(y_test.value_counts(normalize=True))
```

```
1    0.546609
0    0.453391
Name: target, dtype: float64
1    0.548559
0    0.451441
Name: target, dtype: float64
```

In [232…

```
param_grid = {'n_neighbors': [1,3,5,7,9,11,13,15,17,19],
              'weights': ['distance', 'uniform']}
gridKNN = GridSearchCV(KNeighborsClassifier(), param_grid, refit = True, verbose = 3)

gridKNN.fit(X_train, y_train)
```

```
Fitting 5 folds for each of 20 candidates, totalling 100 fits
[CV 1/5] END ...n_neighbors=1, weights=distance;, score=0.950 total time=   0.1s
[CV 2/5] END ...n_neighbors=1, weights=distance;, score=0.956 total time=   0.1s
[CV 3/5] END ...n_neighbors=1, weights=distance;, score=0.951 total time=   0.1s
[CV 4/5] END ...n_neighbors=1, weights=distance;, score=0.959 total time=   0.1s
[CV 5/5] END ...n_neighbors=1, weights=distance;, score=0.957 total time=   0.1s
[CV 1/5] END ....n_neighbors=1, weights=uniform;, score=0.950 total time=   0.2s
[CV 2/5] END ....n_neighbors=1, weights=uniform;, score=0.956 total time=   0.2s
[CV 3/5] END ....n_neighbors=1, weights=uniform;, score=0.951 total time=   0.2s
[CV 4/5] END ....n_neighbors=1, weights=uniform;, score=0.959 total time=   0.2s
[CV 5/5] END ....n_neighbors=1, weights=uniform;, score=0.957 total time=   0.2s
[CV 1/5] END ...n_neighbors=3, weights=distance;, score=0.951 total time=   0.1s
[CV 2/5] END ...n_neighbors=3, weights=distance;, score=0.953 total time=   0.1s
[CV 3/5] END ...n_neighbors=3, weights=distance;, score=0.955 total time=   0.1s
[CV 4/5] END ...n_neighbors=3, weights=distance;, score=0.958 total time=   0.1s
[CV 5/5] END ...n_neighbors=3, weights=distance;, score=0.956 total time=   0.1s
[CV 1/5] END ....n_neighbors=3, weights=uniform;, score=0.951 total time=   0.2s
[CV 2/5] END ....n_neighbors=3, weights=uniform;, score=0.953 total time=   0.2s
[CV 3/5] END ....n_neighbors=3, weights=uniform;, score=0.955 total time=   0.2s
[CV 4/5] END ....n_neighbors=3, weights=uniform;, score=0.958 total time=   0.2s
[CV 5/5] END ....n_neighbors=3, weights=uniform;, score=0.956 total time=   0.2s
[CV 1/5] END ...n_neighbors=5, weights=distance;, score=0.952 total time=   0.1s
[CV 2/5] END ...n_neighbors=5, weights=distance;, score=0.954 total time=   0.1s
[CV 3/5] END ...n_neighbors=5, weights=distance;, score=0.957 total time=   0.1s
[CV 4/5] END ...n_neighbors=5, weights=distance;, score=0.958 total time=   0.1s
[CV 5/5] END ...n_neighbors=5, weights=distance;, score=0.958 total time=   0.1s
[CV 1/5] END ....n_neighbors=5, weights=uniform;, score=0.952 total time=   0.2s
[CV 2/5] END ....n_neighbors=5, weights=uniform;, score=0.954 total time=   0.2s
[CV 3/5] END ....n_neighbors=5, weights=uniform;, score=0.957 total time=   0.2s
[CV 4/5] END ....n_neighbors=5, weights=uniform;, score=0.958 total time=   0.2s
[CV 5/5] END ....n_neighbors=5, weights=uniform;, score=0.958 total time=   0.2s
[CV 1/5] END ...n_neighbors=7, weights=distance;, score=0.953 total time=   0.1s
[CV 2/5] END ...n_neighbors=7, weights=distance;, score=0.952 total time=   0.1s
[CV 3/5] END ...n_neighbors=7, weights=distance;, score=0.958 total time=   0.1s
[CV 4/5] END ...n_neighbors=7, weights=distance;, score=0.959 total time=   0.1s
[CV 5/5] END ...n_neighbors=7, weights=distance;, score=0.959 total time=   0.1s
[CV 1/5] END ....n_neighbors=7, weights=uniform;, score=0.953 total time=   0.2s
[CV 2/5] END ....n_neighbors=7, weights=uniform;, score=0.952 total time=   0.2s
[CV 3/5] END ....n_neighbors=7, weights=uniform;, score=0.958 total time=   0.2s
[CV 4/5] END ....n_neighbors=7, weights=uniform;, score=0.959 total time=   0.2s
[CV 5/5] END ....n_neighbors=7, weights=uniform;, score=0.959 total time=   0.2s
[CV 1/5] END ...n_neighbors=9, weights=distance;, score=0.953 total time=   0.1s
[CV 2/5] END ...n_neighbors=9, weights=distance;, score=0.952 total time=   0.1s
[CV 3/5] END ...n_neighbors=9, weights=distance;, score=0.960 total time=   0.1s
[CV 4/5] END ...n_neighbors=9, weights=distance;, score=0.959 total time=   0.1s
```

```
[CV 5/5] END ...n_neighbors=9, weights=distance;, score=0.959 total time=   0.1s
[CV 1/5] END ....n_neighbors=9, weights=uniform;, score=0.953 total time=   0.2s
[CV 2/5] END ....n_neighbors=9, weights=uniform;, score=0.952 total time=   0.2s
[CV 3/5] END ....n_neighbors=9, weights=uniform;, score=0.960 total time=   0.2s
[CV 4/5] END ....n_neighbors=9, weights=uniform;, score=0.959 total time=   0.2s
[CV 5/5] END ....n_neighbors=9, weights=uniform;, score=0.959 total time=   0.2s
[CV 1/5] END ..n_neighbors=11, weights=distance;, score=0.955 total time=   0.1s
[CV 2/5] END ..n_neighbors=11, weights=distance;, score=0.952 total time=   0.1s
[CV 3/5] END ..n_neighbors=11, weights=distance;, score=0.960 total time=   0.1s
[CV 4/5] END ..n_neighbors=11, weights=distance;, score=0.960 total time=   0.1s
[CV 5/5] END ..n_neighbors=11, weights=distance;, score=0.959 total time=   0.1s
[CV 1/5] END ...n_neighbors=11, weights=uniform;, score=0.955 total time=   0.2s
[CV 2/5] END ...n_neighbors=11, weights=uniform;, score=0.952 total time=   0.2s
[CV 3/5] END ...n_neighbors=11, weights=uniform;, score=0.960 total time=   0.2s
[CV 4/5] END ...n_neighbors=11, weights=uniform;, score=0.960 total time=   0.2s
[CV 5/5] END ...n_neighbors=11, weights=uniform;, score=0.959 total time=   0.2s
[CV 1/5] END ..n_neighbors=13, weights=distance;, score=0.955 total time=   0.1s
[CV 2/5] END ..n_neighbors=13, weights=distance;, score=0.953 total time=   0.1s
[CV 3/5] END ..n_neighbors=13, weights=distance;, score=0.960 total time=   0.1s
[CV 4/5] END ..n_neighbors=13, weights=distance;, score=0.959 total time=   0.1s
[CV 5/5] END ..n_neighbors=13, weights=distance;, score=0.959 total time=   0.1s
[CV 1/5] END ...n_neighbors=13, weights=uniform;, score=0.955 total time=   0.2s
[CV 2/5] END ...n_neighbors=13, weights=uniform;, score=0.953 total time=   0.2s
[CV 3/5] END ...n_neighbors=13, weights=uniform;, score=0.960 total time=   0.3s
[CV 4/5] END ...n_neighbors=13, weights=uniform;, score=0.959 total time=   0.2s
[CV 5/5] END ...n_neighbors=13, weights=uniform;, score=0.959 total time=   0.2s
[CV 1/5] END ..n_neighbors=15, weights=distance;, score=0.954 total time=   0.1s
[CV 2/5] END ..n_neighbors=15, weights=distance;, score=0.953 total time=   0.1s
[CV 3/5] END ..n_neighbors=15, weights=distance;, score=0.960 total time=   0.1s
[CV 4/5] END ..n_neighbors=15, weights=distance;, score=0.959 total time=   0.1s
[CV 5/5] END ..n_neighbors=15, weights=distance;, score=0.958 total time=   0.1s
[CV 1/5] END ...n_neighbors=15, weights=uniform;, score=0.954 total time=   0.2s
[CV 2/5] END ...n_neighbors=15, weights=uniform;, score=0.953 total time=   0.2s
[CV 3/5] END ...n_neighbors=15, weights=uniform;, score=0.960 total time=   0.2s
[CV 4/5] END ...n_neighbors=15, weights=uniform;, score=0.959 total time=   0.2s
[CV 5/5] END ...n_neighbors=15, weights=uniform;, score=0.958 total time=   0.3s
[CV 1/5] END ..n_neighbors=17, weights=distance;, score=0.954 total time=   0.1s
[CV 2/5] END ..n_neighbors=17, weights=distance;, score=0.953 total time=   0.1s
[CV 3/5] END ..n_neighbors=17, weights=distance;, score=0.960 total time=   0.1s
[CV 4/5] END ..n_neighbors=17, weights=distance;, score=0.959 total time=   0.1s
[CV 5/5] END ..n_neighbors=17, weights=distance;, score=0.958 total time=   0.1s
[CV 1/5] END ...n_neighbors=17, weights=uniform;, score=0.954 total time=   0.2s
[CV 2/5] END ...n_neighbors=17, weights=uniform;, score=0.953 total time=   0.2s
[CV 3/5] END ...n_neighbors=17, weights=uniform;, score=0.960 total time=   0.2s
[CV 4/5] END ...n_neighbors=17, weights=uniform;, score=0.959 total time=   0.2s
```

```
[CV 5/5] END ...n_neighbors=17, weights=uniform;, score=0.958 total time=   0.2s
[CV 1/5] END ..n_neighbors=19, weights=distance;, score=0.954 total time=   0.1s
[CV 2/5] END ..n_neighbors=19, weights=distance;, score=0.954 total time=   0.1s
[CV 3/5] END ..n_neighbors=19, weights=distance;, score=0.955 total time=   0.1s
[CV 4/5] END ..n_neighbors=19, weights=distance;, score=0.958 total time=   0.1s
[CV 5/5] END ..n_neighbors=19, weights=distance;, score=0.958 total time=   0.1s
[CV 1/5] END ...n_neighbors=19, weights=uniform;, score=0.954 total time=   0.3s
[CV 2/5] END ...n_neighbors=19, weights=uniform;, score=0.954 total time=   0.2s
[CV 3/5] END ...n_neighbors=19, weights=uniform;, score=0.955 total time=   0.2s
[CV 4/5] END ...n_neighbors=19, weights=uniform;, score=0.958 total time=   0.2s
[CV 5/5] END ...n_neighbors=19, weights=uniform;, score=0.958 total time=   0.2s
```

Out[232]:

```
▸ GridSearchCV
▸ estimator: KNeighborsClassifier
    ▸ KNeighborsClassifier
```

In [233…

```
print(gridKNN.best_params_)
```

```
{'n_neighbors': 13, 'weights': 'distance'}
```

In [234…

```
y_pred_test = gridKNN.predict(X_test)
y_pred_train = gridKNN.predict(X_train)

print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9575393419170243
0.9546933085501859
```

In [235…

```
#function that get y_test and calculate into df all the relevant metric
def train_evaluate_model(y_test):
    #fit the model instance
    predictions = y_pred_test # calculate predictions

    #compute metrics for evaluation
    accuracy = accuracy_score(y_test, predictions)
    f1 = f1_score(y_test, predictions)
    precision = precision_score(y_test, predictions)
    recall = recall_score(y_test, predictions)
    balanced_accuracy = balanced_accuracy_score(y_test, predictions)
    auc = roc_auc_score(y_test, predictions)

    #create a dataframe to visualize the results
    eval_df = pd.DataFrame([[accuracy, f1, precision, recall, balanced_accuracy, auc]], columns=['accuracy',
    return eval_df
```

In [236…

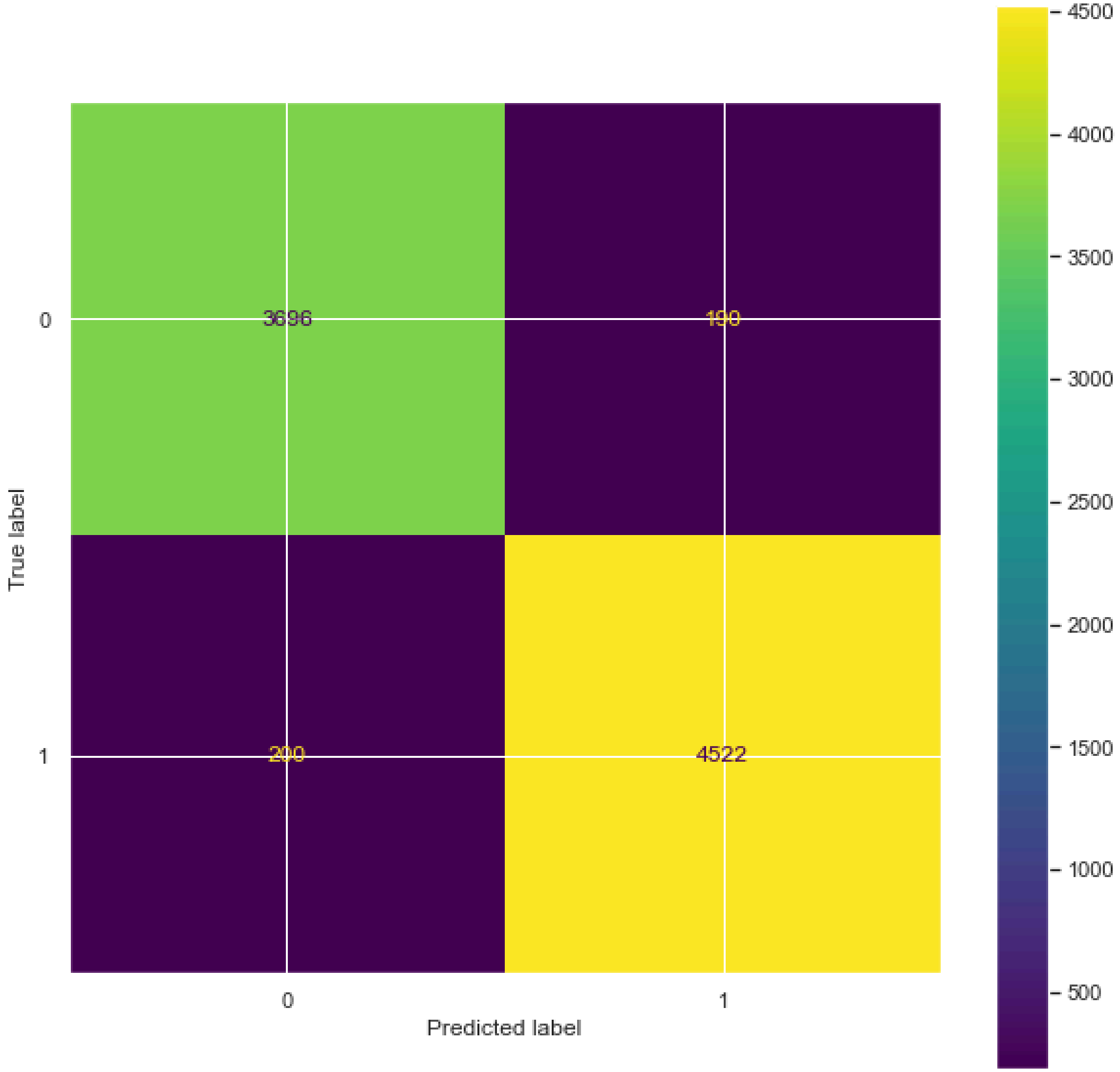
```
results = train_evaluate_model(y_test)
results.index = ['K Nearest Neighbors - Method 1']
results.style.background_gradient(cmap = sns.color_palette("blend:green,red", as_cmap=True))
```

Out[236]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376

In [237…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridKNN.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridKNN.classes_)

disp.plot()
plt.show()
```



In [238…

```
LG = LogisticRegression().fit(X_train, y_train)
#prediction
y_pred_test = LG.predict(X_test)
y_pred_train = LG.predict(X_train)
#scores
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.7675536480686695
0.7707946096654275
```

In [239…

```
 # defining parameter range
param_grid = {'penalty':['l1','l2'],
                'Cs': [2,5,10,20],
                'cv': [4],
                'solver': ['liblinear','saga']}
gridLG = GridSearchCV(LogisticRegressionCV(), param_grid, refit = True, verbose = 3)

  # fitting the model for grid search
gridLG.fit(X_train, y_train)
```

```
Fitting 5 folds for each of 16 candidates, totalling 80 fits
[CV 1/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.765 total time=   0.2s
[CV 2/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.767 total time=   0.1s
[CV 3/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.772 total time=   0.1s
[CV 4/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.763 total time=   0.1s
[CV 5/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.768 total time=   0.1s
[CV 1/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.765 total time=   0.2s
[CV 2/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.767 total time=   0.2s
[CV 3/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.772 total time=   0.2s
[CV 4/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.763 total time=   0.2s
[CV 5/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.768 total time=   0.2s
[CV 1/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.765 total time=   0.1s
[CV 2/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.767 total time=   0.1s
[CV 3/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.772 total time=   0.1s
[CV 4/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.763 total time=   0.1s
[CV 5/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.768 total time=   0.1s
[CV 1/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.765 total time=   0.3s
[CV 2/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.767 total time=   0.3s
[CV 3/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.772 total time=   0.3s
[CV 4/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.763 total time=   0.3s
[CV 5/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.768 total time=   0.3s
[CV 1/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.765 total time=   0.3s
[CV 2/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.771 total time=   0.3s
[CV 3/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.772 total time=   0.3s
[CV 4/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.763 total time=   0.3s
[CV 5/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.768 total time=   0.3s
[CV 1/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.765 total time=   0.3s
[CV 2/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.767 total time=   0.3s
[CV 3/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.772 total time=   0.5s
[CV 4/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.763 total time=   0.5s
[CV 5/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.768 total time=   0.5s
[CV 1/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.765 total time=   0.3s
[CV 2/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.767 total time=   0.3s
[CV 3/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.772 total time=   0.4s
[CV 4/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.763 total time=   0.3s
[CV 5/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.768 total time=   0.3s
[CV 1/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.765 total time=   0.5s
[CV 2/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.767 total time=   0.5s
[CV 3/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.772 total time=   0.5s
[CV 4/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.763 total time=   0.4s
[CV 5/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.768 total time=   0.4s
[CV 1/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.765 total time=   0.6s
[CV 2/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.767 total time=   0.6s
[CV 3/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.772 total time=   0.6s
[CV 4/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.763 total time=   0.6s
```

```
[CV 5/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.768 total time=   0.6s
[CV 1/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.765 total time=   0.7s
[CV 2/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.771 total time=   0.6s
[CV 3/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.772 total time=   0.6s
[CV 4/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.763 total time=   0.7s
[CV 5/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.768 total time=   0.7s
[CV 1/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.765 total time=   0.5s
[CV 2/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.770 total time=   0.5s
[CV 3/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.768 total time=   0.5s
[CV 4/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.763 total time=   0.5s
[CV 5/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.768 total time=   0.5s
[CV 1/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.765 total time=   0.6s
[CV 2/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.767 total time=   0.6s
[CV 3/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.772 total time=   0.6s
[CV 4/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.763 total time=   0.6s
[CV 5/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.768 total time=   0.6s
[CV 1/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.765 total time=   1.1s
[CV 2/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.771 total time=   1.1s
[CV 3/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.772 total time=   1.0s
[CV 4/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.763 total time=   1.1s
[CV 5/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.768 total time=   1.2s
[CV 1/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.765 total time=   1.0s
[CV 2/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.767 total time=   1.0s
[CV 3/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.772 total time=   0.9s
[CV 4/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.763 total time=   1.0s
[CV 5/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.765 total time=   0.9s
[CV 1/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.764 total time=   0.9s
[CV 2/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.770 total time=   0.9s
[CV 3/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.768 total time=   0.9s
[CV 4/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.763 total time=   0.9s
[CV 5/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.765 total time=   0.9s
[CV 1/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.765 total time=   0.9s
[CV 2/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.767 total time=   0.9s
[CV 3/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.772 total time=   0.9s
[CV 4/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.763 total time=   1.0s
[CV 5/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.768 total time=   1.1s
```

