In [1]:
```python
import warnings
warnings.filterwarnings('ignore')
```

In [2]:
```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

In [3]:
```python
data = pd.read_csv('Personalized_Diet_Recommendations.csv')
data.head()
```

Out[3]:

	Patient_ID	Age	Gender	Height_cm	Weight_kg	BMI	Chronic_Disease	Blood_Pressure_Systolic	Blood_Pressure_Diastolic	Cholesterol_Level	...	Protein_Intake	Carbohydrate_Intake	Fat_Intake	Preferred_Cui
0	P00001	56	Other	163	66	24.84	None	175	75	219	...	105	179	143	Wes
1	P00002	69	Female	171	114	38.99	None	155	72	208	...	69	315	75	Mediterrar
2	P00003	46	Female	172	119	40.22	None	137	101	171	...	183	103	148	Wes
3	P00004	32	Female	197	118	30.41	None	148	91	258	...	135	371	120	Wes
4	P00005	60	Female	156	109	44.79	Hypertension	160	109	260	...	167	298	48	In

5 rows × 30 columns

In [4]:
```python
null_counts = data.isnull().sum()
# Print the number of null values
print(f"{null_counts.sum()} null entries have been found in the dataset\n")
# Drop null values
data.dropna(inplace=True)          # or df_data = df_data.dropna()

# Find and handle duplicates
duplicate_count = data.duplicated().sum()
# Print the number of duplicate entries
print(f"{duplicate_count} duplicate entries have been found in the dataset\n")
# Remove duplicates
data.drop_duplicates(inplace=True)  # or df_data = df_data.drop_duplicates()
# Display relative message
print(f"All duplicates have been removed\n")

# Reset the indexes
data.reset_index(drop=True, inplace=True)

# Inspect the dataset for categorical columns
print("Categorical columns:",data.select_dtypes(include=['object']).columns.tolist(),'\n')