Out[239]:

```
▸ GridSearchCV
▸ estimator: LogisticRegressionCV
  ▸ LogisticRegressionCV
```

In [240…

```
print(gridLG.best_params_)
```

```
{'Cs': 10, 'cv': 4, 'penalty': 'l1', 'solver': 'saga'}
```

In [241…

```
y_pred_test = gridLG.predict(X_test)
y_pred_train = gridLG.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.7675536480686695
0.7707946096654275
```

In [242…

```
resultsLG = train_evaluate_model(y_test)
resultsLG.index = ['Logistic Regression - Method 1']
results = results.append(resultsLG)

results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

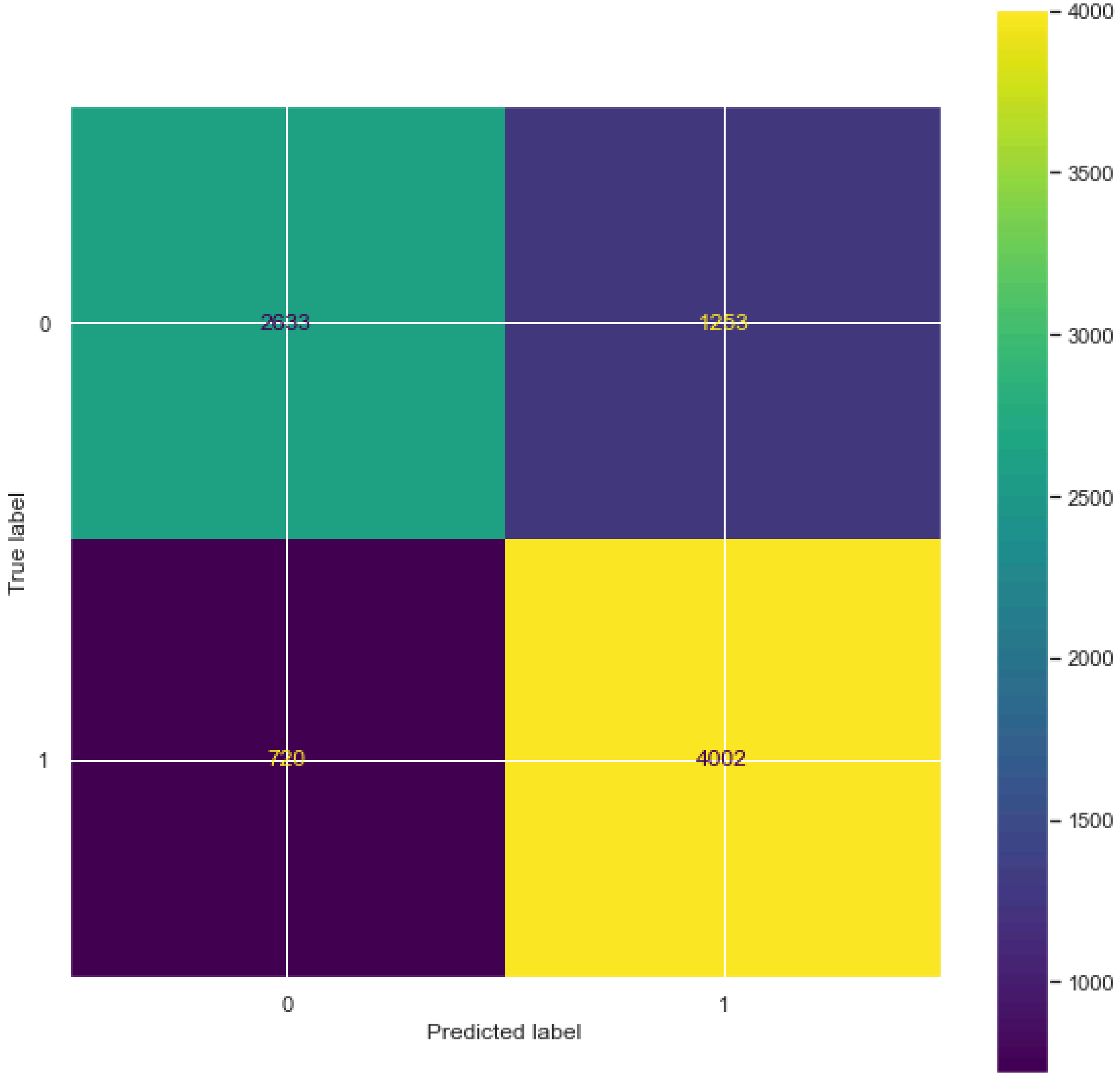
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/2403315288.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsLG)
```

Out[242]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541

In [243…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridLG.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridLG.classes_)

disp.plot()
plt.show()
```



In [244…

```
cv_N = 10
nb = {'gaussian': GaussianNB(),
      'bernoulli': BernoulliNB()
      }
scores = {}
for key, model in nb.items():
    s = cross_val_score(model, X_train, y_train, cv=cv_N, n_jobs=cv_N, scoring='accuracy')
    scores[key] = np.mean(s)
scores
```

Out[244]:

```
{'gaussian': 0.7438630001873103, 'bernoulli': 0.7640062925787129}
```

In [245…

```
GNB = GaussianNB()
GNB.fit(X_train, y_train)

y_pred_test = GNB.predict(X_test)
y_pred_train = GNB.predict(X_train)

print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.7438626609442061
0.7494191449814126
```

In [246…

```
resultsNB = train_evaluate_model(y_test)
resultsNB.index = ['Naive Bayes - Method 1']
results = results.append(resultsNB)

results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

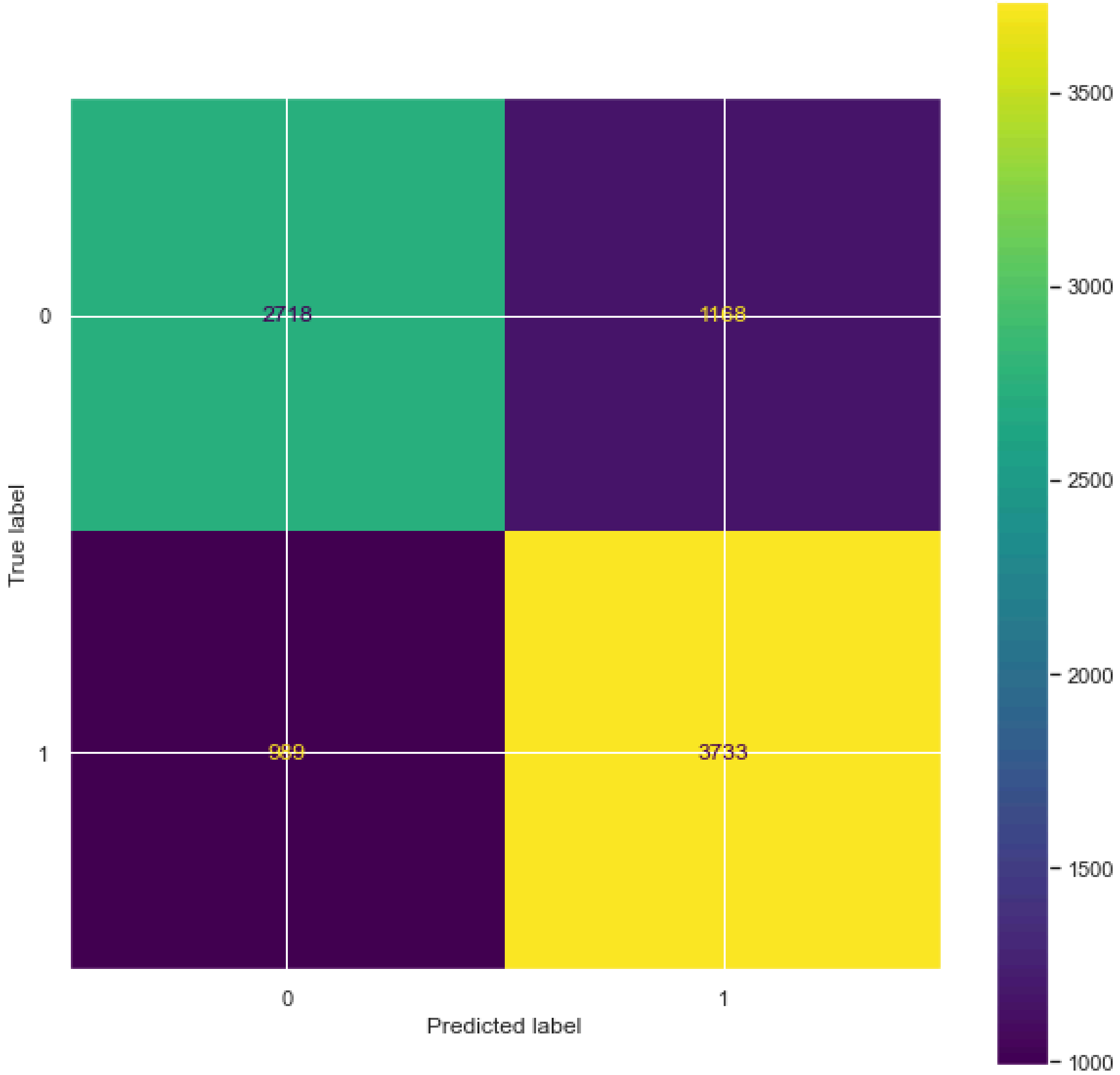
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1729499558.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsNB)
```

Out[246]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994

In [247…

```
cm = confusion_matrix(y_test, y_pred_test, labels=GNB.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=GNB.classes_)

disp.plot()
plt.show()
```



```
In [248…
param_grid = {'C': [1,10,100,1000],
                'gamma': [1, 0.1, 0.01, 0.001],
                'kernel': ['rbf']}

gridSVM = GridSearchCV(SVC(), param_grid, refit = True, verbose = 3, cv=2)

  # fitting the model for grid search
gridSVM.fit(X_train, y_train)
```

```
Fitting 2 folds for each of 16 candidates, totalling 32 fits
[CV 1/2] END .........C=1, gamma=1, kernel=rbf;, score=0.839 total time=   5.5s
[CV 2/2] END .........C=1, gamma=1, kernel=rbf;, score=0.838 total time=   5.3s
[CV 1/2] END .......C=1, gamma=0.1, kernel=rbf;, score=0.802 total time=   6.7s
[CV 2/2] END .......C=1, gamma=0.1, kernel=rbf;, score=0.802 total time=   6.8s
[CV 1/2] END ......C=1, gamma=0.01, kernel=rbf;, score=0.757 total time=   7.2s
[CV 2/2] END ......C=1, gamma=0.01, kernel=rbf;, score=0.777 total time=   7.3s
[CV 1/2] END .....C=1, gamma=0.001, kernel=rbf;, score=0.765 total time=   7.9s
[CV 2/2] END .....C=1, gamma=0.001, kernel=rbf;, score=0.768 total time=   7.9s
[CV 1/2] END ........C=10, gamma=1, kernel=rbf;, score=0.844 total time=   5.4s
[CV 2/2] END ........C=10, gamma=1, kernel=rbf;, score=0.840 total time=   5.2s
[CV 1/2] END ......C=10, gamma=0.1, kernel=rbf;, score=0.814 total time=   8.5s
[CV 2/2] END ......C=10, gamma=0.1, kernel=rbf;, score=0.816 total time=   8.5s
[CV 1/2] END .....C=10, gamma=0.01, kernel=rbf;, score=0.783 total time=   7.3s
[CV 2/2] END .....C=10, gamma=0.01, kernel=rbf;, score=0.775 total time=   7.7s
[CV 1/2] END ....C=10, gamma=0.001, kernel=rbf;, score=0.763 total time=   7.6s
[CV 2/2] END ....C=10, gamma=0.001, kernel=rbf;, score=0.770 total time=   7.3s
[CV 1/2] END .......C=100, gamma=1, kernel=rbf;, score=0.858 total time=   7.4s
[CV 2/2] END .......C=100, gamma=1, kernel=rbf;, score=0.848 total time=   7.2s
[CV 1/2] END .....C=100, gamma=0.1, kernel=rbf;, score=0.825 total time=  12.9s
[CV 2/2] END .....C=100, gamma=0.1, kernel=rbf;, score=0.826 total time=  16.2s
[CV 1/2] END ....C=100, gamma=0.01, kernel=rbf;, score=0.787 total time=   8.1s
[CV 2/2] END ....C=100, gamma=0.01, kernel=rbf;, score=0.797 total time=   8.2s
[CV 1/2] END ...C=100, gamma=0.001, kernel=rbf;, score=0.759 total time=   7.7s
[CV 2/2] END ...C=100, gamma=0.001, kernel=rbf;, score=0.773 total time=   7.6s
[CV 1/2] END ......C=1000, gamma=1, kernel=rbf;, score=0.881 total time=   8.6s
[CV 2/2] END ......C=1000, gamma=1, kernel=rbf;, score=0.853 total time=  13.8s
[CV 1/2] END ....C=1000, gamma=0.1, kernel=rbf;, score=0.835 total time= 1.1min
[CV 2/2] END ....C=1000, gamma=0.1, kernel=rbf;, score=0.833 total time= 1.0min
[CV 1/2] END ...C=1000, gamma=0.01, kernel=rbf;, score=0.799 total time=  13.5s
[CV 2/2] END ...C=1000, gamma=0.01, kernel=rbf;, score=0.801 total time=  12.8s
[CV 1/2] END ..C=1000, gamma=0.001, kernel=rbf;, score=0.783 total time=   8.8s
[CV 2/2] END ..C=1000, gamma=0.001, kernel=rbf;, score=0.763 total time=   9.3s
```

Out[248]:

```
▸ GridSearchCV
▸ estimator: SVC
    ▸ SVC
```

In [249…

```
print(gridSVM.best_params_)
```

```
{'C': 1000, 'gamma': 1, 'kernel': 'rbf'}
```

In [250…

```
y_pred_test = gridSVM.predict(X_test)
y_pred_train = gridSVM.predict(X_train)

print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.8684978540772532
0.8729089219330854
```

In [251…

```
resultsSVM = train_evaluate_model(y_test)
resultsSVM.index = ['Support Vector Machine - Method 1']
results = results.append(resultsSVM)

results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

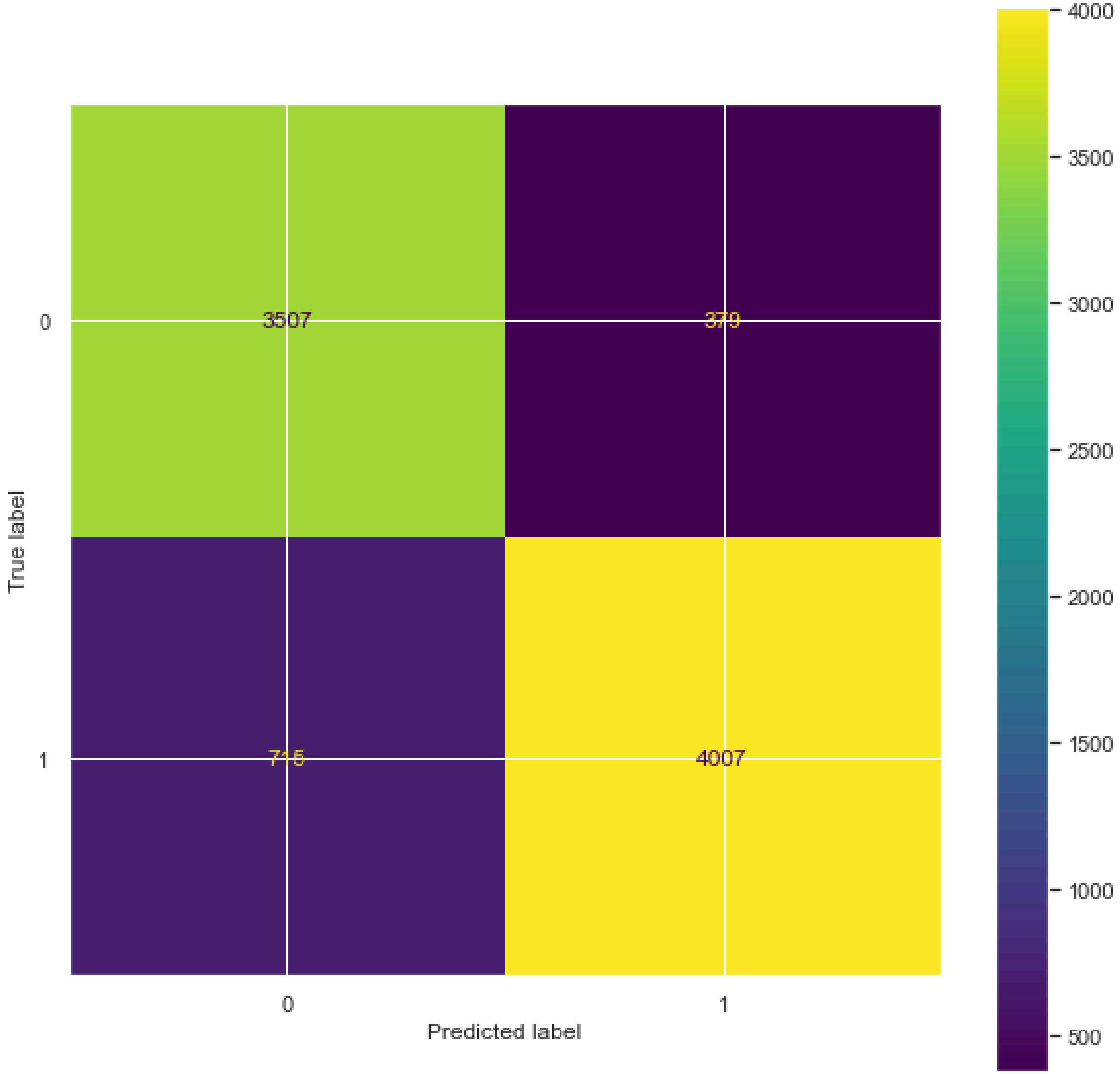
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/3810661069.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsSVM)
```

Out[251]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526

In [252…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridSVM.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridSVM.classes_)

disp.plot()
plt.show()
```



In [253…

```
dt = DecisionTreeClassifier(random_state=42)
dt = dt.fit(X_train, y_train)

# defining parameter range
param_grid = {'max_depth':range(1, dt.tree_.max_depth+1, 2),
              'max_features': range(1, len(dt.feature_importances_)+1)}
gridDT = GridSearchCV(DecisionTreeClassifier(random_state=42), param_grid, n_jobs=-1)
```

```
# fitting the model for grid search
gridDT.fit(X_train, y_train)
```

Out[253]:

```
▸ GridSearchCV
▸ estimator: DecisionTreeClassifier
    ▸ DecisionTreeClassifier
```

In [254…

```
print(gridDT.best_params_)
```

```
{'max_depth': 15, 'max_features': 1}
```

In [255…

```
y_pred_test = gridDT.predict(X_test)
y_pred_train = gridDT.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9600572246065808
0.9551579925650557
```

In [256…

```
resultsDT = train_evaluate_model(y_test)
resultsDT.index = ['Decision Trees - Method 1']
results = results.append(resultsDT)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

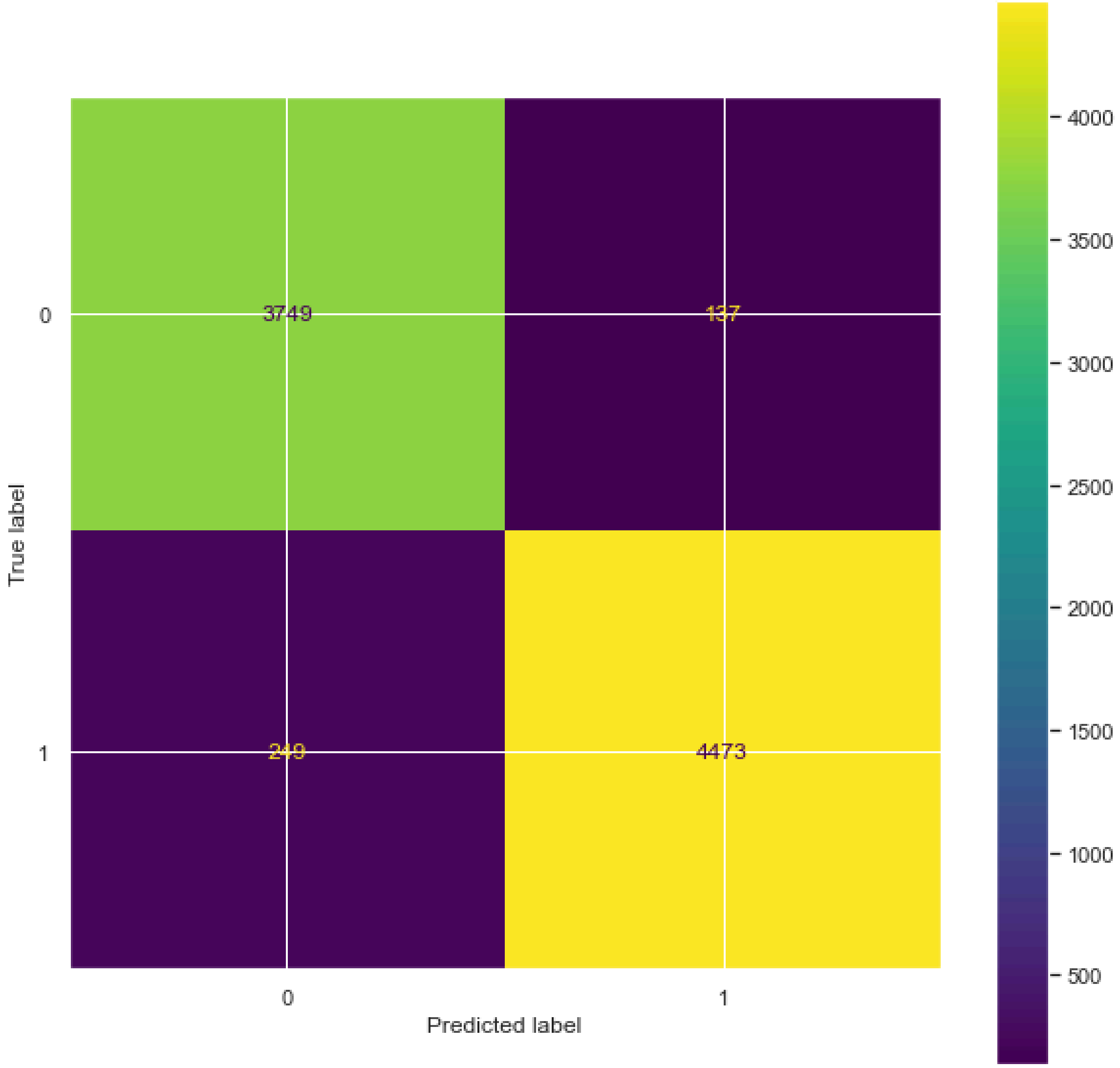
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/3196929587.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsDT)
```

Out[256]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007

In [257…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridDT.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridDT.classes_)

disp.plot()
plt.show()
```



In [258…

```
RF = RandomForestClassifier(oob_score=True,
                            random_state=42,
                            warm_start=True,
                            n_jobs=-1)

# defining parameter range
param_grid = {'n_estimators':[15, 20, 30, 40, 50, 100, 150, 200, 300, 400]
             }
gridRF = GridSearchCV(RF, param_grid)

# fitting the model for grid search
gridRF.fit(X_train, y_train)
```

```
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
```

Out[258]:

```
▸ GridSearchCV
▸ estimator: RandomForestClassifier
    ▸ RandomForestClassifier
```

In [259…

```
print(gridRF.best_params_)
```

```
{'n_estimators': 15}
```

In [260…

```
y_pred_test = gridRF.predict(X_test)
y_pred_train = gridRF.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9600572246065808
0.9551579925650557
```

In [261…

```
resultsRF = train_evaluate_model(y_test)
resultsRF.index = ['Random Forest - Method 1']
results = results.append(resultsRF)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

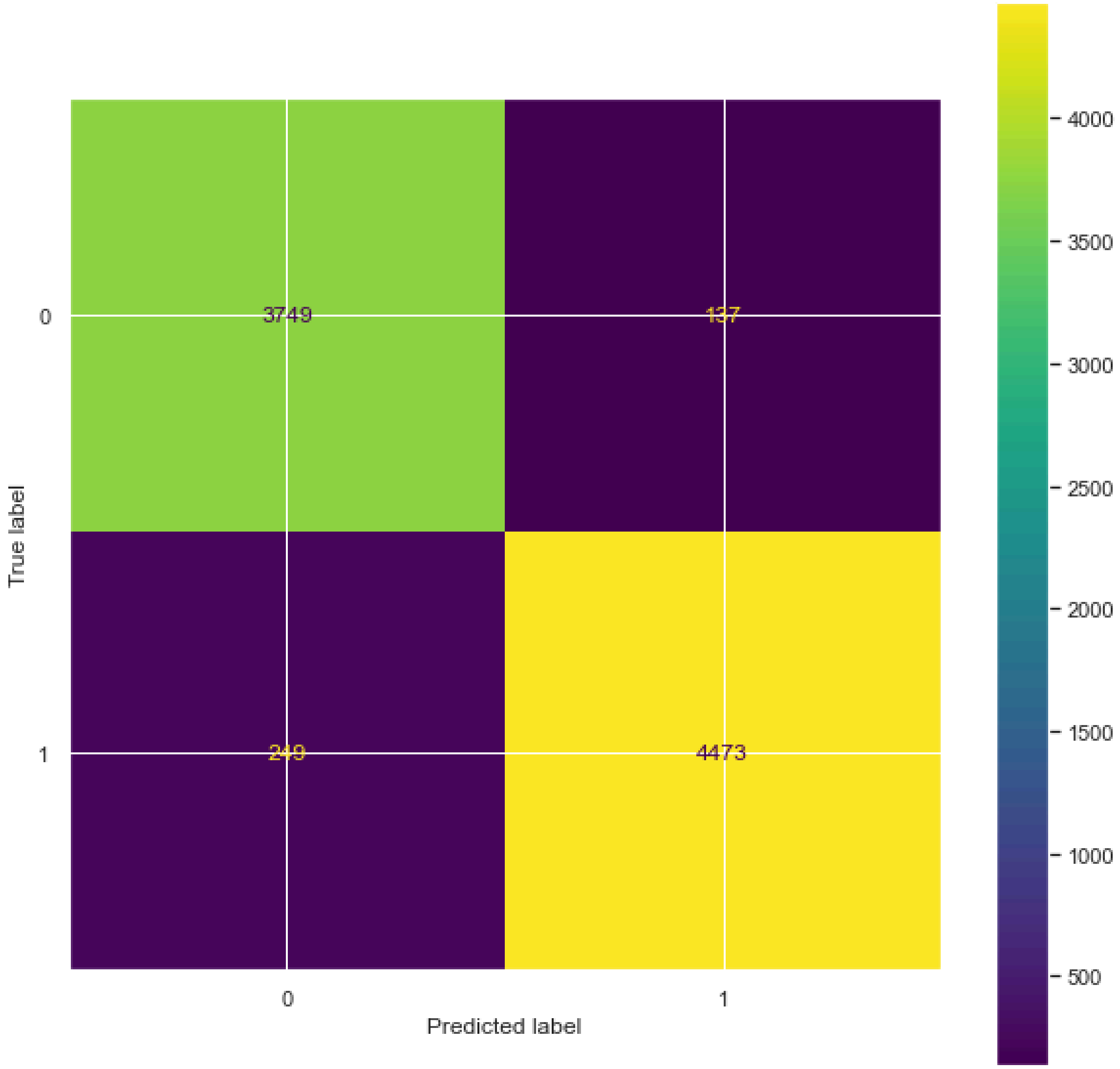
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/143072221.py:3: FutureWarning: The frame.app
end method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsRF)
```

Out[261]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007

In [262…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridRF.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridRF.classes_)

disp.plot()
plt.show()
```



In [263…

```
EF = ExtraTreesClassifier(oob_score=True,
                          random_state=42,
                          warm_start=True,
                          bootstrap=True,
                          n_jobs=-1)

# defining parameter range
param_grid = {'n_estimators':[15, 20, 30, 40, 50, 100, 150, 200, 300, 400]
              }
gridEF = GridSearchCV(EF, param_grid)

# fitting the model for grid search
gridEF.fit(X_train, y_train)
```

```
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
```

Out[263]:

```
▸ GridSearchCV
▸ estimator: ExtraTreesClassifier
    ▸ ExtraTreesClassifier
```

In [264…

```
print(gridEF.best_params_)
```

```
{'n_estimators': 15}
```

In [265…

```
y_pred_test = gridEF.predict(X_test)
y_pred_train = gridEF.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9600572246065808
0.9551579925650557
```

In [266…

```
resultsEF = train_evaluate_model(y_test)
resultsEF.index = ['Extra Trees - Method 1']
results = results.append(resultsEF)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

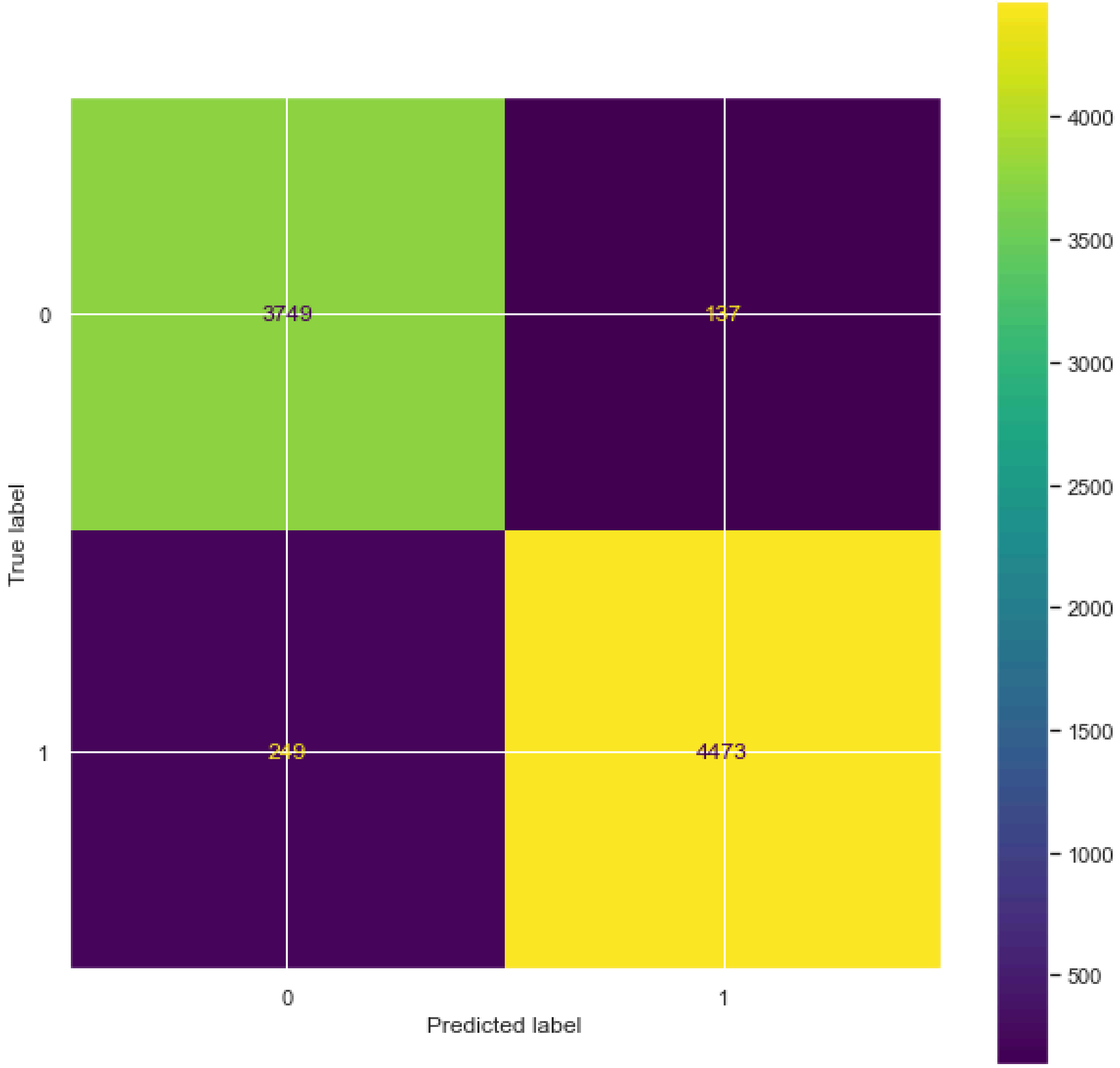
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/162385805.py:3: FutureWarning: The frame.app
end method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsEF)
```

Out[266]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007

In [267…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridRF.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridRF.classes_)

disp.plot()
plt.show()
```



In [268…

```
param_grid = {'n_estimators': [100,200,400],
              'learning_rate': [0.8,0.5,0.1, 0.01]}

# defining parameter range
gridGB = GridSearchCV(GradientBoostingClassifier(subsample=0.5,
                                                  max_features=6,
                                                  random_state=42),
                                                  param_grid=param_grid,
                                                  scoring='accuracy',
                                                  n_jobs=-1)

# fitting the model for grid search
gridGB.fit(X_train, y_train)
```

Out[268]:

```
▸             GridSearchCV
▸ estimator: GradientBoostingClassifier
      ▸ GradientBoostingClassifier
```

In [269…

```
print(gridGB.best_params_)
```

```
{'learning_rate': 0.5, 'n_estimators': 200}
```

In [270…

```
y_pred_test = gridGB.predict(X_test)
y_pred_train = gridGB.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9591416309012876
0.9572490706319703
```

In [271…

```
resultsGB = train_evaluate_model(y_test)
resultsGB.index = ['Gradient Boosting - Method 1']
results = results.append(resultsGB)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

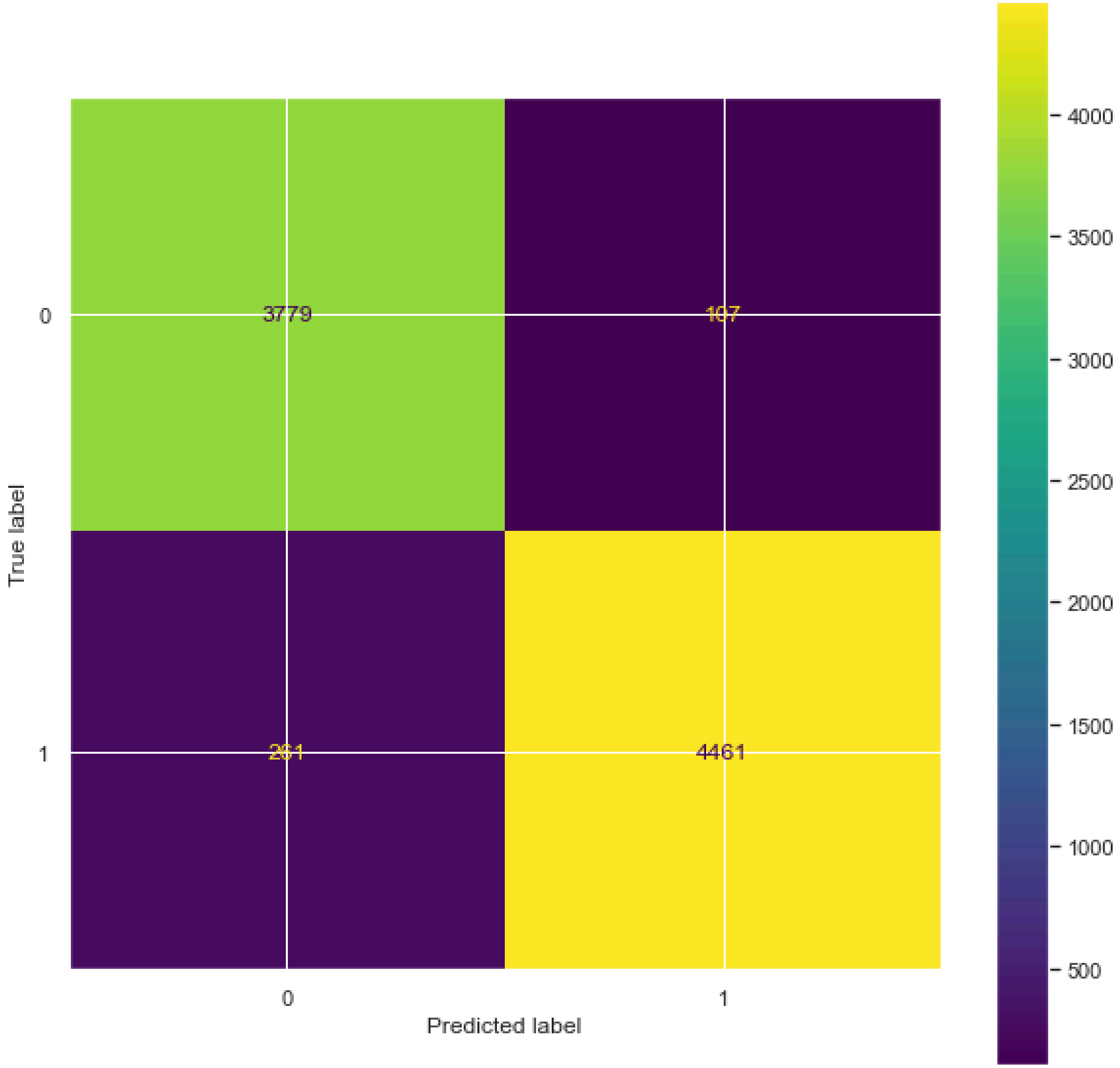
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/3410373561.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsGB)
```

Out[271]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596

In [272…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridGB.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridGB.classes_)

disp.plot()
plt.show()
```