# Print the first 5 lines
data.head()
```

```
0 null entries have been found in the dataset

0 duplicate entries have been found in the dataset

All duplicates have been removed

Categorical columns: ['Patient_ID', 'Gender', 'Chronic_Disease', 'Genetic_Risk_Factor', 'Allergies', 'Alcohol_Consumption', 'Smoking_Habit', 'Dietary_Habits', 'Preferred_Cuisine', 'Food_Aversi
ons', 'Recommended_Meal_Plan']
```

Out[4]:

	Patient_ID	Age	Gender	Height_cm	Weight_kg	BMI	Chronic_Disease	Blood_Pressure_Systolic	Blood_Pressure_Diastolic	Cholesterol_Level	...	Protein_Intake	Carbohydrate_Intake	Fat_Intake	Preferred_Cui
0	P00001	56	Other	163	66	24.84	None	175	75	219	...	105	179	143	Wes
1	P00002	69	Female	171	114	38.99	None	155	72	208	...	69	315	75	Mediterrar
2	P00003	46	Female	172	119	40.22	None	137	101	171	...	183	103	148	Wes
3	P00004	32	Female	197	118	30.41	None	148	91	258	...	135	371	120	Wes
4	P00005	60	Female	156	109	44.79	Hypertension	160	109	260	...	167	298	48	In

5 rows × 30 columns

In [5]:
```python
data.columns
```

Out[5]:
```
Index(['Patient_ID', 'Age', 'Gender', 'Height_cm', 'Weight_kg', 'BMI',
       'Chronic_Disease', 'Blood_Pressure_Systolic',
       'Blood_Pressure_Diastolic', 'Cholesterol_Level', 'Blood_Sugar_Level',
       'Genetic_Risk_Factor', 'Allergies', 'Daily_Steps', 'Exercise_Frequency',
       'Sleep_Hours', 'Alcohol_Consumption', 'Smoking_Habit', 'Dietary_Habits',
       'Caloric_Intake', 'Protein_Intake', 'Carbohydrate_Intake', 'Fat_Intake',
       'Preferred_Cuisine', 'Food_Aversions', 'Recommended_Calories',
       'Recommended_Protein', 'Recommended_Carbs', 'Recommended_Fats',
       'Recommended_Meal_Plan'],
      dtype='object')
```

In [6]:
```python
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5000 entries, 0 to 4999
Data columns (total 30 columns):
 #   Column                   Non-Null Count  Dtype  
---  ------                   --------------  -----  
 0   Patient_ID               5000 non-null   object 
 1   Age                      5000 non-null   int64  
 2   Gender                   5000 non-null   object 
 3   Height_cm                5000 non-null   int64  
 4   Weight_kg                5000 non-null   int64  
 5   BMI                      5000 non-null   float64
 6   Chronic_Disease          5000 non-null   object 
 7   Blood_Pressure_Systolic  5000 non-null   int64  
 8   Blood_Pressure_Diastolic 5000 non-null   int64  
 9   Cholesterol_Level        5000 non-null   int64  
 10  Blood_Sugar_Level        5000 non-null   int64  
 11  Genetic_Risk_Factor      5000 non-null   object 