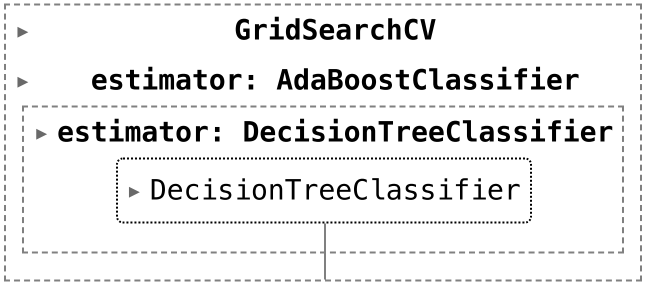


In [273…

```
param_grid = {'n_estimators': [100,200,400],
              'learning_rate': [1,0.8,0.5,0.1, 0.01]}
AB = AdaBoostClassifier(DecisionTreeClassifier(max_features=6))
# defining parameter range
gridAB = GridSearchCV(AB,
                      param_grid=param_grid,
                      scoring='accuracy',
                      n_jobs=-1)
```

```
# fitting the model for grid search
gridAB.fit(X_train, y_train)
```

Out[273]:



```
▸ GridSearchCV
▸ estimator: AdaBoostClassifier
▸ estimator: DecisionTreeClassifier
▸ DecisionTreeClassifier
```

In [274…

```
print(gridAB.best_params_)
```

```
{'learning_rate': 0.8, 'n_estimators': 400}
```

In [275…

```
y_pred_test = gridAB.predict(X_test)
y_pred_train = gridAB.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9600572246065808
0.9551579925650557
```

In [276…

```
resultsAB = train_evaluate_model(y_test)
resultsAB.index = ['Ada Boost - Method 1']
results = results.append(resultsAB)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

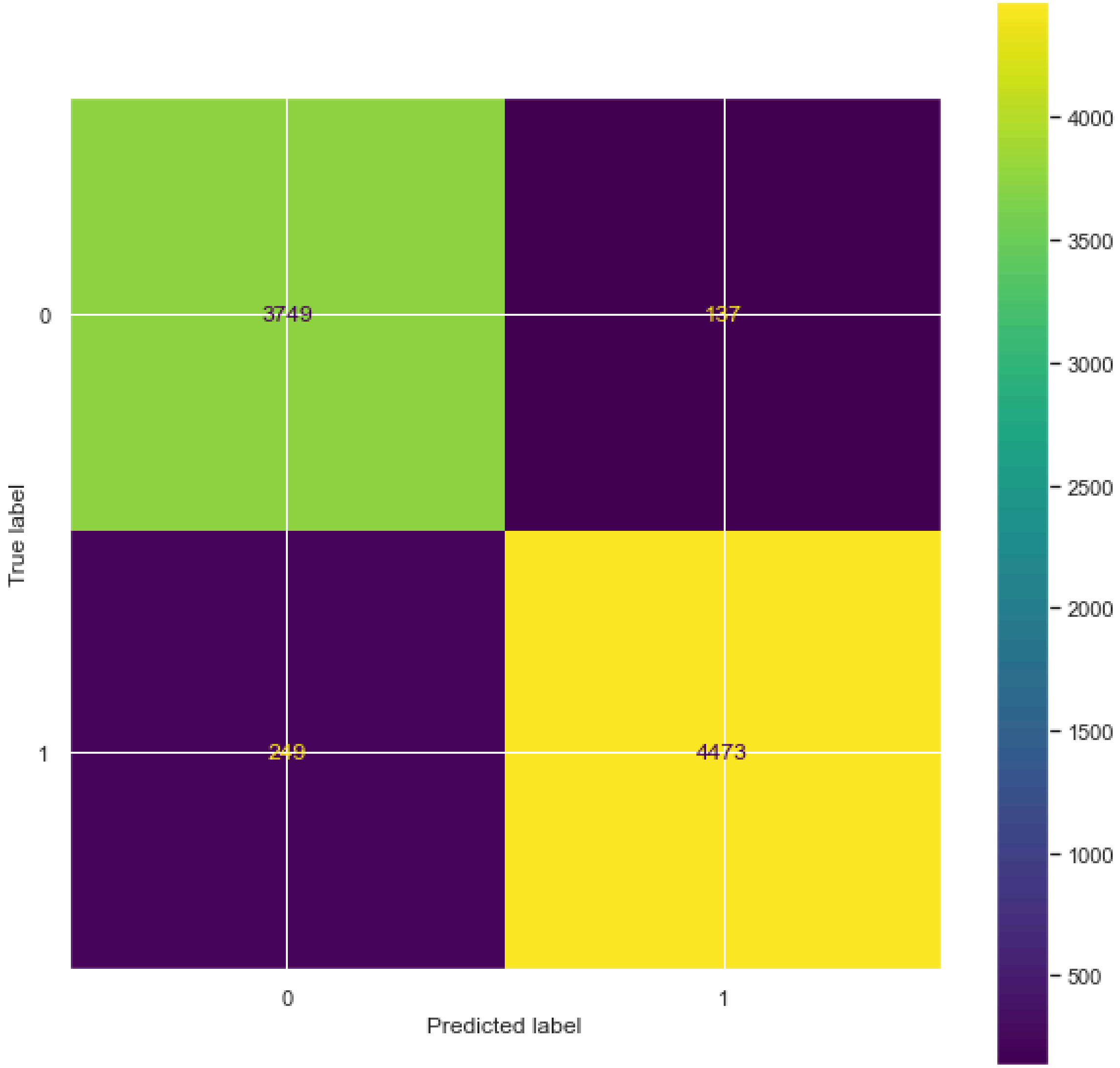
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/3485686748.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsAB)
```

Out[276]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007

In [277…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridAB.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridAB.classes_)

disp.plot()
plt.show()
```



In [278…

```
estimators = [('Decision Trees', gridDT), ('Random Forest', gridRF)]
VC = VotingClassifier(estimators, voting='soft')
VC = VC.fit(X_train, y_train)
```

```
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
```

In [279…

```
y_pred_test = VC.predict(X_test)
y_pred_train = VC.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9600572246065808
0.9551579925650557
```

In [280…

```
resultsVC = train_evaluate_model(y_test)
resultsVC.index = ['Stacking Voting - Method 1']
results = results.append(resultsVC)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

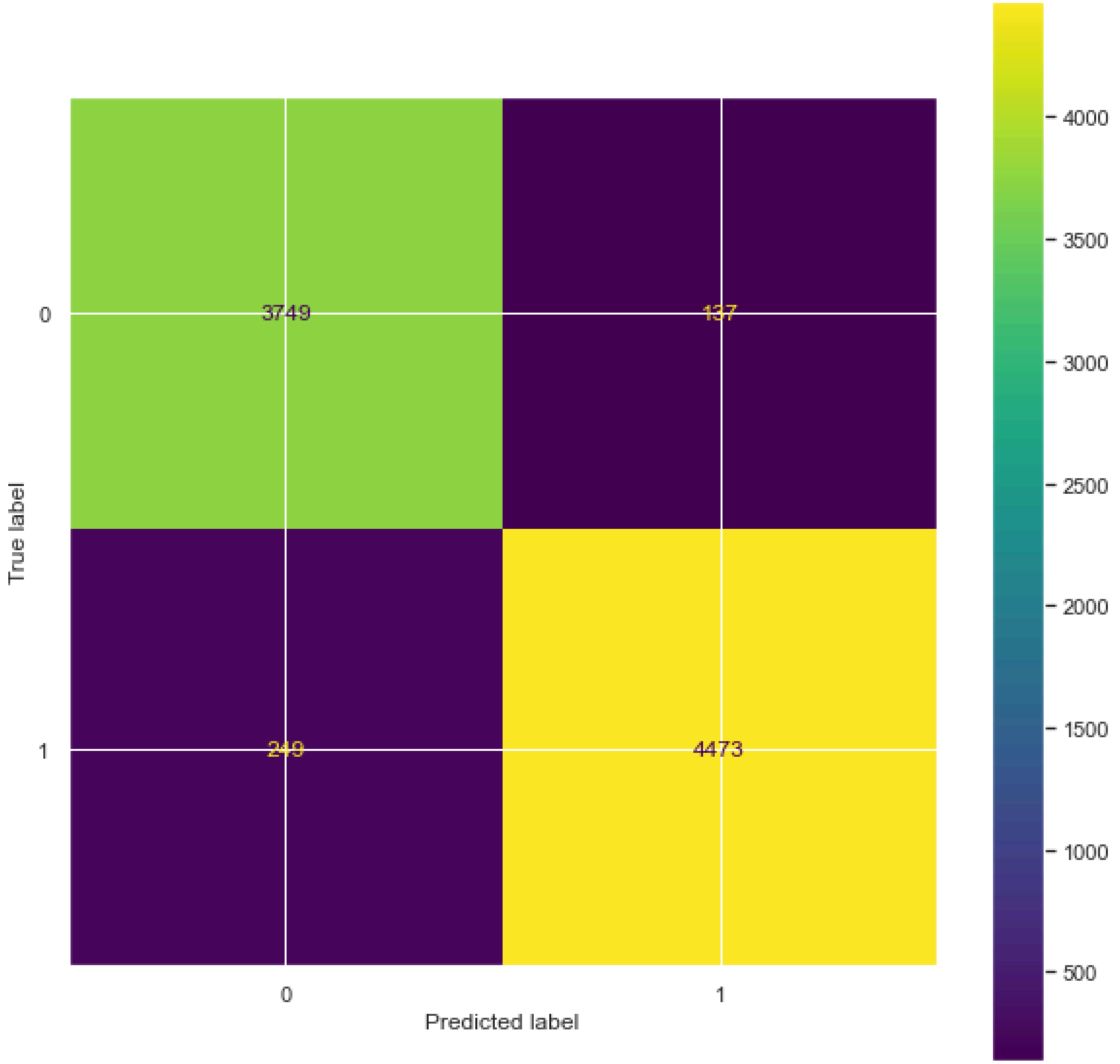
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/374672978.py:3: FutureWarning: The frame.app
end method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsVC)
```

Out[280]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.954693	0.958660	0.959677	0.957645	0.954376	0.954376
Logistic Regression - Method 1	0.770795	0.802245	0.761560	0.847522	0.762541	0.762541
Naive Bayes - Method 1	0.749419	0.775850	0.761681	0.790555	0.744994	0.744994
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007

In [281…

```
cm = confusion_matrix(y_test, y_pred_test, labels=VC.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=VC.classes_)

disp.plot()
plt.show()
```



In [283…

```
#With feature selection
mms = MinMaxScaler()
hypertesion_data[['cp']] = mms.fit_transform(hypertesion_data[['cp']])
hypertesion_data[['slope_down slope']] = mms.fit_transform(hypertesion_data[['slope_down slope']])
hypertesion_data[['slope_normal']] = mms.fit_transform(hypertesion_data[['slope_normal']])
hypertesion_data[['thalach']] = mms.fit_transform(hypertesion_data[['thalach']])
hypertesion_data[['restecg']] = mms.fit_transform(hypertesion_data[['restecg']])
hypertesion_data.head()
```

Out[283]:

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	ca	thal	target	slope_down slope	slope_normal
0	57.0	1.0	1.000000	0.481132	0.244292	1	0.0	0.603053	0	2.3	0	1	1	0.0	0.0
1	64.0	0.0	0.666667	0.339623	0.283105	0	0.5	0.885496	0	3.5	0	2	1	0.0	0.0
2	52.0	1.0	0.333333	0.339623	0.178082	0	0.0	0.770992	0	1.4	0	2	1	1.0	0.0
3	56.0	0.0	0.333333	0.245283	0.251142	0	0.5	0.816794	0	0.8	0	2	1	1.0	0.0
4	66.0	0.0	0.000000	0.245283	0.520548	0	0.5	0.702290	1	0.6	0	2	1	1.0	0.0

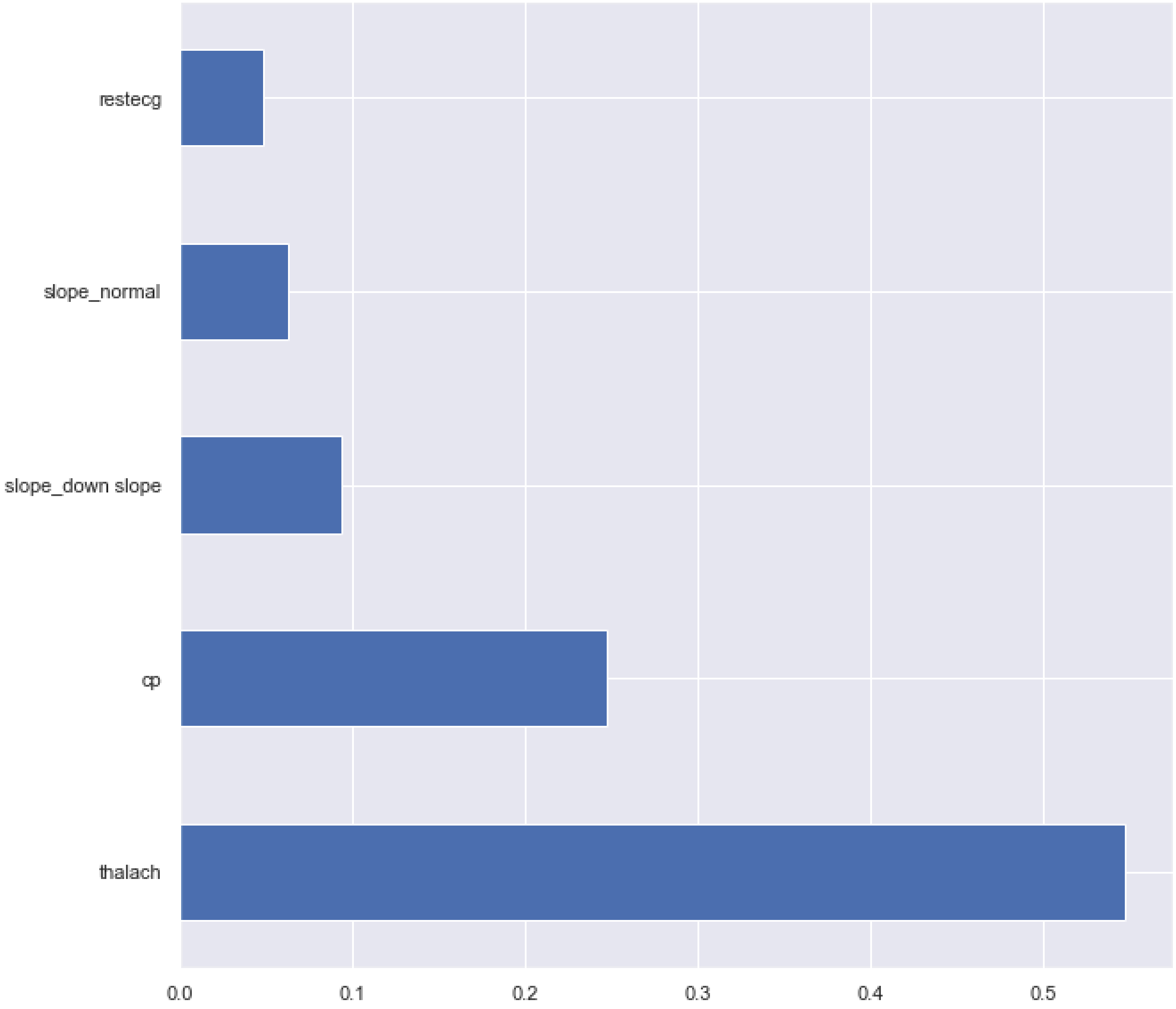
In [284…

```
y = (hypertesion_data['target']).astype(int)
X = hypertesion_data[['cp','slope_down slope','slope_normal','thalach','restecg']]
```

In [285…

```
model = ExtraTreesClassifier()
model.fit(X,y)
print(model.feature_importances_) #use inbuilt class feature_importances of tree based classifiers
#plot graph of feature importances for better visualization
feat_importances = pd.Series(model.feature_importances_, index=X.columns)
feat_importances.nlargest(5).plot(kind='barh')
plt.show()
```

```
[0.24780007 0.09381944 0.06277229 0.54724488 0.04836332]
```



In [290…

```
bestfeatures = SelectKBest(score_func=chi2, k=4)
fit = bestfeatures.fit(X,y)
dfscores = pd.DataFrame(fit.scores_)
dfcolumns = pd.DataFrame(X.columns)
#concat two dataframes for better visualization
featureScores = pd.concat([dfcolumns,dfscores],axis=1)
featureScores.columns = ['Specs','Score']  #naming the dataframe columns
print(featureScores.nlargest(4,'Score'))  #print 4 best features
```

```
              Specs        Score
1  slope_down slope  2150.936239
2      slope_normal  1801.772365
0                cp  1789.566335
3           thalach   232.239305
```

In [289…

```
#Create a logistic regression classifier
lr = LogisticRegression()
# Create an EFS object
efs = EFS(estimator=lr,        # Use logistic regression as the classifier/estimator
          min_features=1,      # The minimum number of features to consider is 1
          max_features=5,      # The maximum number of features to consider is 4
          scoring='accuracy',  # The metric to use to evaluate the classifier is accuracy
          cv=4)                # The number of cross-validations to perform is 4

# Train EFS with our dataset
efs = efs.fit(X, y)
# Print the results
print('Best accuracy score: %.2f' % efs.best_score_) # best_score_ shows the best score
print('Best subset (indices):', efs.best_idx_)       # best_idx_ shows the index of features that yield the
print('Best subset (corresponding names):', efs.best_feature_names_) # best_feature_names_ shows the feature
```

```
Features: 31/31
Best accuracy score: 0.77
Best subset (indices): (0, 1, 3, 4)
Best subset (corresponding names): ('cp', 'slope_down slope', 'thalach', 'restecg')
```

In [94]:

```
#It's more likely using top 3 ranked features('cp', 'down slope' and 'thalach')
y = (hypertesion_data['target']).astype(int)
X = hypertesion_data[['cp','thalach','slope_down slope']]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=0)
```

In [95]:

```
param_grid = {'n_neighbors': [1,3,5,7,9,11,13,15,17,19],  #odd numbers because there are 2 classes in target
              'weights': ['distance', 'uniform']}
gridKNN = GridSearchCV(KNeighborsClassifier(), param_grid, refit = True, verbose = 3)

# fitting the model for grid search
gridKNN.fit(X_train, y_train)
```

```
Fitting 5 folds for each of 20 candidates, totalling 100 fits
[CV 1/5] END ...n_neighbors=1, weights=distance;, score=0.921 total time=   0.1s
[CV 2/5] END ...n_neighbors=1, weights=distance;, score=0.929 total time=   0.0s
[CV 3/5] END ...n_neighbors=1, weights=distance;, score=0.926 total time=   0.0s
[CV 4/5] END ...n_neighbors=1, weights=distance;, score=0.924 total time=   0.0s
[CV 5/5] END ...n_neighbors=1, weights=distance;, score=0.915 total time=   0.1s
[CV 1/5] END ....n_neighbors=1, weights=uniform;, score=0.921 total time=   0.2s
[CV 2/5] END ....n_neighbors=1, weights=uniform;, score=0.929 total time=   0.2s
[CV 3/5] END ....n_neighbors=1, weights=uniform;, score=0.926 total time=   0.2s
[CV 4/5] END ....n_neighbors=1, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=1, weights=uniform;, score=0.915 total time=   0.2s
[CV 1/5] END ...n_neighbors=3, weights=distance;, score=0.921 total time=   0.1s
[CV 2/5] END ...n_neighbors=3, weights=distance;, score=0.929 total time=   0.1s
[CV 3/5] END ...n_neighbors=3, weights=distance;, score=0.930 total time=   0.0s
[CV 4/5] END ...n_neighbors=3, weights=distance;, score=0.930 total time=   0.0s
[CV 5/5] END ...n_neighbors=3, weights=distance;, score=0.918 total time=   0.1s
[CV 1/5] END ....n_neighbors=3, weights=uniform;, score=0.921 total time=   0.2s
[CV 2/5] END ....n_neighbors=3, weights=uniform;, score=0.929 total time=   0.2s
[CV 3/5] END ....n_neighbors=3, weights=uniform;, score=0.930 total time=   0.2s
[CV 4/5] END ....n_neighbors=3, weights=uniform;, score=0.930 total time=   0.2s
[CV 5/5] END ....n_neighbors=3, weights=uniform;, score=0.918 total time=   0.2s
[CV 1/5] END ...n_neighbors=5, weights=distance;, score=0.926 total time=   0.1s
[CV 2/5] END ...n_neighbors=5, weights=distance;, score=0.934 total time=   0.1s
[CV 3/5] END ...n_neighbors=5, weights=distance;, score=0.931 total time=   0.1s
[CV 4/5] END ...n_neighbors=5, weights=distance;, score=0.924 total time=   0.1s
[CV 5/5] END ...n_neighbors=5, weights=distance;, score=0.927 total time=   0.1s
[CV 1/5] END ....n_neighbors=5, weights=uniform;, score=0.926 total time=   0.2s
[CV 2/5] END ....n_neighbors=5, weights=uniform;, score=0.934 total time=   0.2s
[CV 3/5] END ....n_neighbors=5, weights=uniform;, score=0.931 total time=   0.3s
[CV 4/5] END ....n_neighbors=5, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=5, weights=uniform;, score=0.927 total time=   0.2s
[CV 1/5] END ...n_neighbors=7, weights=distance;, score=0.923 total time=   0.1s
[CV 2/5] END ...n_neighbors=7, weights=distance;, score=0.936 total time=   0.1s
[CV 3/5] END ...n_neighbors=7, weights=distance;, score=0.928 total time=   0.1s
[CV 4/5] END ...n_neighbors=7, weights=distance;, score=0.924 total time=   0.1s
[CV 5/5] END ...n_neighbors=7, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ....n_neighbors=7, weights=uniform;, score=0.923 total time=   0.2s
[CV 2/5] END ....n_neighbors=7, weights=uniform;, score=0.936 total time=   0.2s
[CV 3/5] END ....n_neighbors=7, weights=uniform;, score=0.928 total time=   0.2s
[CV 4/5] END ....n_neighbors=7, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=7, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ...n_neighbors=9, weights=distance;, score=0.922 total time=   0.1s
[CV 2/5] END ...n_neighbors=9, weights=distance;, score=0.935 total time=   0.1s
[CV 3/5] END ...n_neighbors=9, weights=distance;, score=0.930 total time=   0.1s
[CV 4/5] END ...n_neighbors=9, weights=distance;, score=0.924 total time=   0.1s
```

```
[CV 5/5] END ...n_neighbors=9, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ....n_neighbors=9, weights=uniform;, score=0.922 total time=   0.2s
[CV 2/5] END ....n_neighbors=9, weights=uniform;, score=0.935 total time=   0.2s
[CV 3/5] END ....n_neighbors=9, weights=uniform;, score=0.930 total time=   0.2s
[CV 4/5] END ....n_neighbors=9, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=9, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ..n_neighbors=11, weights=distance;, score=0.920 total time=   0.1s
[CV 2/5] END ..n_neighbors=11, weights=distance;, score=0.936 total time=   0.1s
[CV 3/5] END ..n_neighbors=11, weights=distance;, score=0.930 total time=   0.1s
[CV 4/5] END ..n_neighbors=11, weights=distance;, score=0.926 total time=   0.1s
[CV 5/5] END ..n_neighbors=11, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ...n_neighbors=11, weights=uniform;, score=0.920 total time=   0.2s
[CV 2/5] END ...n_neighbors=11, weights=uniform;, score=0.936 total time=   0.2s
[CV 3/5] END ...n_neighbors=11, weights=uniform;, score=0.930 total time=   0.2s
[CV 4/5] END ...n_neighbors=11, weights=uniform;, score=0.926 total time=   0.2s
[CV 5/5] END ...n_neighbors=11, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ..n_neighbors=13, weights=distance;, score=0.917 total time=   0.1s
[CV 2/5] END ..n_neighbors=13, weights=distance;, score=0.934 total time=   0.1s
[CV 3/5] END ..n_neighbors=13, weights=distance;, score=0.931 total time=   0.1s
[CV 4/5] END ..n_neighbors=13, weights=distance;, score=0.927 total time=   0.1s
[CV 5/5] END ..n_neighbors=13, weights=distance;, score=0.927 total time=   0.1s
[CV 1/5] END ...n_neighbors=13, weights=uniform;, score=0.917 total time=   0.2s
[CV 2/5] END ...n_neighbors=13, weights=uniform;, score=0.934 total time=   0.2s
[CV 3/5] END ...n_neighbors=13, weights=uniform;, score=0.931 total time=   0.2s
[CV 4/5] END ...n_neighbors=13, weights=uniform;, score=0.927 total time=   0.2s
[CV 5/5] END ...n_neighbors=13, weights=uniform;, score=0.927 total time=   0.2s
[CV 1/5] END ..n_neighbors=15, weights=distance;, score=0.919 total time=   0.1s
[CV 2/5] END ..n_neighbors=15, weights=distance;, score=0.935 total time=   0.1s
[CV 3/5] END ..n_neighbors=15, weights=distance;, score=0.928 total time=   0.1s
[CV 4/5] END ..n_neighbors=15, weights=distance;, score=0.926 total time=   0.1s
[CV 5/5] END ..n_neighbors=15, weights=distance;, score=0.927 total time=   0.1s
[CV 1/5] END ...n_neighbors=15, weights=uniform;, score=0.919 total time=   0.2s
[CV 2/5] END ...n_neighbors=15, weights=uniform;, score=0.935 total time=   0.2s
[CV 3/5] END ...n_neighbors=15, weights=uniform;, score=0.928 total time=   0.3s
[CV 4/5] END ...n_neighbors=15, weights=uniform;, score=0.926 total time=   0.3s
[CV 5/5] END ...n_neighbors=15, weights=uniform;, score=0.927 total time=   0.2s
[CV 1/5] END ..n_neighbors=17, weights=distance;, score=0.920 total time=   0.1s
[CV 2/5] END ..n_neighbors=17, weights=distance;, score=0.936 total time=   0.1s
[CV 3/5] END ..n_neighbors=17, weights=distance;, score=0.929 total time=   0.1s
[CV 4/5] END ..n_neighbors=17, weights=distance;, score=0.927 total time=   0.1s
[CV 5/5] END ..n_neighbors=17, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ...n_neighbors=17, weights=uniform;, score=0.920 total time=   0.3s
[CV 2/5] END ...n_neighbors=17, weights=uniform;, score=0.936 total time=   0.2s
[CV 3/5] END ...n_neighbors=17, weights=uniform;, score=0.929 total time=   0.2s
[CV 4/5] END ...n_neighbors=17, weights=uniform;, score=0.927 total time=   0.2s
```

```
[CV 5/5] END ...n_neighbors=17, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ..n_neighbors=19, weights=distance;, score=0.921 total time=   0.1s
[CV 2/5] END ..n_neighbors=19, weights=distance;, score=0.936 total time=   0.1s
[CV 3/5] END ..n_neighbors=19, weights=distance;, score=0.929 total time=   0.1s
[CV 4/5] END ..n_neighbors=19, weights=distance;, score=0.928 total time=   0.1s
[CV 5/5] END ..n_neighbors=19, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ...n_neighbors=19, weights=uniform;, score=0.921 total time=   0.2s
[CV 2/5] END ...n_neighbors=19, weights=uniform;, score=0.936 total time=   0.3s
[CV 3/5] END ...n_neighbors=19, weights=uniform;, score=0.929 total time=   0.3s
[CV 4/5] END ...n_neighbors=19, weights=uniform;, score=0.928 total time=   0.3s
[CV 5/5] END ...n_neighbors=19, weights=uniform;, score=0.925 total time=   0.2s
```

Out[95]:

```
▸          GridSearchCV
▸ estimator: KNeighborsClassifier
      ▸ KNeighborsClassifier
```

In [96]:

```python
print(gridKNN.best_params_)
```

```
{'n_neighbors': 5, 'weights': 'distance'}
```

In [97]:

```python
y_pred_test = gridKNN.predict(X_test)
y_pred_train = gridKNN.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9220615620549896
0.9215335463258786
```

In [98]:

```python
resultsKNN2 = train_evaluate_model(y_test)
resultsKNN2.index = ['K Nearest Neighbors - Method 2']
results = results.append(resultsKNN2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

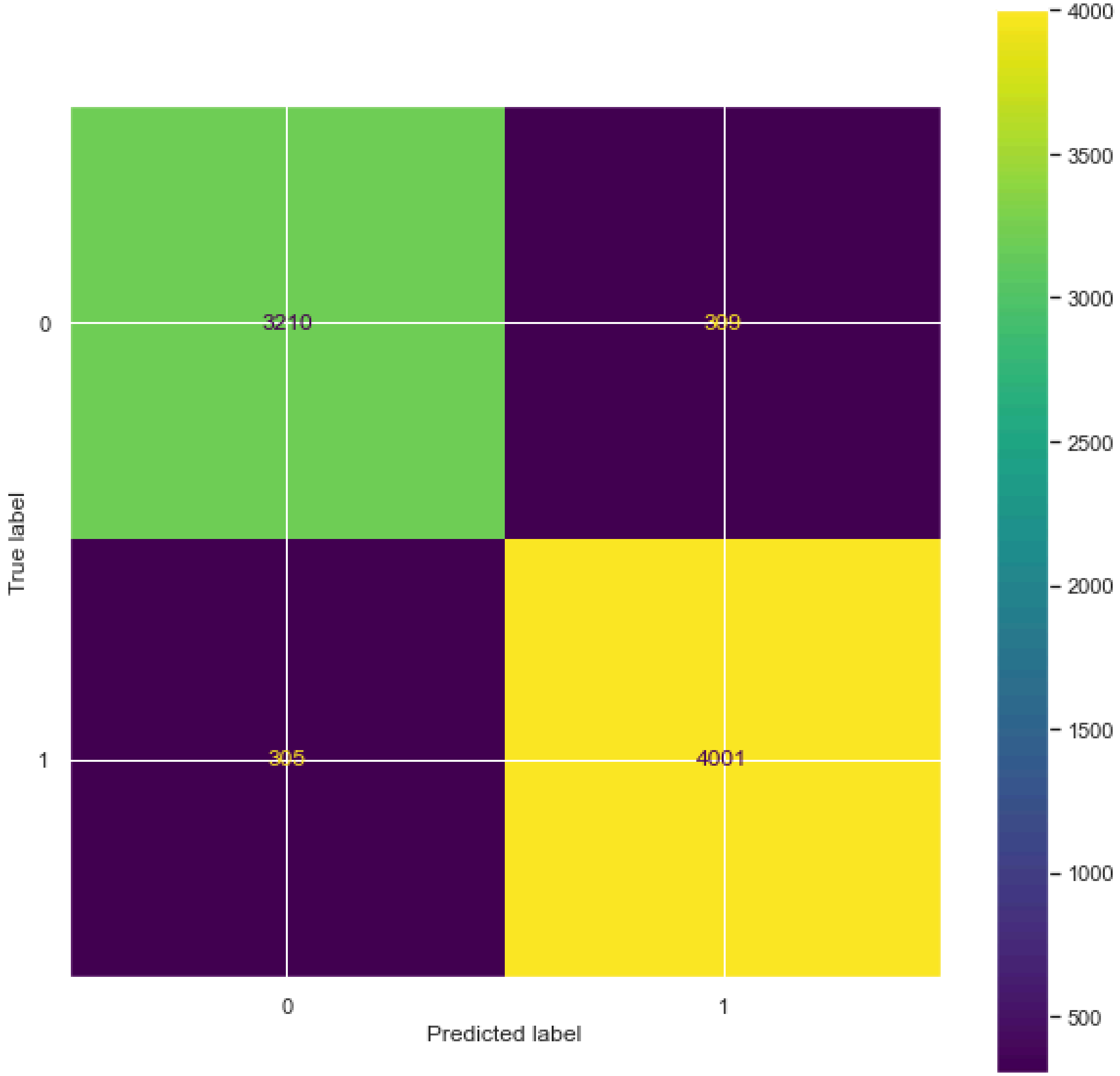
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/2379876878.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsKNN2)
```

Out[98]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680

In [99]:

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridKNN.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridKNN.classes_)

disp.plot()
plt.show()
```



In [100…

```
LG = LogisticRegression().fit(X_train, y_train)
#prediction
y_pred_test = LG.predict(X_test)
y_pred_train = LG.predict(X_train)
#scores
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.7494796801402125
0.7478594249201278
```

In [101…

```
param_grid = {'penalty':['l1','l2'],
                'Cs': [2,5,10,20],
                'cv': [4],
                'solver': ['liblinear','saga']}
gridLG = GridSearchCV(LogisticRegressionCV(), param_grid, refit = True, verbose = 3)

  # fitting the model for grid search
gridLG.fit(X_train, y_train)
```

```
Fitting 5 folds for each of 16 candidates, totalling 80 fits
[CV 1/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.747 total time=   0.3s
[CV 2/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.752 total time=   0.3s
[CV 3/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.746 total time=   0.3s
[CV 4/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.750 total time=   0.2s
[CV 5/5] END Cs=2, cv=4, penalty=l1, solver=liblinear;, score=0.758 total time=   0.3s
[CV 1/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.747 total time=   0.2s
[CV 2/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.752 total time=   0.2s
[CV 3/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.746 total time=   0.2s
[CV 4/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.750 total time=   0.2s
[CV 5/5] END Cs=2, cv=4, penalty=l1, solver=saga;, score=0.758 total time=   0.2s
[CV 1/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.747 total time=   0.1s
[CV 2/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.752 total time=   0.1s
[CV 3/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.746 total time=   0.1s
[CV 4/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.750 total time=   0.1s
[CV 5/5] END Cs=2, cv=4, penalty=l2, solver=liblinear;, score=0.758 total time=   0.1s
[CV 1/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.747 total time=   0.3s
[CV 2/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.752 total time=   0.3s
[CV 3/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.746 total time=   0.3s
[CV 4/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.750 total time=   0.3s
[CV 5/5] END Cs=2, cv=4, penalty=l2, solver=saga;, score=0.758 total time=   0.4s
[CV 1/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.747 total time=   0.7s
[CV 2/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.757 total time=   0.7s
[CV 3/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.746 total time=   0.6s
[CV 4/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.750 total time=   0.6s
[CV 5/5] END Cs=5, cv=4, penalty=l1, solver=liblinear;, score=0.758 total time=   0.6s
[CV 1/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.747 total time=   0.3s
[CV 2/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.752 total time=   0.3s
[CV 3/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.746 total time=   0.3s
[CV 4/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.750 total time=   0.3s
[CV 5/5] END Cs=5, cv=4, penalty=l1, solver=saga;, score=0.758 total time=   0.4s
[CV 1/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.747 total time=   0.3s
[CV 2/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.752 total time=   0.3s
[CV 3/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.746 total time=   0.3s
[CV 4/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.747 total time=   0.3s
[CV 5/5] END Cs=5, cv=4, penalty=l2, solver=liblinear;, score=0.758 total time=   0.3s
[CV 1/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.747 total time=   0.5s
[CV 2/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.757 total time=   0.4s
[CV 3/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.746 total time=   0.5s
[CV 4/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.747 total time=   0.4s
[CV 5/5] END Cs=5, cv=4, penalty=l2, solver=saga;, score=0.758 total time=   0.4s
[CV 1/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.747 total time=   1.1s
[CV 2/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.752 total time=   1.2s
[CV 3/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.746 total time=   1.1s
[CV 4/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.747 total time=   1.1s
```

```
[CV 5/5] END Cs=10, cv=4, penalty=l1, solver=liblinear;, score=0.758 total time=   1.2s
[CV 1/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.747 total time=   0.5s
[CV 2/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.757 total time=   0.5s
[CV 3/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.746 total time=   0.6s
[CV 4/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.750 total time=   0.6s
[CV 5/5] END Cs=10, cv=4, penalty=l1, solver=saga;, score=0.758 total time=   0.5s
[CV 1/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.746 total time=   0.5s
[CV 2/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.750 total time=   0.4s
[CV 3/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.763 total time=   0.5s
[CV 4/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.759 total time=   0.5s
[CV 5/5] END Cs=10, cv=4, penalty=l2, solver=liblinear;, score=0.770 total time=   0.4s
[CV 1/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.747 total time=   0.6s
[CV 2/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.757 total time=   0.6s
[CV 3/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.746 total time=   0.7s
[CV 4/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.747 total time=   0.6s
[CV 5/5] END Cs=10, cv=4, penalty=l2, solver=saga;, score=0.758 total time=   0.6s
[CV 1/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.751 total time=   2.1s
[CV 2/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.754 total time=   2.3s
[CV 3/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.757 total time=   2.4s
[CV 4/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.751 total time=   2.2s
[CV 5/5] END Cs=20, cv=4, penalty=l1, solver=liblinear;, score=0.764 total time=   2.0s
[CV 1/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.743 total time=   0.8s
[CV 2/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.746 total time=   0.8s
[CV 3/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.748 total time=   0.8s
[CV 4/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.745 total time=   0.8s
[CV 5/5] END Cs=20, cv=4, penalty=l1, solver=saga;, score=0.755 total time=   0.8s
[CV 1/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.755 total time=   0.8s
[CV 2/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.759 total time=   0.8s
[CV 3/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.760 total time=   0.8s
[CV 4/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.754 total time=   0.8s
[CV 5/5] END Cs=20, cv=4, penalty=l2, solver=liblinear;, score=0.767 total time=   0.9s
[CV 1/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.747 total time=   0.9s
[CV 2/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.752 total time=   1.0s
[CV 3/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.746 total time=   0.9s
[CV 4/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.747 total time=   0.9s
[CV 5/5] END Cs=20, cv=4, penalty=l2, solver=saga;, score=0.758 total time=   0.9s
```

Out[101]:

```
▸         GridSearchCV
▸ estimator: LogisticRegressionCV
      ▸ LogisticRegressionCV
```