 12  Allergies                5000 non-null   object 
 13  Daily_Steps              5000 non-null   int64  
 14  Exercise_Frequency       5000 non-null   int64  
 15  Sleep_Hours              5000 non-null   float64
 16  Alcohol_Consumption      5000 non-null   object 
 17  Smoking_Habit            5000 non-null   object 
 18  Dietary_Habits           5000 non-null   object 
 19  Caloric_Intake           5000 non-null   int64  
 20  Protein_Intake           5000 non-null   int64  
 21  Carbohydrate_Intake      5000 non-null   int64  
 22  Fat_Intake               5000 non-null   int64  
 23  Preferred_Cuisine        5000 non-null   object 
 24  Food_Aversions           5000 non-null   object 
 25  Recommended_Calories     5000 non-null   int64  
 26  Recommended_Protein      5000 non-null   int64  
 27  Recommended_Carbs        5000 non-null   int64  
 28  Recommended_Fats         5000 non-null   int64  
 29  Recommended_Meal_Plan    5000 non-null   object 
dtypes: float64(2), int64(17), object(11)
memory usage: 1.1+ MB
```

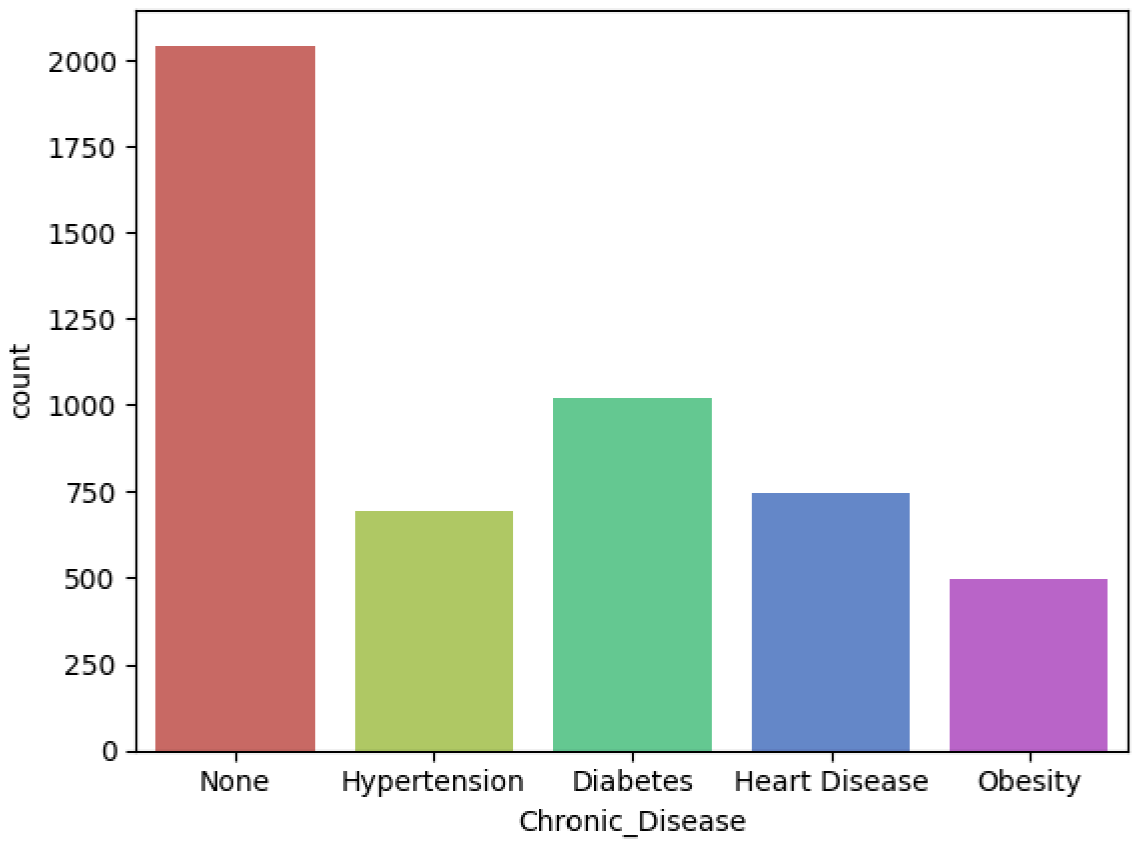
In [7]:
```
columns_to_drop = ['Patient_ID','Preferred_Cuisine', 'Food_Aversions', 'Recommended_Meal_Plan','Recommended_Calories',
       'Recommended_Protein', 'Recommended_Carbs', 'Recommended_Fats']
```

In [8]:
```
data.drop(columns=columns_to_drop, inplace=True)
```

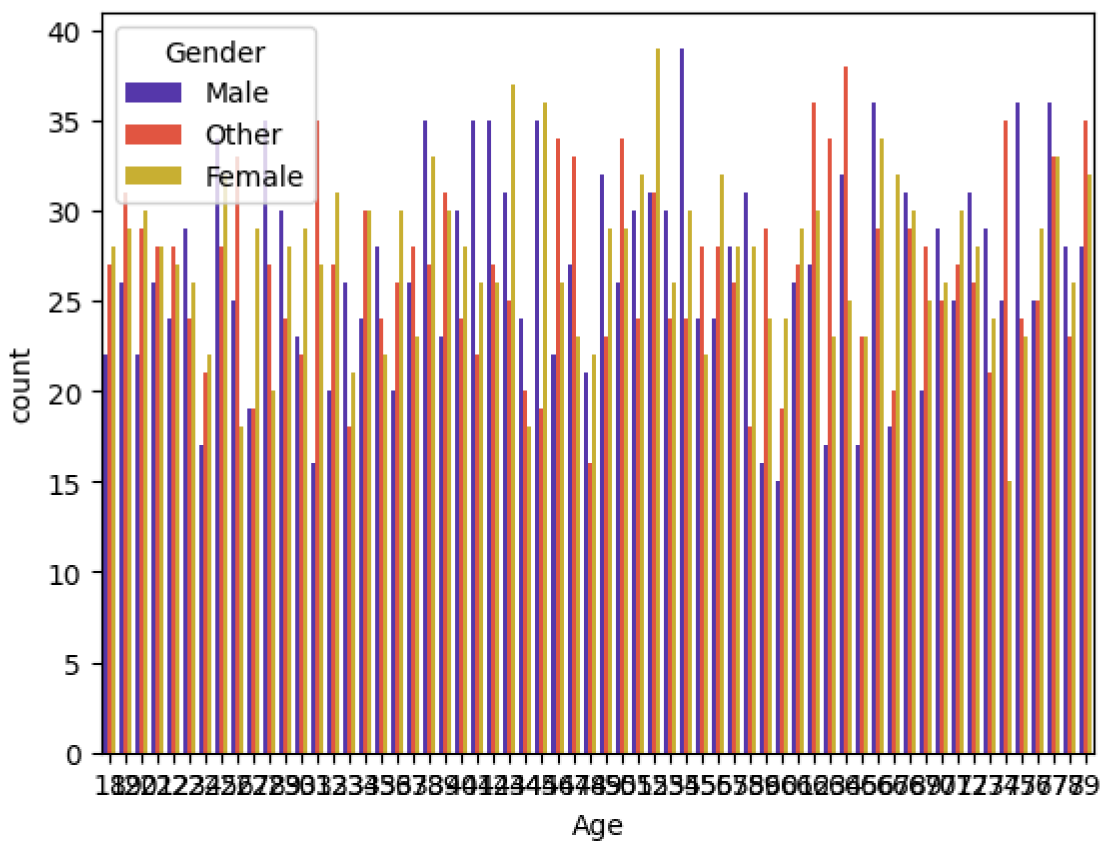
In [9]:
```
data.columns
```

Out[9]:
```
Index(['Age', 'Gender', 'Height_cm', 'Weight_kg', 'BMI', 'Chronic_Disease',
       'Blood_Pressure_Systolic', 'Blood_Pressure_Diastolic',
       'Cholesterol_Level', 'Blood_Sugar_Level', 'Genetic_Risk_Factor',
       'Allergies', 'Daily_Steps', 'Exercise_Frequency', 'Sleep_Hours',
       'Alcohol_Consumption', 'Smoking_Habit', 'Dietary_Habits',
       'Caloric_Intake', 'Protein_Intake', 'Carbohydrate_Intake',
       'Fat_Intake'],
      dtype='object')
```

In [10]:
```
sns.countplot(x='Chronic_Disease',data=data, palette='hls')
plt.show()
```



In [11]:
```
sns.countplot(x='Age',hue='Gender',data=data, palette='CMRmap')
plt.show()
```

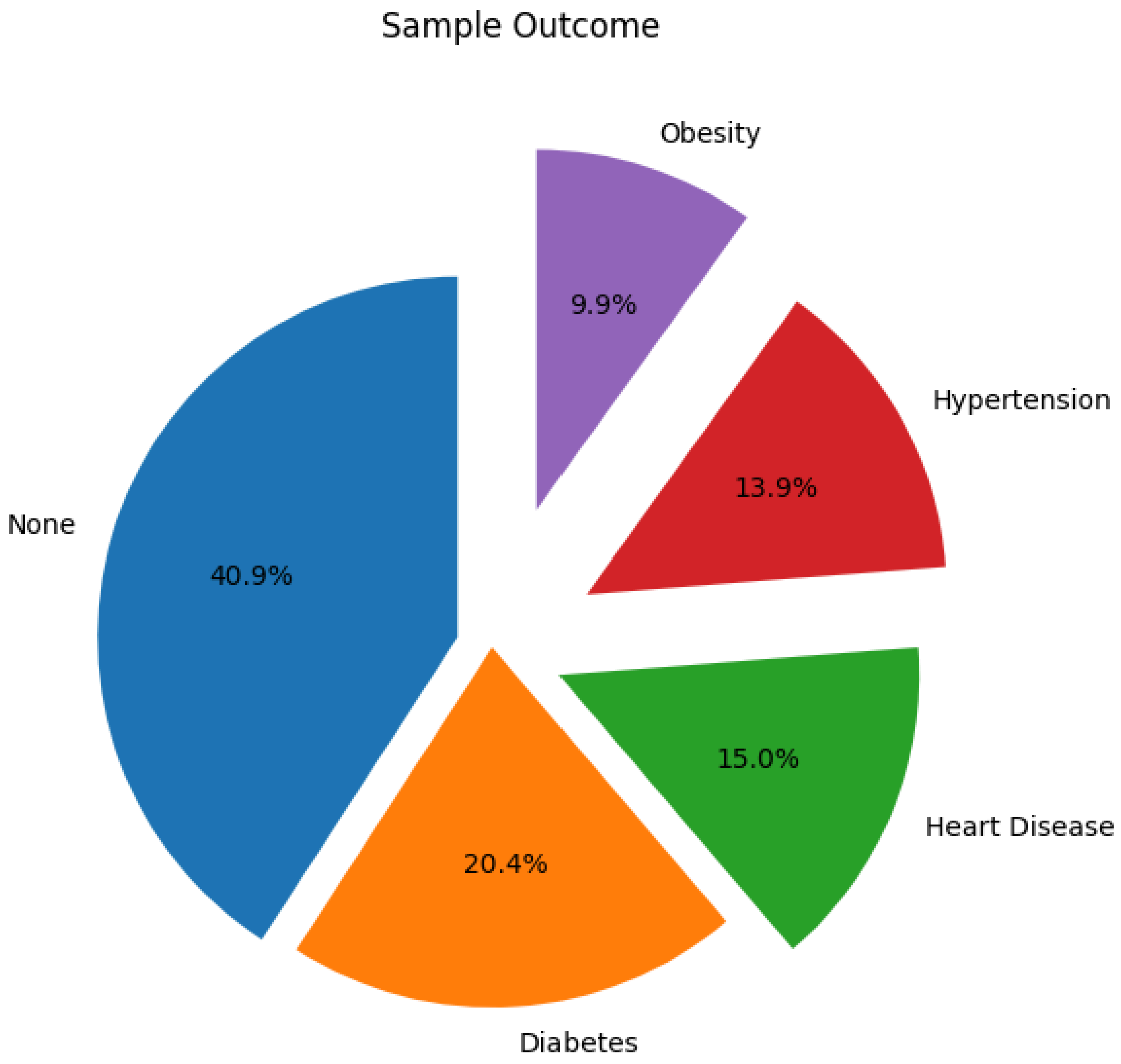


In [12]:
```
data['Chronic_Disease'].value_counts()
```

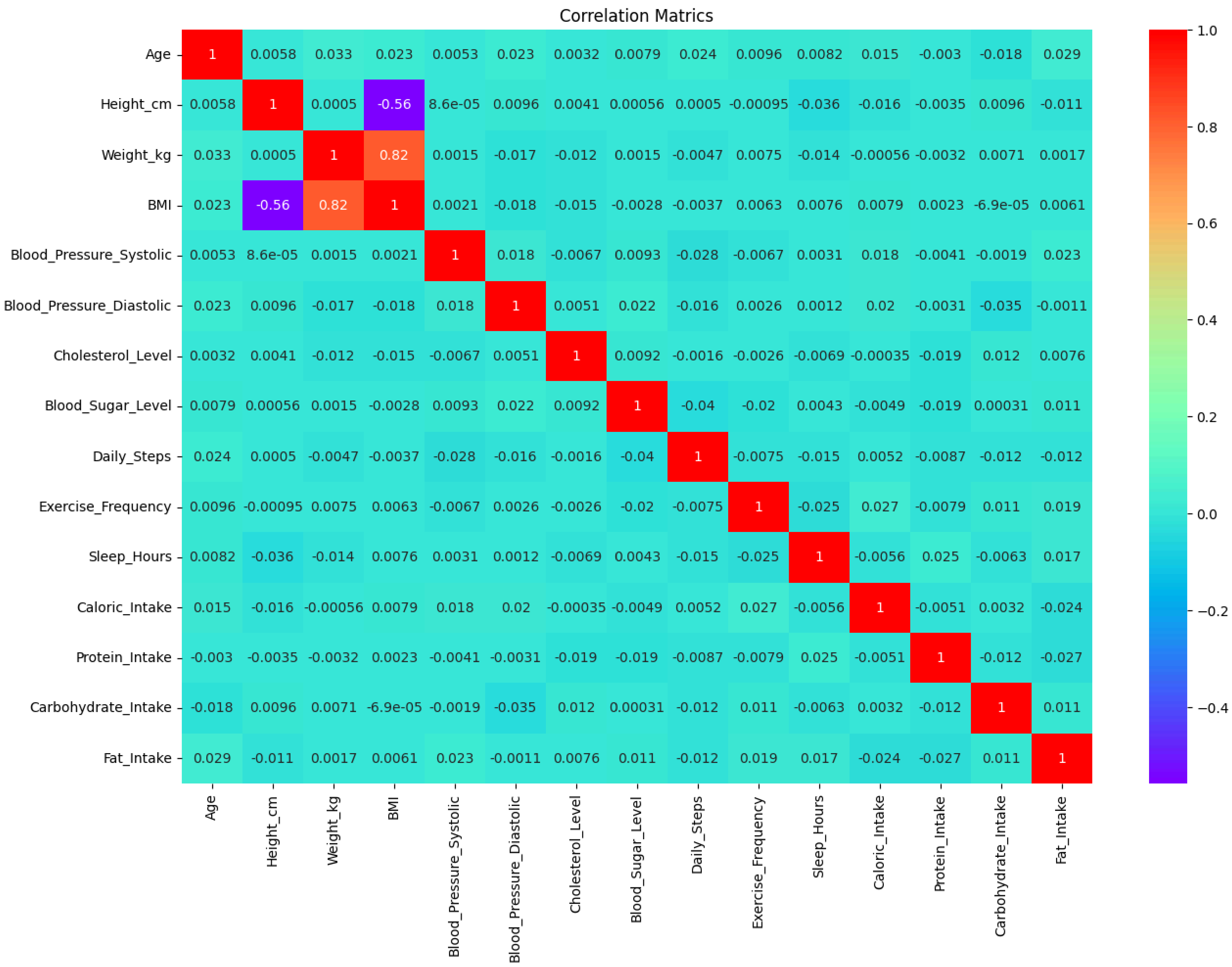
Out[12]:
```
None             2043
Diabetes         1019
Heart Disease     749
Hypertension      693
Obesity           496
Name: Chronic_Disease, dtype: int64
```

In [13]:
```
target = data['Chronic_Disease'].value_counts()
labels = ['None','Diabetes','Heart Disease','Hypertension','Obesity']
sizes = [target[0], target[1],target[2], target[3],target[4]]
```

```python
# Create pie chart
plt.figure(figsize=(6, 6))
plt.pie(sizes, labels=labels,  autopct='%1.1f%%',
        startangle=90,  explode =[0.1, 0, 0.2,0.3,0.4])
plt.title('Sample Outcome')
plt.axis('equal')
plt.tight_layout()
plt.show()
```



In [14]:
```python
plt.figure(figsize = (15,10))
sns.heatmap(data.corr(), annot = True, cmap="rainbow")
plt.title('Correlation Matrics')
plt.show()
```



	Age	Height_cm	Weight_kg	BMI	Blood_Pressure_Systolic	Blood_Pressure_Diastolic	Cholesterol_Level	Blood_Sugar_Level	Daily_Steps	Exercise_Frequency	Sleep_Hours	Caloric_Intake	Protein_Intake	Carbohydrate_Intake	Fat_Intake
Age	1	0.0058	0.033	0.023	0.0053	0.023	0.0032	0.0079	0.024	0.0096	0.0082	0.015	-0.003	-0.018	0.029
Height_cm	0.0058	1	0.0005	-0.56	8.6e-05	0.0096	0.0041	0.00056	0.0005	-0.00095	-0.036	-0.016	-0.0035	0.0096	-0.011
Weight_kg	0.033	0.0005	1	0.82	0.0015	-0.017	-0.012	0.0015	-0.0047	0.0075	-0.014	-0.00056	-0.0032	0.0071	0.0017
BMI	0.023	-0.56	0.82	1	0.0021	-0.018	-0.015	-0.0028	-0.0037	0.0063	0.0076	0.0079	0.0023	-6.9e-05	0.0061
Blood_Pressure_Systolic	0.0053	8.6e-05	0.0015	0.0021	1	0.018	-0.0067	0.0093	-0.028	-0.0067	0.0031	0.018	-0.0041	-0.0019	0.023
Blood_Pressure_Diastolic	0.023	0.0096	-0.017	-0.018	0.018	1	0.0051	0.022	-0.016	0.0026	0.0012	0.02	-0.0031	-0.035	-0.0011
Cholesterol_Level	0.0032	0.0041	-0.012	-0.015	-0.0067	0.0051	1	0.0092	-0.0016	-0.0026	-0.0069	-0.00035	-0.019	0.012	0.0076
Blood_Sugar_Level	0.0079	0.00056	0.0015	-0.0028	0.0093	0.022	0.0092	1	-0.04	-0.02	0.0043	-0.0049	-0.019	0.00031	0.011
Daily_Steps	0.024	0.0005	-0.0047	-0.0037	-0.028	-0.016	-0.0016	-0.04	1	-0.0075	-0.015	0.0052	-0.0087	-0.012	-0.012
Exercise_Frequency	0.0096	-0.00095	0.0075	0.0063	-0.0067	0.0026	-0.0026	-0.02	-0.0075	1	-0.025	0.027	-0.0079	0.011	0.019
Sleep_Hours	0.0082	-0.036	-0.014	0.0076	0.0031	0.0012	-0.0069	0.0043	-0.015	-0.025	1	-0.0056	0.025	-0.0063	0.017
Caloric_Intake	0.015	-0.016	-0.00056	0.0079	0.018	0.02	-0.00035	-0.0049	0.0052	0.027	-0.0056	1	-0.0051	0.0032	-0.024
Protein_Intake	-0.003	-0.0035	-0.0032	0.0023	-0.0041	-0.0031	-0.019	-0.019	-0.0087	-0.0079	0.025	-0.0051	1	-0.012	-0.027
Carbohydrate_Intake	-0.018	0.0096	0.0071	-6.9e-05	-0.0019	-0.035	0.012	0.00031	-0.012	0.011	-0.0063	0.0032	-0.012	1	0.011
Fat_Intake	0.029	-0.011	0.0017	0.0061	0.023	-0.0011	0.0076	0.011	-0.012	0.019	0.017	-0.024	-0.027	0.011	1

In [15]:
```python
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5000 entries, 0 to 4999
Data columns (total 22 columns):
 #   Column                   Non-Null Count  Dtype  
---  ------                   --------------  -----  
 0   Age                      5000 non-null   int64  
 1   Gender                   5000 non-null   object 
 2   Height_cm                5000 non-null   int64  
 3   Weight_kg                5000 non-null   int64  
 4   BMI                      5000 non-null   float64
 5   Chronic_Disease          5000 non-null   object 
 6   Blood_Pressure_Systolic  5000 non-null   int64  
 7   Blood_Pressure_Diastolic 5000 non-null   int64  
 8   Cholesterol_Level        5000 non-null   int64  
 9   Blood_Sugar_Level        5000 non-null   int64  
 10  Genetic_Risk_Factor      5000 non-null   object 
 11  Allergies                5000 non-null   object 
 12  Daily_Steps              5000 non-null   int64  
 13  Exercise_Frequency       5000 non-null   int64  
 14  Sleep_Hours              5000 non-null   float64
 15  Alcohol_Consumption      5000 non-null   object 
 16  Smoking_Habit            5000 non-null   object 
 17  Dietary_Habits           5000 non-null   object 
 18  Caloric_Intake           5000 non-null   int64  
 19  Protein_Intake           5000 non-null   int64  
 20  Carbohydrate_Intake      5000 non-null   int64  
 21  Fat_Intake               5000 non-null   int64  
dtypes: float64(2), int64(13), object(7)
memory usage: 859.5+ KB
```

In [16]:
```
data.columns
```

Out[16]:
```
Index(['Age', 'Gender', 'Height_cm', 'Weight_kg', 'BMI', 'Chronic_Disease',
       'Blood_Pressure_Systolic', 'Blood_Pressure_Diastolic',
       'Cholesterol_Level', 'Blood_Sugar_Level', 'Genetic_Risk_Factor',
       'Allergies', 'Daily_Steps', 'Exercise_Frequency', 'Sleep_Hours',
       'Alcohol_Consumption', 'Smoking_Habit', 'Dietary_Habits',
       'Caloric_Intake', 'Protein_Intake', 'Carbohydrate_Intake',
       'Fat_Intake'],
      dtype='object')
```

In [17]:
```
data = data[['Age', 'Gender', 'Height_cm', 'Weight_kg', 'BMI',
       'Blood_Pressure_Systolic', 'Blood_Pressure_Diastolic',
       'Cholesterol_Level', 'Blood_Sugar_Level', 'Genetic_Risk_Factor',
       'Allergies', 'Daily_Steps', 'Exercise_Frequency', 'Sleep_Hours',
       'Alcohol_Consumption', 'Smoking_Habit', 'Dietary_Habits',
       'Caloric_Intake', 'Protein_Intake', 'Carbohydrate_Intake',
       'Fat_Intake','Chronic_Disease']]
```

In [18]:
```
data.to_csv('processed.csv')
```

In [19]:
```
print("Categorical columns:",data.select_dtypes(include=['object']).columns.tolist(),'\n')
```