In [102…

```
y_pred_test = gridLG.predict(X_test)
y_pred_train = gridLG.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.7595574542666228
0.7539936102236422
```

In [103…

```
resultsLG2 = train_evaluate_model(y_test)
resultsLG2.index = ['Logistic Regression - Method 2']
results = results.append(resultsLG2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/2598149167.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsLG2)
```

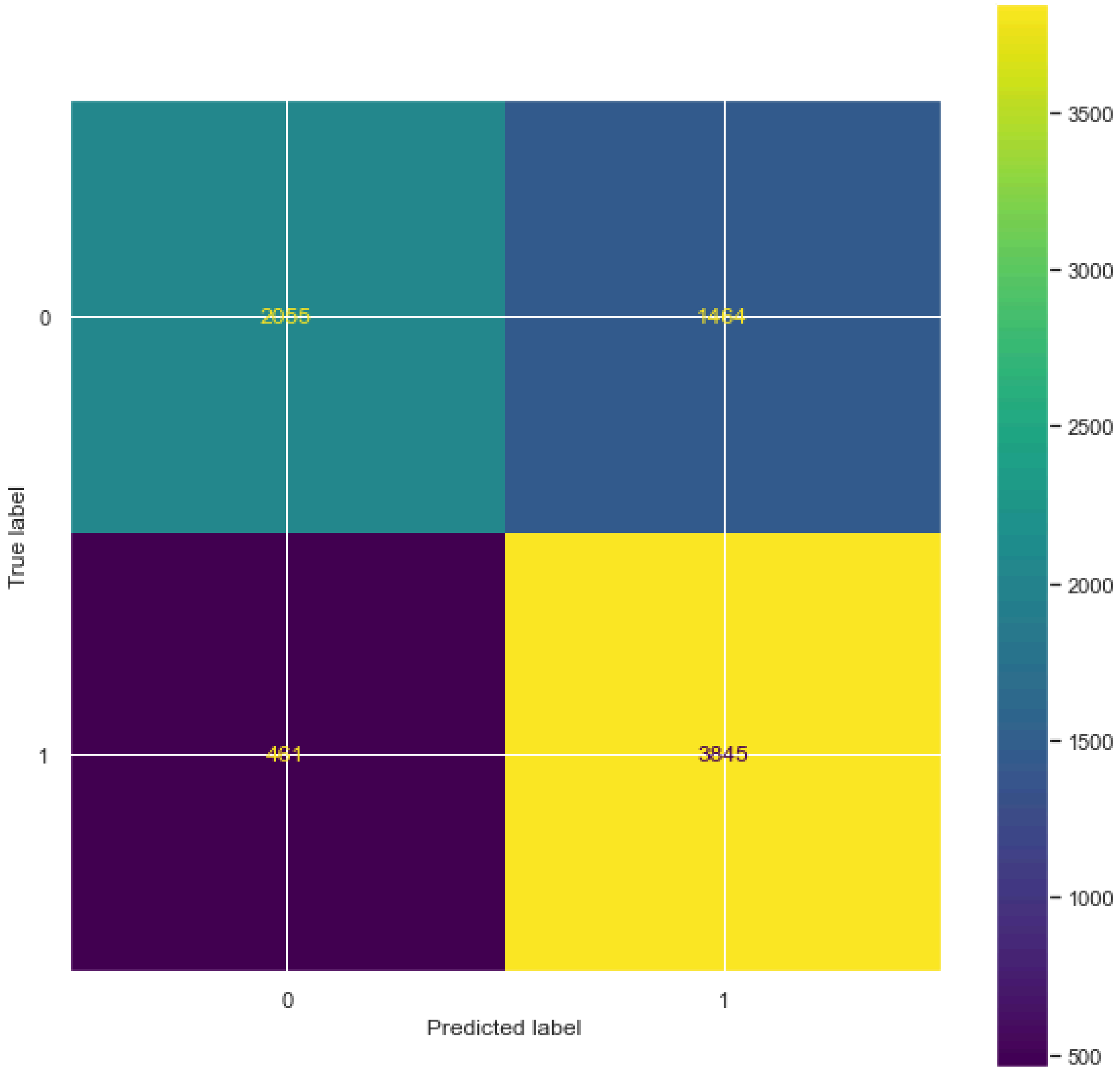
Out[103]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456

In [104…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridLG.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridLG.classes_)
```

```
disp.plot()
plt.show()
```



In [105…

```
cv_N = 10
nb = {'gaussian': GaussianNB(),
      'bernoulli': BernoulliNB()
      }
scores = {}
```

```
for key, model in nb.items():
    s = cross_val_score(model, X_train, y_train, cv=cv_N, n_jobs=cv_N, scoring='accuracy')
    scores[key] = np.mean(s)
scores
```

Out[105]:

```
{'gaussian': 0.7510685231586369, 'bernoulli': 0.7619136971297393}
```

In [106…

```
GNB = GaussianNB()
GNB.fit(X_train, y_train)
```

Out[106]:

```
▾ GaussianNB

GaussianNB()
```

In [107…

```
y_pred_test = GNB.predict(X_test)
y_pred_train = GNB.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.7510680249753533
0.7523322683706071
```

In [108…

```
resultsNB2 = train_evaluate_model(y_test)
resultsNB2.index = ['Naive Bayes - Method 2']
results = results.append(resultsNB2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

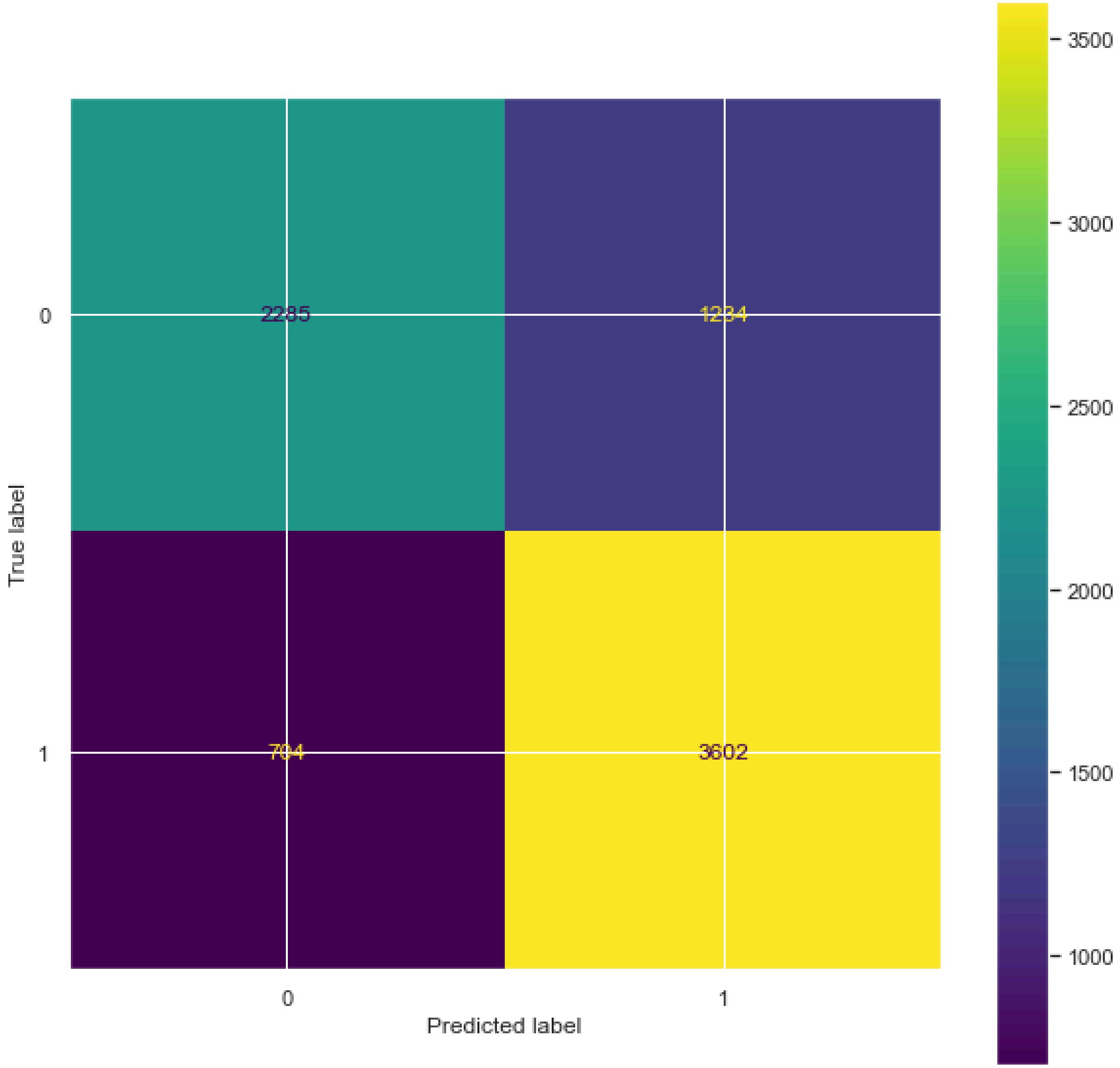
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1088990190.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsNB2)
```

Out[108]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920

In [109…

```
cm = confusion_matrix(y_test, y_pred_test, labels=GNB.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=GNB.classes_)

disp.plot()
plt.show()
```



In [110…

```
param_grid = {'C': [1,10,100,1000],
                'gamma': [1, 0.1, 0.01, 0.001],
                'kernel': ['rbf']}

gridSVM = GridSearchCV(SVC(), param_grid, refit = True, verbose = 3, cv=2)

  # fitting the model for grid search
gridSVM.fit(X_train, y_train)
```

```
Fitting 2 folds for each of 16 candidates, totalling 32 fits
[CV 1/2] END .........C=1, gamma=1, kernel=rbf;, score=0.767 total time=   8.2s
[CV 2/2] END .........C=1, gamma=1, kernel=rbf;, score=0.773 total time=   9.1s
[CV 1/2] END .......C=1, gamma=0.1, kernel=rbf;, score=0.751 total time=   7.8s
[CV 2/2] END .......C=1, gamma=0.1, kernel=rbf;, score=0.759 total time=   8.0s
[CV 1/2] END ......C=1, gamma=0.01, kernel=rbf;, score=0.739 total time=   8.3s
[CV 2/2] END ......C=1, gamma=0.01, kernel=rbf;, score=0.744 total time=   8.7s
[CV 1/2] END .....C=1, gamma=0.001, kernel=rbf;, score=0.727 total time=  10.7s
[CV 2/2] END .....C=1, gamma=0.001, kernel=rbf;, score=0.708 total time=  10.6s
[CV 1/2] END ........C=10, gamma=1, kernel=rbf;, score=0.778 total time=   9.1s
[CV 2/2] END ........C=10, gamma=1, kernel=rbf;, score=0.780 total time=   9.9s
[CV 1/2] END ......C=10, gamma=0.1, kernel=rbf;, score=0.767 total time=   7.8s
[CV 2/2] END ......C=10, gamma=0.1, kernel=rbf;, score=0.773 total time=   7.9s
[CV 1/2] END .....C=10, gamma=0.01, kernel=rbf;, score=0.741 total time=   7.9s
[CV 2/2] END .....C=10, gamma=0.01, kernel=rbf;, score=0.760 total time=   8.0s
[CV 1/2] END ....C=10, gamma=0.001, kernel=rbf;, score=0.739 total time=   8.4s
[CV 2/2] END ....C=10, gamma=0.001, kernel=rbf;, score=0.744 total time=   8.5s
[CV 1/2] END .......C=100, gamma=1, kernel=rbf;, score=0.779 total time=  22.1s
[CV 2/2] END .......C=100, gamma=1, kernel=rbf;, score=0.784 total time=  18.2s
[CV 1/2] END .....C=100, gamma=0.1, kernel=rbf;, score=0.770 total time=   9.5s
[CV 2/2] END .....C=100, gamma=0.1, kernel=rbf;, score=0.772 total time=   9.6s
[CV 1/2] END ....C=100, gamma=0.01, kernel=rbf;, score=0.750 total time=   9.1s
[CV 2/2] END ....C=100, gamma=0.01, kernel=rbf;, score=0.759 total time=   9.1s
[CV 1/2] END ...C=100, gamma=0.001, kernel=rbf;, score=0.750 total time=   8.5s
[CV 2/2] END ...C=100, gamma=0.001, kernel=rbf;, score=0.751 total time=   8.9s
[CV 1/2] END ......C=1000, gamma=1, kernel=rbf;, score=0.783 total time= 1.1min
[CV 2/2] END ......C=1000, gamma=1, kernel=rbf;, score=0.785 total time=  55.3s
[CV 1/2] END ....C=1000, gamma=0.1, kernel=rbf;, score=0.769 total time=  11.4s
[CV 2/2] END ....C=1000, gamma=0.1, kernel=rbf;, score=0.779 total time=  12.2s
[CV 1/2] END ...C=1000, gamma=0.01, kernel=rbf;, score=0.774 total time=   9.5s
[CV 2/2] END ...C=1000, gamma=0.01, kernel=rbf;, score=0.772 total time=   9.5s
[CV 1/2] END ..C=1000, gamma=0.001, kernel=rbf;, score=0.753 total time=   7.8s
[CV 2/2] END ..C=1000, gamma=0.001, kernel=rbf;, score=0.758 total time=   8.2s
```

Out[110]:

```
▸ GridSearchCV
▸ estimator: SVC
    ▸ SVC
```

In [111…

```
print(gridSVM.best_params_)
```

```
{'C': 1000, 'gamma': 1, 'kernel': 'rbf'}
```

In [112…

```
y_pred_test = gridSVM.predict(X_test)
y_pred_train = gridSVM.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.7864497754409027
0.7796805111821086
```

In [113…

```
resultsSVM2 = train_evaluate_model(y_test)
resultsSVM2.index = ['Support Vector Machine - Method 2']
results = results.append(resultsSVM2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

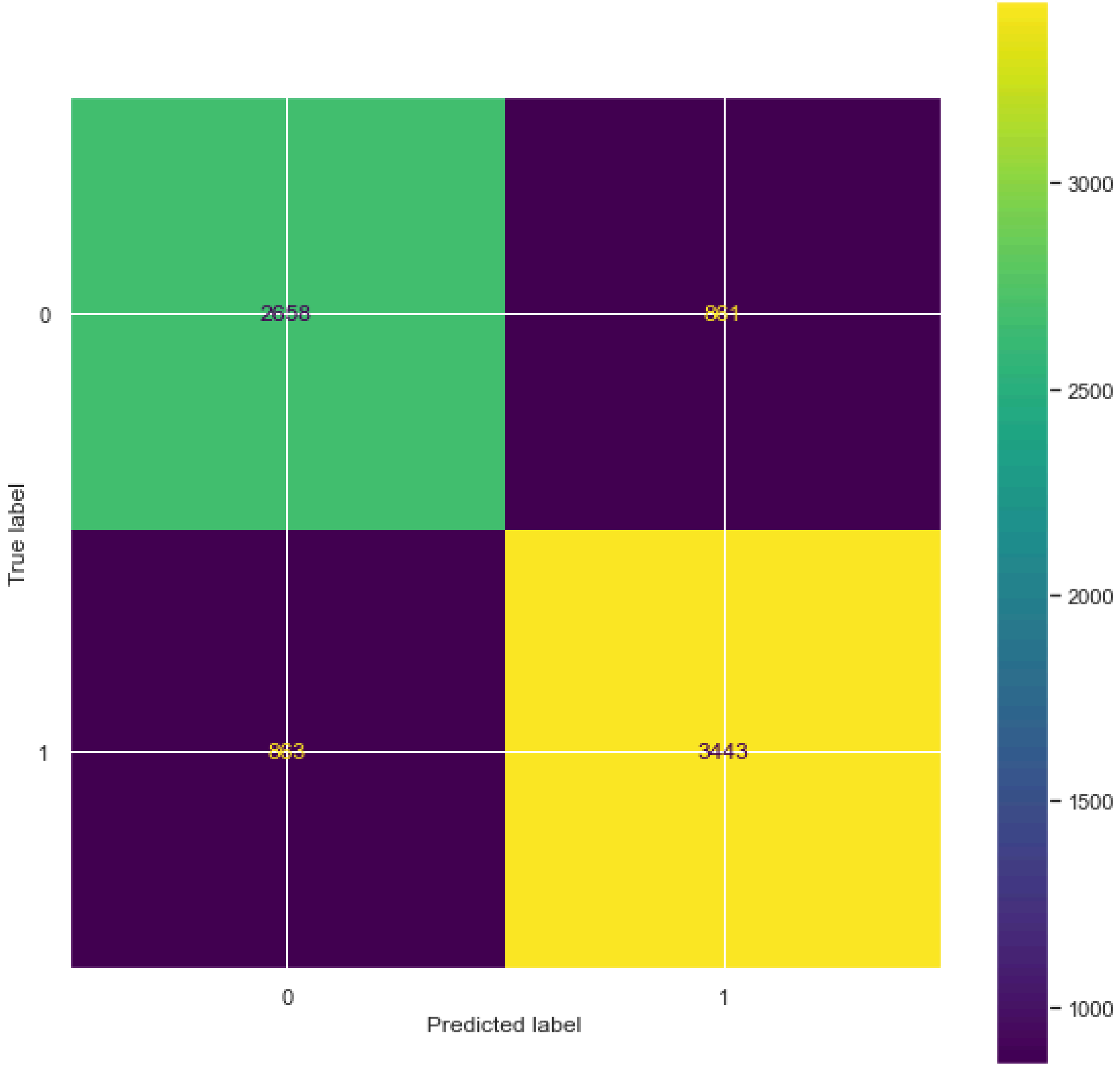
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/3645259320.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsSVM2)
```

Out[113]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455

In [114…

```
cm = confusion_matrix(y_test, y_pred_test, labels=GNB.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=GNB.classes_)

disp.plot()
plt.show()
```



In [115…

```
dt = DecisionTreeClassifier(random_state=42)
dt = dt.fit(X_train, y_train)

param_grid = {'max_depth':range(1, dt.tree_.max_depth+1, 2),
              'max_features': range(1, len(dt.feature_importances_)+1)}
gridDT = GridSearchCV(DecisionTreeClassifier(random_state=42), param_grid, n_jobs=-1)

# fitting the model for grid search
gridDT.fit(X_train, y_train)
```

Out[115]:

```
▸            GridSearchCV
▸ estimator: DecisionTreeClassifier
      ▸ DecisionTreeClassifier
```

In [116…

```
print(gridDT.best_params_)
```

```
{'max_depth': 15, 'max_features': 1}
```

In [117…

```
y_pred_test = gridDT.predict(X_test)
y_pred_train = gridDT.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9318654836236171
0.9267731629392971
```

In [118…

```
resultsDT2 = train_evaluate_model(y_test)
resultsDT2.index = ['Decision Trees - Method 2']
results = results.append(resultsDT2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