```
Categorical columns: ['Gender', 'Genetic_Risk_Factor', 'Allergies', 'Alcohol_Consumption', 'Smoking_Habit', 'Dietary_Habits', 'Chronic_Disease']
```

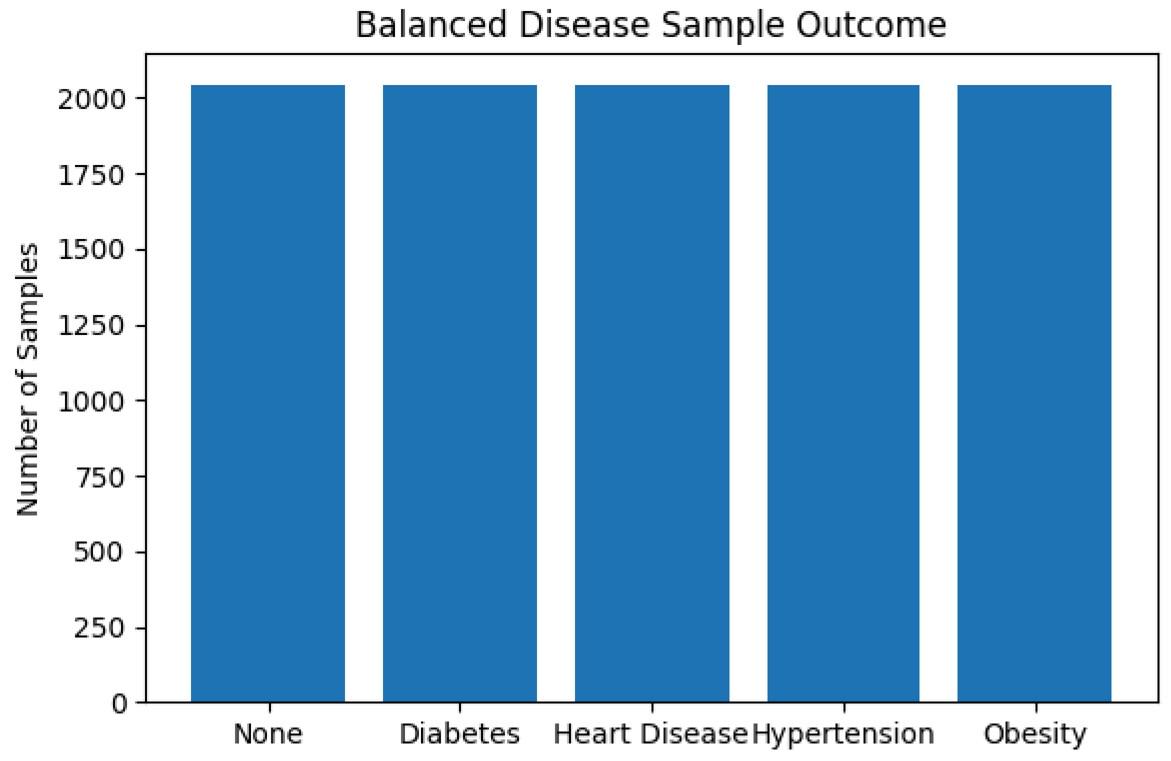
In [20]:
```
# Import label encoder
from sklearn import preprocessing

# label_encoder object knows
# how to understand word labels.
label_encoder = preprocessing.LabelEncoder()

# Encode labels in column 'species'.
data['Gender']= label_encoder.fit_transform(data['Gender'])
data['Genetic_Risk_Factor']= label_encoder.fit_transform(data['Genetic_Risk_Factor'])
data['Allergies']= label_encoder.fit_transform(data['Allergies'])
data['Alcohol_Consumption']= label_encoder.fit_transform(data['Alcohol_Consumption'])
data['Smoking_Habit']= label_encoder.fit_transform(data['Smoking_Habit'])
data['Dietary_Habits']= label_encoder.fit_transform(data['Dietary_Habits'])
data['Chronic_Disease']= label_encoder.fit_transform(data['Chronic_Disease'])
```

In [21]:
```
ML_Model = []
accuracy = []
precision = []
recall = []
f1score = []

def storeResults(model, a, b, c, d):
    ML_Model.append(model)
    accuracy.append(round(a, 3))
    precision.append(round(b, 3))
    recall.append(round(c, 3))
    f1score.append(round(d, 3))
```

In [22]:
```
X = data.drop(["Chronic_Disease"],axis =1)
y = data["Chronic_Disease"]
```

In [23]:
```
from imblearn.over_sampling import RandomOverSampler

sm = RandomOverSampler(random_state=42)
X_res, y_res = sm.fit_resample(X, y)
```

In [24]:
```
target = y_res.value_counts()
labels = ['None','Diabetes','Heart Disease','Hypertension','Obesity']
sizes = [target[0], target[1], target[2], target[3], target[4]]

# Create bar chart
plt.figure(figsize=(6, 4))
plt.bar(labels, sizes)
plt.title('Balanced Disease Sample Outcome')
plt.ylabel('Number of Samples')
plt.tight_layout()
plt.show()
```



In [25]:
```
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()
X_scaled = scaler.fit_transform(X_res)
```

In [26]:
```
import os, joblib

os.makedirs('Models', exist_ok=True)
joblib.dump(scaler, 'Models/scaler.sav')
```

Out[26]:
```
['Models/scaler.sav']
```

In [27]:
```
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, confusion_matrix, ConfusionMatrixDisplay,classification_report


X_train, X_test, y_train, y_test = train_test_split(X_scaled, y_res, test_size=0.3)
```

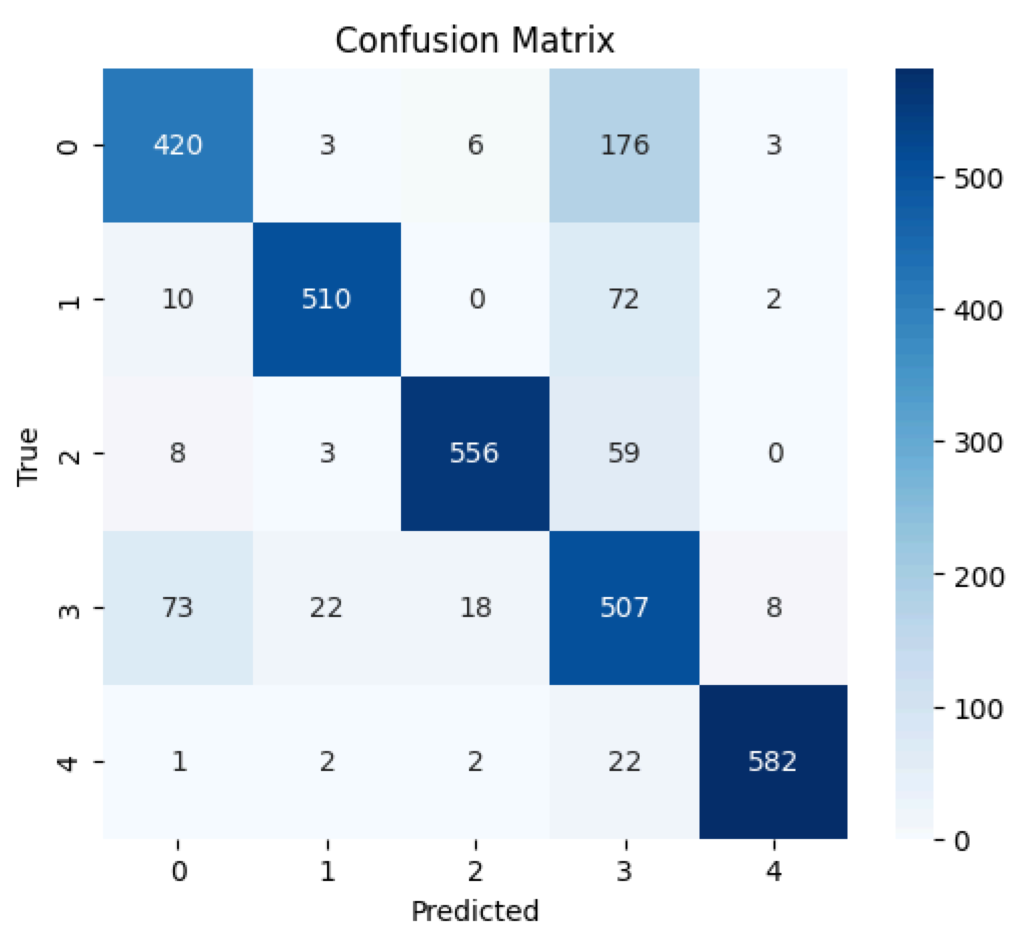
Random Forest

In [29]:
```
from sklearn.ensemble import RandomForestClassifier

rf = RandomForestClassifier(
    n_estimators=500,
    max_depth=100,
    n_jobs=-1,
    random_state=42
)
rf.fit(X_train, y_train)

y_pred = rf.predict(X_test)

rf_acc = accuracy_score(y_pred, y_test)
rf_prec = precision_score(y_pred, y_test,average='weighted')
rf_rec = recall_score(y_pred, y_test,average='weighted')
rf_f1 = f1_score(y_pred, y_test,average='macro')
```

In [30]:
```
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.82      0.69      0.75       608
           1       0.94      0.86      0.90       594
           2       0.96      0.89      0.92       626
           3       0.61      0.81      0.69       628
           4       0.98      0.96      0.97       609

    accuracy                           0.84      3065
   macro avg       0.86      0.84      0.85      3065
weighted avg       0.86      0.84      0.85      3065
```

In [31]:
```
cm = confusion_matrix(y_test, y_pred)