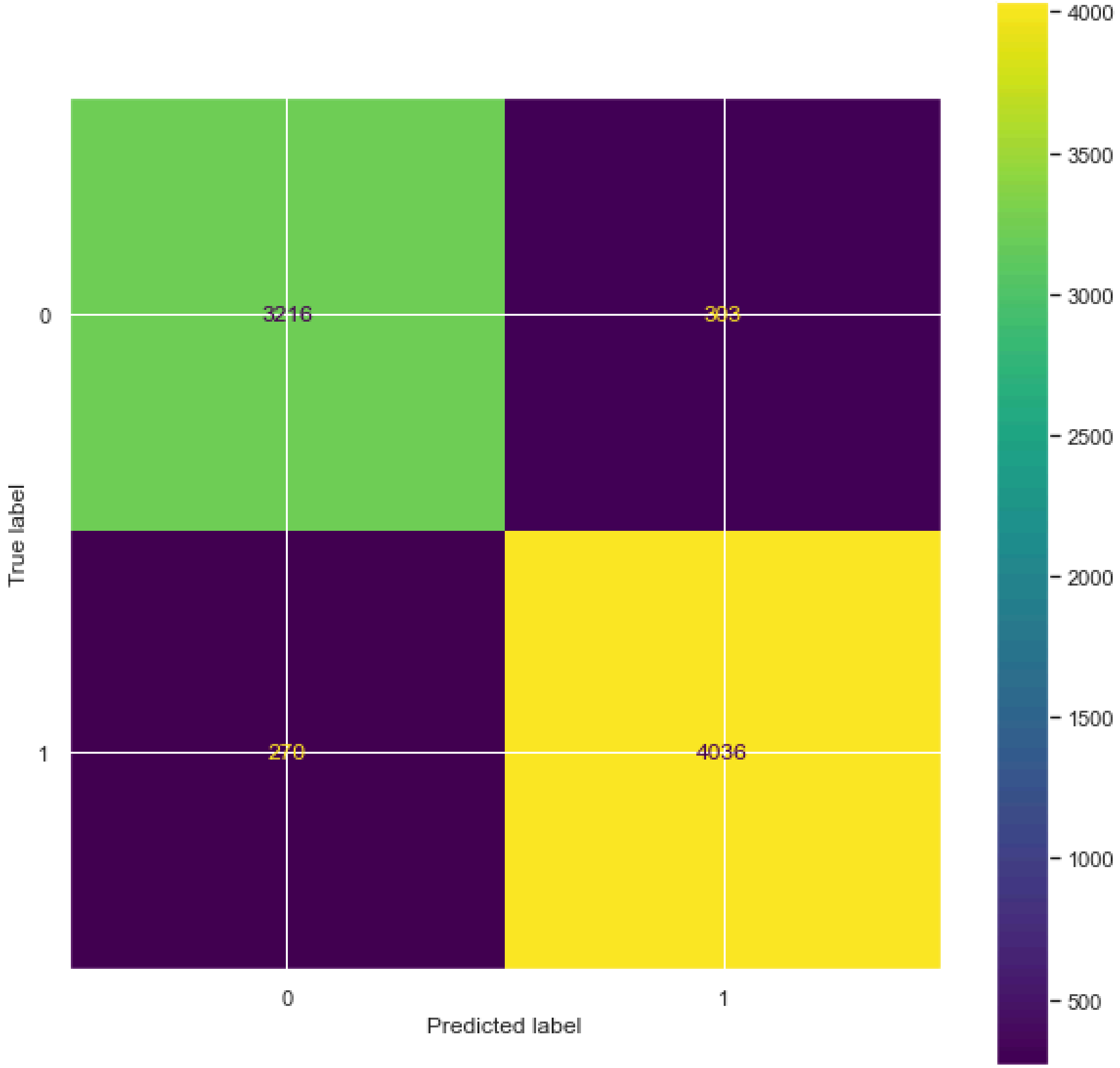
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/2200591120.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsDT2)
```

Out[118]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455
Decision Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596

In [119…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridDT.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridDT.classes_)

disp.plot()
plt.show()
```



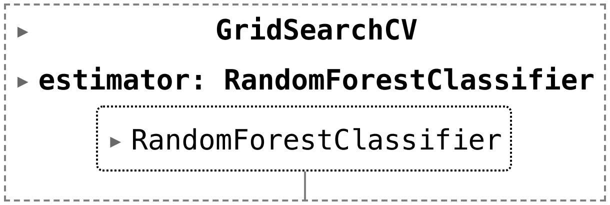
In [120…

```
RF = RandomForestClassifier(oob_score=True,
                            random_state=42,
                            warm_start=True,
                            n_jobs=-1)

# defining parameter range
param_grid = {'n_estimators':[15, 20, 30, 40, 50, 100, 150, 200, 300, 400]
              }
gridRF = GridSearchCV(RF, param_grid)
```

```python
# fitting the model for grid search
gridRF.fit(X_train, y_train)
```

```
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
```

Out[120]:



```
▸ GridSearchCV
▸ estimator: RandomForestClassifier
    ▸ RandomForestClassifier
```

In [121…

```python
print(gridRF.best_params_)
```

```
{'n_estimators': 200}
```

In [122…

```python
y_pred_test = gridRF.predict(X_test)
y_pred_train = gridRF.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9318654836236171
0.9267731629392971
```

In [123…

```python
resultsRF2 = train_evaluate_model(y_test)
resultsRF2.index = ['Random Forest - Method 2']
results = results.append(resultsRF2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

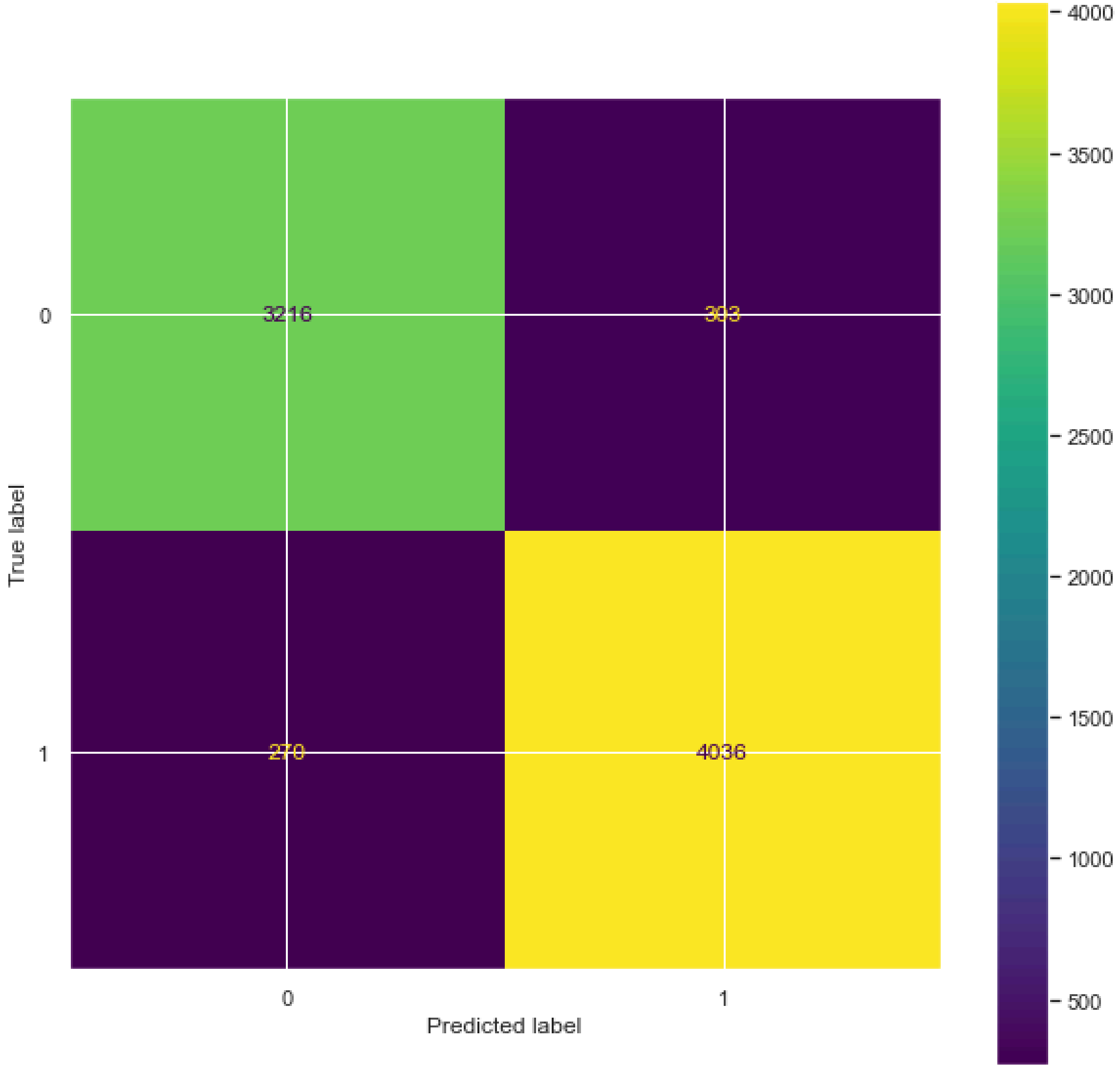
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/2502023712.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsRF2)
```

Out[123]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455
Decision Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Random Forest - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596

In [124…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridRF.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridRF.classes_)

disp.plot()
plt.show()
```



In [125…

```
EF = ExtraTreesClassifier(oob_score=True,
                          random_state=42,
                          warm_start=True,
                          bootstrap=True,
                          n_jobs=-1)

# defining parameter range
param_grid = {'n_estimators':[15, 20, 30, 40, 50, 100, 150, 200, 300, 400]
              }
```

```
gridEF = GridSearchCV(EF, param_grid)

# fitting the model for grid search
gridEF.fit(X_train, y_train)
```

```
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
```

Out[125]:

```
▸         GridSearchCV
▸ estimator: ExtraTreesClassifier
      ▸ ExtraTreesClassifier
```

In [126…

```
print(gridEF.best_params_)
```

```
{'n_estimators': 200}
```

In [127…

```
y_pred_test = gridEF.predict(X_test)
y_pred_train = gridEF.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9318654836236171
0.9267731629392971
```

In [128…

```
resultsEF2 = train_evaluate_model(y_test)
resultsEF2.index = ['Extra Trees - Method 2']
results = results.append(resultsEF2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

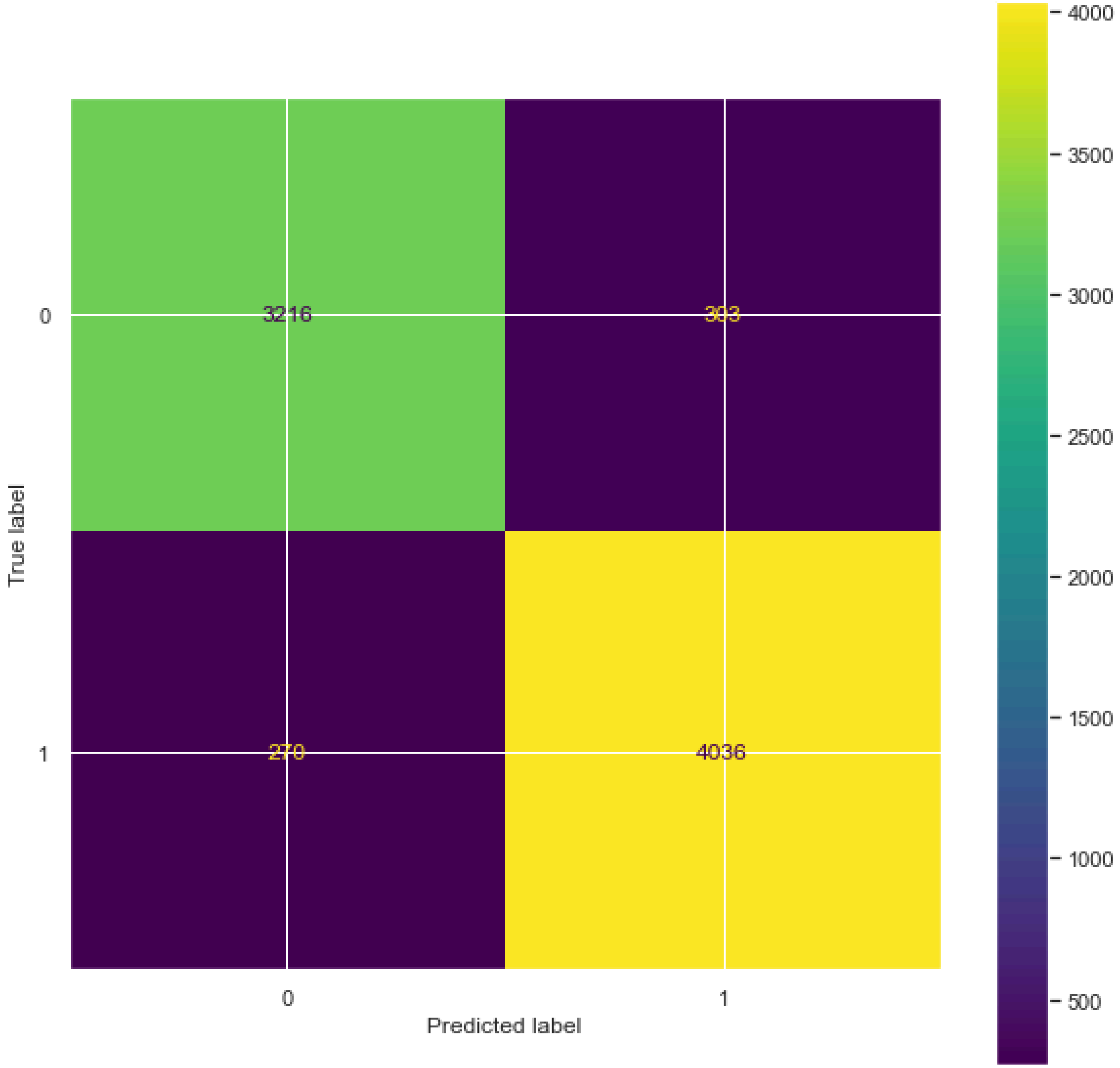
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/3408495484.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsEF2)
```

Out[128]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455
Decision Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Random Forest - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Extra Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596

In [129…

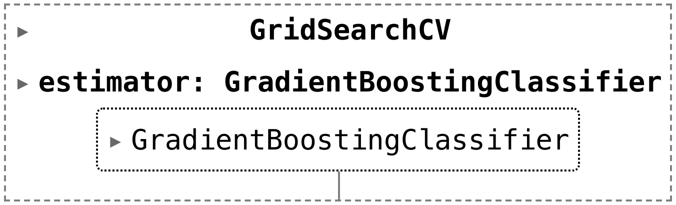
```
cm = confusion_matrix(y_test, y_pred_test, labels=gridEF.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridEF.classes_)

disp.plot()
plt.show()
```



In [130…

```
param_grid = {'n_estimators': [100,200,400],
              'learning_rate': [0.8,0.5,0.1, 0.01]}

# defining parameter range
gridGB = GridSearchCV(GradientBoostingClassifier(subsample=0.5,
                                                  max_features=6,
                                                  random_state=42),
                                                  param_grid=param_grid,
                                                  scoring='accuracy',
                                               n_jobs=-1)

# fitting the model for grid search
gridGB.fit(X_train, y_train)
```

Out[130]:



▸ GridSearchCV

▸ estimator: GradientBoostingClassifier

▸ GradientBoostingClassifier

In [131…

```
print(gridGB.best_params_)
```

```
{'learning_rate': 0.5, 'n_estimators': 200}
```

In [132…

```
y_pred_test = gridGB.predict(X_test)
y_pred_train = gridGB.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9316464015773908
0.9285623003194888
```

In [133…

```
resultsGB2 = train_evaluate_model(y_test)
resultsGB2.index = ['Gradient Boosting - Method 2']
results = results.append(resultsGB2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

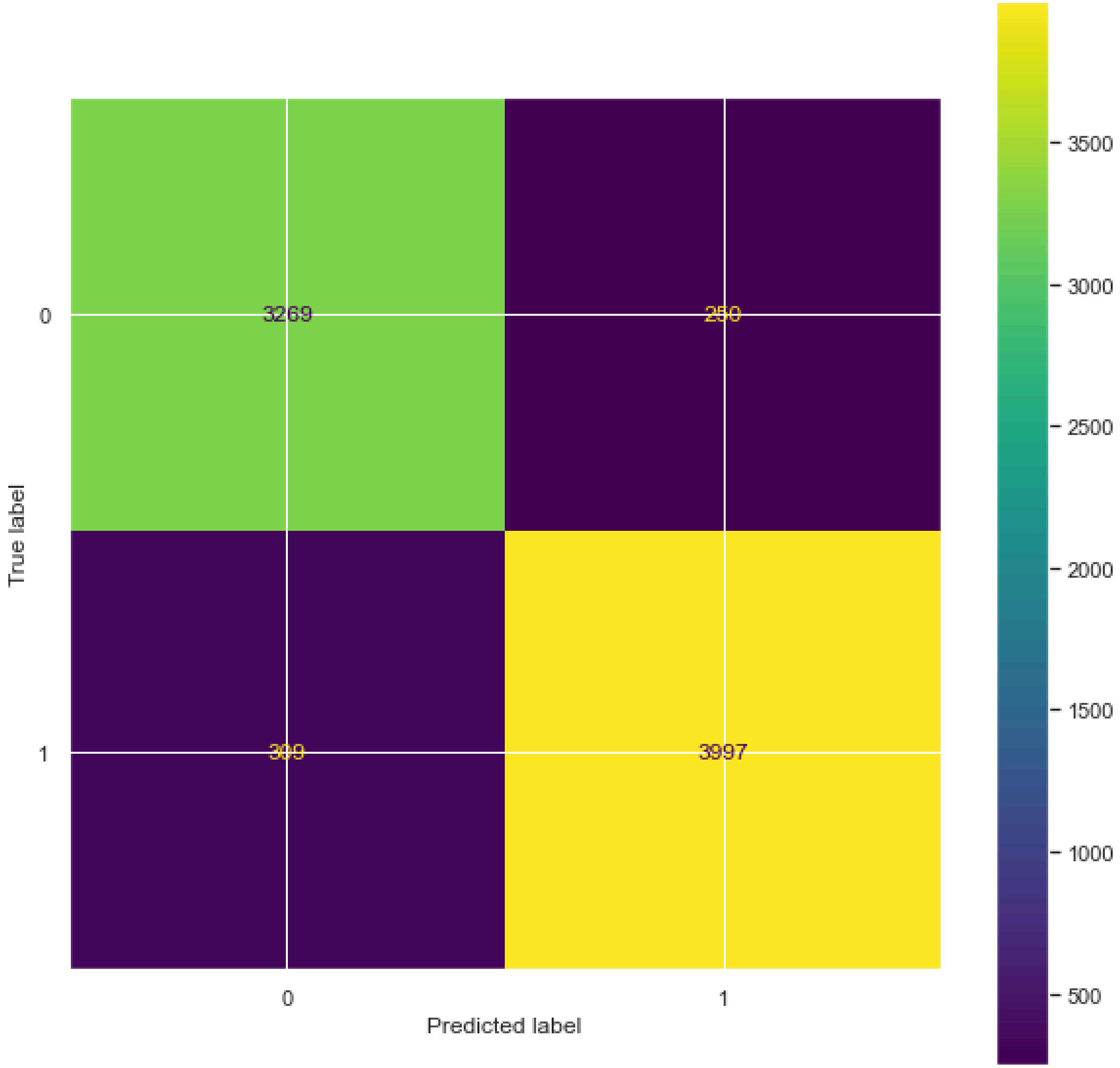
```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/941071743.py:3: FutureWarning: The frame.app
end method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsGB2)
```