# Plot Confusion Matrix
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```



In [32]:
```
storeResults('Random Forest',rf_acc,rf_prec,rf_rec,rf_f1)
```

Decision Tree

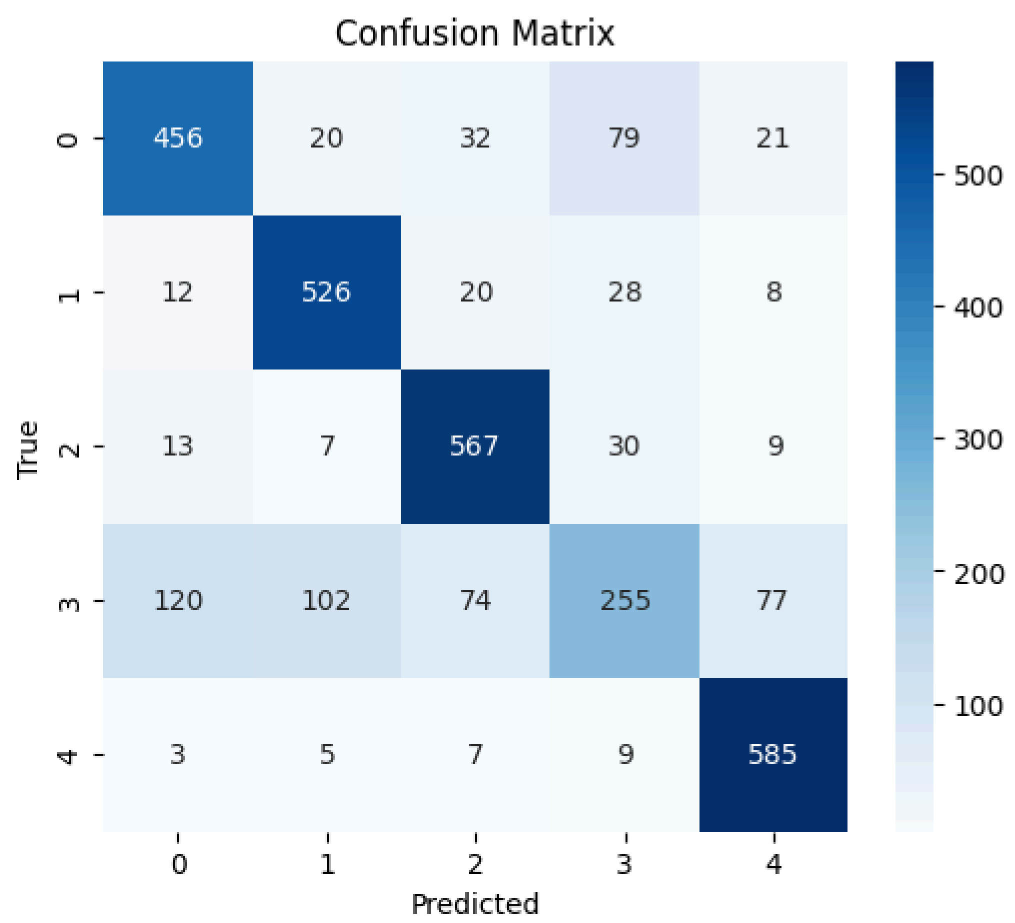
In [33]:
```
from sklearn.tree import DecisionTreeClassifier
dt = DecisionTreeClassifier(
```

```
    max_depth=1000,
    random_state=42
)


dt.fit(X_train, y_train)

y_pred = dt.predict(X_test)

dt_acc = accuracy_score(y_pred, y_test)
dt_prec = precision_score(y_pred, y_test,average='weighted')
dt_rec = recall_score(y_pred, y_test,average='weighted')
dt_f1 = f1_score(y_pred, y_test,average='macro')
```

In [34]:
```
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.75      0.75      0.75       608
           1       0.80      0.89      0.84       594
           2       0.81      0.91      0.86       626
           3       0.64      0.41      0.50       628
           4       0.84      0.96      0.89       609

    accuracy                           0.78      3065
   macro avg       0.77      0.78      0.77      3065
weighted avg       0.77      0.78      0.77      3065
```

In [35]:
```
cm = confusion_matrix(y_test, y_pred)

# Plot Confusion Matrix
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```



In [36]:
```
storeResults('DecisionTree',dt_acc,dt_prec,dt_rec,dt_f1)
```

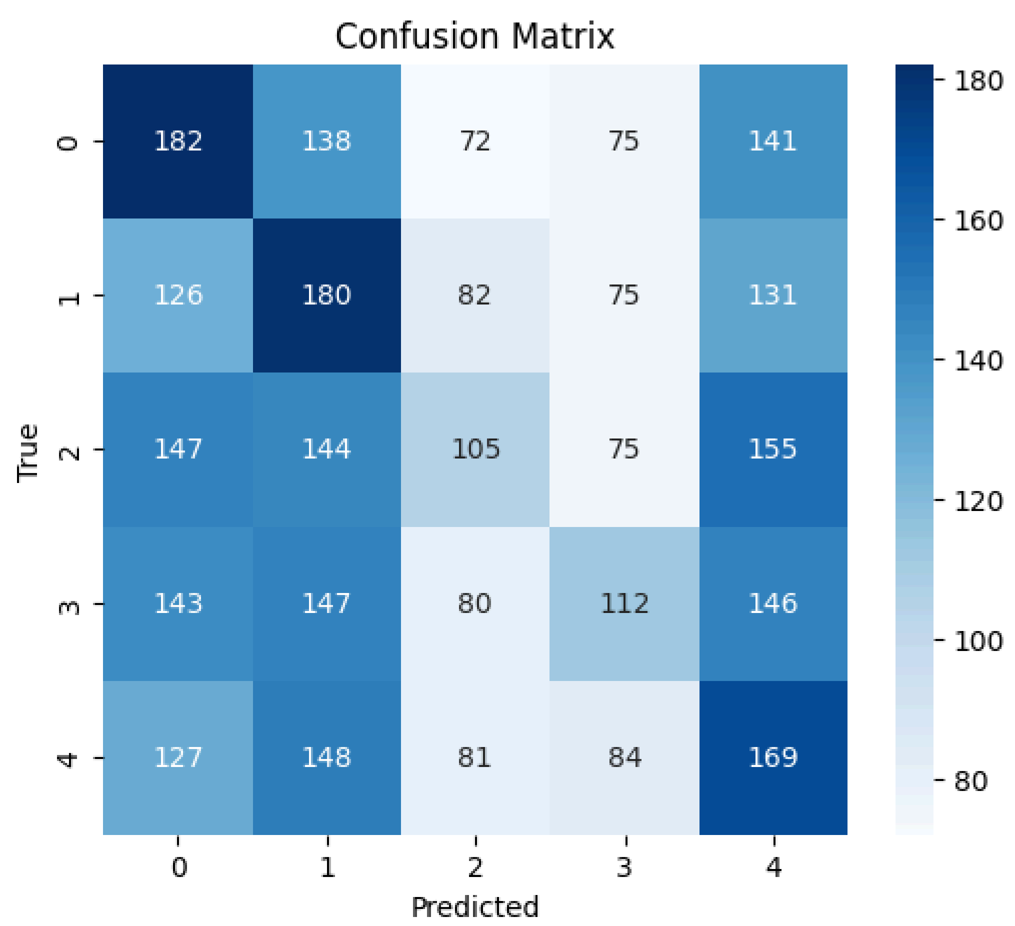
Logistic Regression

In [37]:
```
from sklearn.linear_model import LogisticRegression
lr = LogisticRegression(max_iter=100, C=0.1, random_state=42)

lr.fit(X_train, y_train)
```

Out[37]:
```
LogisticRegression(C=0.1, random_state=42)
```

In [38]:
```
y_pred    = lr.predict(X_test)

lr_acc = accuracy_score(y_pred, y_test)
lr_prec = precision_score(y_pred, y_test,average='weighted')
lr_rec = recall_score(y_pred, y_test,average='weighted')
lr_f1 = f1_score(y_pred, y_test,average='weighted')
```

In [39]:
```
cm = confusion_matrix(y_test, y_pred)

# Plot Confusion Matrix
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```



In [40]:
```
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.25      0.30      0.27       608
           1       0.24      0.30      0.27       594
           2       0.25      0.17      0.20       626
           3       0.27      0.18      0.21       628
           4       0.23      0.28      0.25       609

    accuracy                           0.24      3065
   macro avg       0.25      0.25      0.24      3065
weighted avg       0.25      0.24      0.24      3065
```

In [41]:
```
storeResults('Logistic Regression',lr_acc,lr_prec,lr_rec,lr_f1)
```

SVM

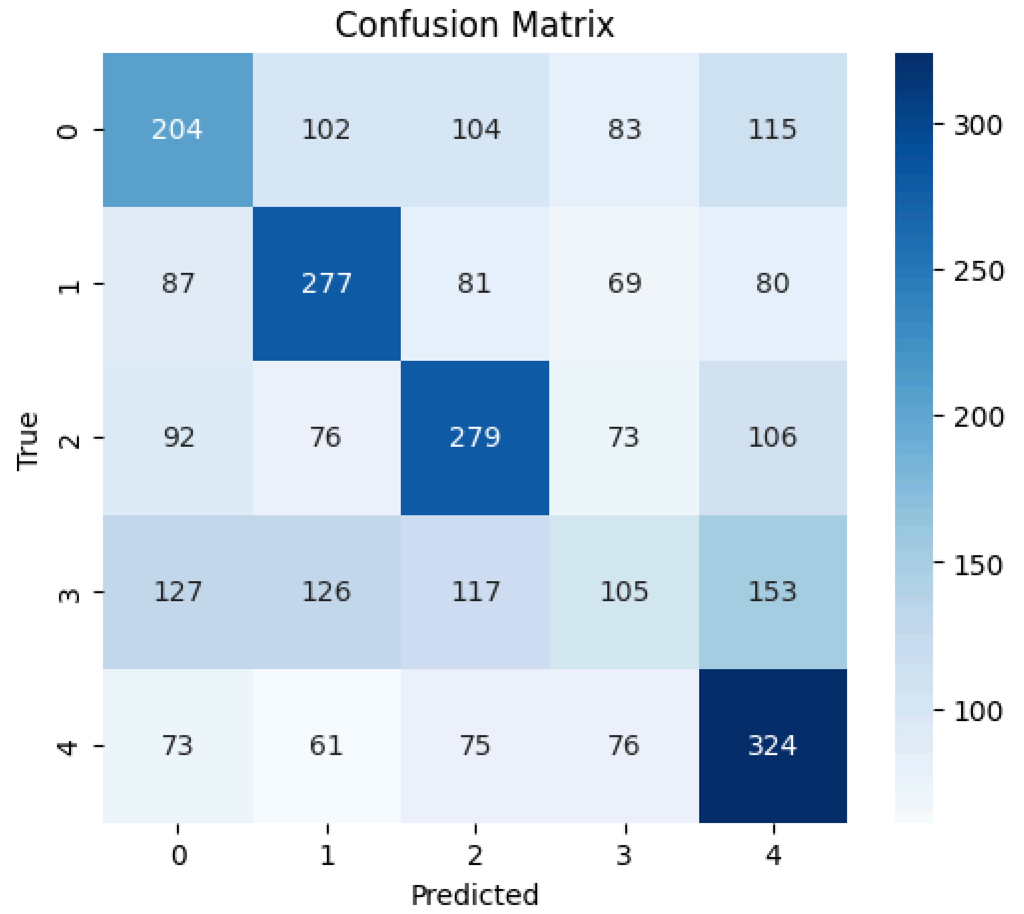
In [42]:
```
from sklearn.kernel_approximation import RBFSampler
from sklearn.svm import LinearSVC
from sklearn.pipeline import make_pipeline

svm = make_pipeline(
    RBFSampler(gamma=0.1, n_components=500),
    LinearSVC(max_iter=100)
)
```

In [43]:
```
svm.fit(X_train, y_train)
```

Out[43]:
```
Pipeline(steps=[('rbfsampler', RBFSampler(gamma=0.1, n_components=500)),
                ('linearsvc', LinearSVC(max_iter=100))])
```

In [44]:
```
y_pred    = svm.predict(X_test)

svm_acc = accuracy_score(y_pred, y_test)
svm_prec = precision_score(y_pred, y_test,average='weighted')
svm_rec = recall_score(y_pred, y_test,average='weighted')
svm_f1 = f1_score(y_pred, y_test,average='weighted')
```

In [45]:
```
cm = confusion_matrix(y_test, y_pred)

# Plot Confusion Matrix
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```



In [46]:
```
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.35      0.34      0.34       608
           1       0.43      0.47      0.45       594
           2       0.43      0.45      0.44       626
           3       0.26      0.17      0.20       628
           4       0.42      0.53      0.47       609

    accuracy                           0.39      3065
   macro avg       0.38      0.39      0.38      3065
weighted avg       0.38      0.39      0.38      3065
```

In [47]:
```
storeResults('SVM',svm_acc,svm_prec,svm_rec,svm_f1)
```