Out[133]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455
Decision Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Random Forest - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Extra Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Gradient Boosting - Method 2	0.928562	0.934643	0.941135	0.928240	0.928598	0.928598

In [134…

```
cm = confusion_matrix(y_test, y_pred_test, labels=gridGB.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=gridGB.classes_)

disp.plot()
plt.show()
```

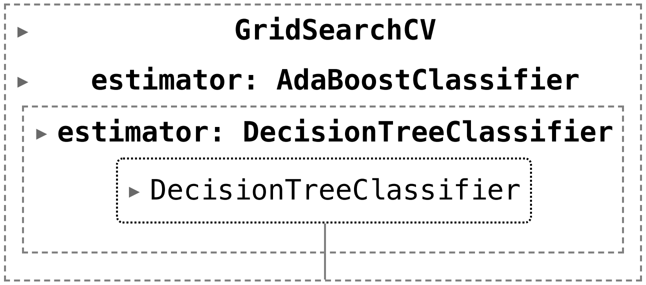


In [135…

```
param_grid = {'n_estimators': [100,200,400],
              'learning_rate': [1,0.8,0.5,0.1, 0.01]}
AB = AdaBoostClassifier(DecisionTreeClassifier(max_features=6))
# defining parameter range
gridAB = GridSearchCV(AB,
                      param_grid=param_grid,
                      scoring='accuracy',
                      n_jobs=-1)
```

```
# fitting the model for grid search
gridAB.fit(X_train, y_train)
```

Out[135]:



▸ GridSearchCV

▸ estimator: AdaBoostClassifier

▸ estimator: DecisionTreeClassifier

▸ DecisionTreeClassifier

In [136…

```
print(gridAB.best_params_)
```

```
{'learning_rate': 1, 'n_estimators': 100}
```

In [137…

```
y_pred_test = gridAB.predict(X_test)
y_pred_train = gridAB.predict(X_train)
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9318654836236171
0.9267731629392971
```

In [138…

```
resultsAB2 = train_evaluate_model(y_test)
resultsAB2.index = ['Ada Boost - Method 2']
results = results.append(resultsAB2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/2288110681.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsAB2)
```

Out[138]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455
Decision Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Random Forest - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Extra Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Gradient Boosting - Method 2	0.928562	0.934643	0.941135	0.928240	0.928598	0.928598
Ada Boost - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596

In [139…

```
estimators = [('KNN', gridKNN), ('Random Forest', gridRF)]
VC = VotingClassifier(estimators, voting='soft')
VC = VC.fit(X_train, y_train)
```

```
Fitting 5 folds for each of 20 candidates, totalling 100 fits
[CV 1/5] END ...n_neighbors=1, weights=distance;, score=0.921 total time=   0.1s
[CV 2/5] END ...n_neighbors=1, weights=distance;, score=0.929 total time=   0.1s
[CV 3/5] END ...n_neighbors=1, weights=distance;, score=0.926 total time=   0.0s
[CV 4/5] END ...n_neighbors=1, weights=distance;, score=0.924 total time=   0.0s
[CV 5/5] END ...n_neighbors=1, weights=distance;, score=0.915 total time=   0.0s
[CV 1/5] END ....n_neighbors=1, weights=uniform;, score=0.921 total time=   0.2s
[CV 2/5] END ....n_neighbors=1, weights=uniform;, score=0.929 total time=   0.2s
[CV 3/5] END ....n_neighbors=1, weights=uniform;, score=0.926 total time=   0.2s
[CV 4/5] END ....n_neighbors=1, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=1, weights=uniform;, score=0.915 total time=   0.2s
[CV 1/5] END ...n_neighbors=3, weights=distance;, score=0.921 total time=   0.1s
[CV 2/5] END ...n_neighbors=3, weights=distance;, score=0.929 total time=   0.1s
[CV 3/5] END ...n_neighbors=3, weights=distance;, score=0.930 total time=   0.0s
[CV 4/5] END ...n_neighbors=3, weights=distance;, score=0.930 total time=   0.1s
[CV 5/5] END ...n_neighbors=3, weights=distance;, score=0.918 total time=   0.1s
[CV 1/5] END ....n_neighbors=3, weights=uniform;, score=0.921 total time=   0.2s
[CV 2/5] END ....n_neighbors=3, weights=uniform;, score=0.929 total time=   0.2s
[CV 3/5] END ....n_neighbors=3, weights=uniform;, score=0.930 total time=   0.2s
[CV 4/5] END ....n_neighbors=3, weights=uniform;, score=0.930 total time=   0.2s
[CV 5/5] END ....n_neighbors=3, weights=uniform;, score=0.918 total time=   0.2s
[CV 1/5] END ...n_neighbors=5, weights=distance;, score=0.926 total time=   0.1s
[CV 2/5] END ...n_neighbors=5, weights=distance;, score=0.934 total time=   0.0s
[CV 3/5] END ...n_neighbors=5, weights=distance;, score=0.931 total time=   0.0s
[CV 4/5] END ...n_neighbors=5, weights=distance;, score=0.924 total time=   0.0s
[CV 5/5] END ...n_neighbors=5, weights=distance;, score=0.927 total time=   0.1s
[CV 1/5] END ....n_neighbors=5, weights=uniform;, score=0.926 total time=   0.2s
[CV 2/5] END ....n_neighbors=5, weights=uniform;, score=0.934 total time=   0.2s
[CV 3/5] END ....n_neighbors=5, weights=uniform;, score=0.931 total time=   0.2s
[CV 4/5] END ....n_neighbors=5, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=5, weights=uniform;, score=0.927 total time=   0.2s
[CV 1/5] END ...n_neighbors=7, weights=distance;, score=0.923 total time=   0.1s
[CV 2/5] END ...n_neighbors=7, weights=distance;, score=0.936 total time=   0.1s
[CV 3/5] END ...n_neighbors=7, weights=distance;, score=0.928 total time=   0.1s
[CV 4/5] END ...n_neighbors=7, weights=distance;, score=0.924 total time=   0.1s
[CV 5/5] END ...n_neighbors=7, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ....n_neighbors=7, weights=uniform;, score=0.923 total time=   0.2s
[CV 2/5] END ....n_neighbors=7, weights=uniform;, score=0.936 total time=   0.2s
[CV 3/5] END ....n_neighbors=7, weights=uniform;, score=0.928 total time=   0.2s
[CV 4/5] END ....n_neighbors=7, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=7, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ...n_neighbors=9, weights=distance;, score=0.922 total time=   0.1s
[CV 2/5] END ...n_neighbors=9, weights=distance;, score=0.935 total time=   0.0s
[CV 3/5] END ...n_neighbors=9, weights=distance;, score=0.930 total time=   0.0s
[CV 4/5] END ...n_neighbors=9, weights=distance;, score=0.924 total time=   0.0s
```

```
[CV 5/5] END ...n_neighbors=9, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ....n_neighbors=9, weights=uniform;, score=0.922 total time=   0.2s
[CV 2/5] END ....n_neighbors=9, weights=uniform;, score=0.935 total time=   0.2s
[CV 3/5] END ....n_neighbors=9, weights=uniform;, score=0.930 total time=   0.2s
[CV 4/5] END ....n_neighbors=9, weights=uniform;, score=0.924 total time=   0.2s
[CV 5/5] END ....n_neighbors=9, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ..n_neighbors=11, weights=distance;, score=0.920 total time=   0.1s
[CV 2/5] END ..n_neighbors=11, weights=distance;, score=0.936 total time=   0.0s
[CV 3/5] END ..n_neighbors=11, weights=distance;, score=0.930 total time=   0.0s
[CV 4/5] END ..n_neighbors=11, weights=distance;, score=0.926 total time=   0.0s
[CV 5/5] END ..n_neighbors=11, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ...n_neighbors=11, weights=uniform;, score=0.920 total time=   0.2s
[CV 2/5] END ...n_neighbors=11, weights=uniform;, score=0.936 total time=   0.2s
[CV 3/5] END ...n_neighbors=11, weights=uniform;, score=0.930 total time=   0.2s
[CV 4/5] END ...n_neighbors=11, weights=uniform;, score=0.926 total time=   0.2s
[CV 5/5] END ...n_neighbors=11, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ..n_neighbors=13, weights=distance;, score=0.917 total time=   0.0s
[CV 2/5] END ..n_neighbors=13, weights=distance;, score=0.934 total time=   0.0s
[CV 3/5] END ..n_neighbors=13, weights=distance;, score=0.931 total time=   0.0s
[CV 4/5] END ..n_neighbors=13, weights=distance;, score=0.927 total time=   0.0s
[CV 5/5] END ..n_neighbors=13, weights=distance;, score=0.927 total time=   0.1s
[CV 1/5] END ...n_neighbors=13, weights=uniform;, score=0.917 total time=   0.2s
[CV 2/5] END ...n_neighbors=13, weights=uniform;, score=0.934 total time=   0.2s
[CV 3/5] END ...n_neighbors=13, weights=uniform;, score=0.931 total time=   0.2s
[CV 4/5] END ...n_neighbors=13, weights=uniform;, score=0.927 total time=   0.2s
[CV 5/5] END ...n_neighbors=13, weights=uniform;, score=0.927 total time=   0.2s
[CV 1/5] END ..n_neighbors=15, weights=distance;, score=0.919 total time=   0.1s
[CV 2/5] END ..n_neighbors=15, weights=distance;, score=0.935 total time=   0.1s
[CV 3/5] END ..n_neighbors=15, weights=distance;, score=0.928 total time=   0.0s
[CV 4/5] END ..n_neighbors=15, weights=distance;, score=0.926 total time=   0.0s
[CV 5/5] END ..n_neighbors=15, weights=distance;, score=0.927 total time=   0.1s
[CV 1/5] END ...n_neighbors=15, weights=uniform;, score=0.919 total time=   0.2s
[CV 2/5] END ...n_neighbors=15, weights=uniform;, score=0.935 total time=   0.2s
[CV 3/5] END ...n_neighbors=15, weights=uniform;, score=0.928 total time=   0.2s
[CV 4/5] END ...n_neighbors=15, weights=uniform;, score=0.926 total time=   0.2s
[CV 5/5] END ...n_neighbors=15, weights=uniform;, score=0.927 total time=   0.2s
[CV 1/5] END ..n_neighbors=17, weights=distance;, score=0.920 total time=   0.1s
[CV 2/5] END ..n_neighbors=17, weights=distance;, score=0.936 total time=   0.1s
[CV 3/5] END ..n_neighbors=17, weights=distance;, score=0.929 total time=   0.1s
[CV 4/5] END ..n_neighbors=17, weights=distance;, score=0.927 total time=   0.1s
[CV 5/5] END ..n_neighbors=17, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ...n_neighbors=17, weights=uniform;, score=0.920 total time=   0.2s
[CV 2/5] END ...n_neighbors=17, weights=uniform;, score=0.936 total time=   0.2s
[CV 3/5] END ...n_neighbors=17, weights=uniform;, score=0.929 total time=   0.2s
[CV 4/5] END ...n_neighbors=17, weights=uniform;, score=0.927 total time=   0.2s
```

```
[CV 5/5] END ...n_neighbors=17, weights=uniform;, score=0.925 total time=   0.2s
[CV 1/5] END ..n_neighbors=19, weights=distance;, score=0.921 total time=   0.1s
[CV 2/5] END ..n_neighbors=19, weights=distance;, score=0.936 total time=   0.1s
[CV 3/5] END ..n_neighbors=19, weights=distance;, score=0.929 total time=   0.1s
[CV 4/5] END ..n_neighbors=19, weights=distance;, score=0.928 total time=   0.1s
[CV 5/5] END ..n_neighbors=19, weights=distance;, score=0.925 total time=   0.1s
[CV 1/5] END ...n_neighbors=19, weights=uniform;, score=0.921 total time=   0.2s
[CV 2/5] END ...n_neighbors=19, weights=uniform;, score=0.936 total time=   0.2s
[CV 3/5] END ...n_neighbors=19, weights=uniform;, score=0.929 total time=   0.2s
[CV 4/5] END ...n_neighbors=19, weights=uniform;, score=0.928 total time=   0.2s
[CV 5/5] END ...n_neighbors=19, weights=uniform;, score=0.925 total time=   0.2s
```

```
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
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es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
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es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
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es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
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/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
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es.
  warn(
/Users/wiizh/Library/Python/3.8/lib/python/site-packages/sklearn/ensemble/_forest.py:578: UserWarning: Some i
nputs do not have OOB scores. This probably means too few trees were used to compute any reliable OOB estimat
es.
  warn(
```

In [140…

```
y_pred_test = VC.predict(X_test)
y_pred_train = VC.predict(X_train)
```

```
print(accuracy_score(y_train, y_pred_train))
print(accuracy_score(y_test, y_pred_test))
```

```
0.9294555811151276
0.9277955271565496
```

In [141…

```
resultsVC2 = train_evaluate_model(y_test)
resultsVC2.index = ['Stacking Voting - Method 2']
results = results.append(resultsVC2)
results.style.background_gradient(cmap = sns.color_palette("blend:red,green", as_cmap=True))
```

```
/var/folders/rz/zl6hf1ds4sz4m5vqhxw5klh00000gn/T/ipykernel_73606/1848185463.py:3: FutureWarning: The frame.ap
pend method is deprecated and will be removed from pandas in a future version. Use pandas.concat instead.
  results = results.append(resultsVC2)
```

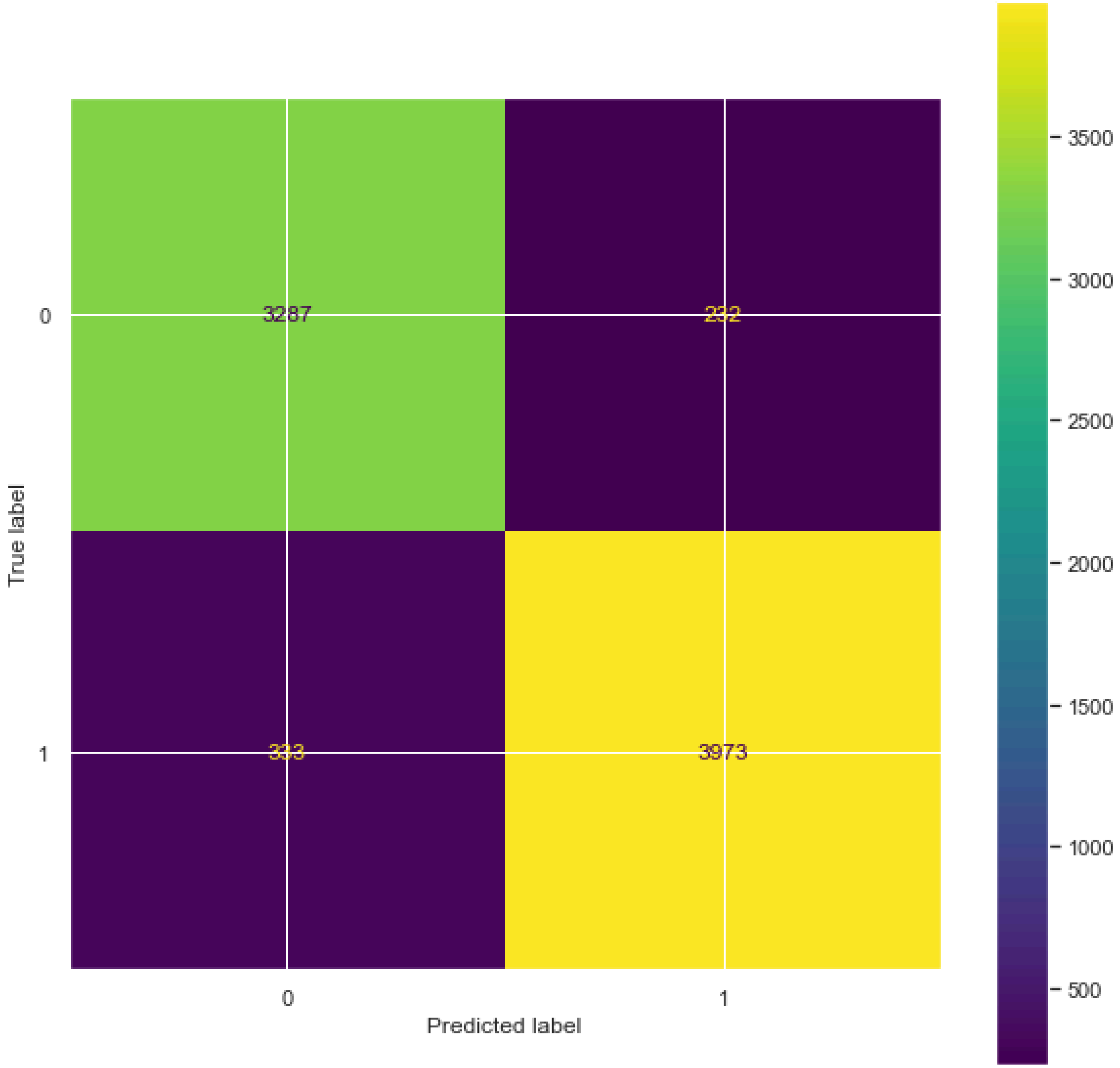
Out[141]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455
Decision Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Random Forest - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Extra Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Gradient Boosting - Method 2	0.928562	0.934643	0.941135	0.928240	0.928598	0.928598
Ada Boost - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Stacking Voting - Method 2	0.927796	0.933615	0.944828	0.922666	0.928369	0.928369

In [142…

```
cm = confusion_matrix(y_test, y_pred_test, labels=VC.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=VC.classes_)

disp.plot()
plt.show()
```



In [143…

```
results.sort_values(results.columns[0], ascending = False)
```

Out[143]:

	accuracy	f1_score	precision	recall	balanced_accuracy	auc
Gradient Boosting - Method 1	0.957249	0.960388	0.976576	0.944727	0.958596	0.958596
Ada Boost - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Stacking Voting - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Decision Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Random Forest - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
Extra Trees - Method 1	0.955158	0.958637	0.970282	0.947268	0.956007	0.956007
K Nearest Neighbors - Method 1	0.953764	0.957542	0.964746	0.950445	0.954121	0.954121
Gradient Boosting - Method 2	0.928562	0.934643	0.941135	0.928240	0.928598	0.928598
Stacking Voting - Method 2	0.927796	0.933615	0.944828	0.922666	0.928369	0.928369
Decision Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Random Forest - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Extra Trees - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
Ada Boost - Method 2	0.926773	0.933719	0.930168	0.937297	0.925596	0.925596
K Nearest Neighbors - Method 2	0.921534	0.928737	0.928306	0.929169	0.920680	0.920680
Support Vector Machine - Method 1	0.872909	0.879886	0.913589	0.848581	0.875526	0.875526
Support Vector Machine - Method 2	0.779681	0.799768	0.799954	0.799582	0.777455	0.777455
Logistic Regression - Method 1	0.769865	0.802394	0.758439	0.851758	0.761056	0.761056
Logistic Regression - Method 2	0.753994	0.799792	0.724242	0.892940	0.738456	0.738456
Naive Bayes - Method 2	0.752332	0.788011	0.744830	0.836507	0.742920	0.742920
Naive Bayes - Method 1	0.728857	0.748762	0.761384	0.736552	0.728029	0.728029

In [ ]: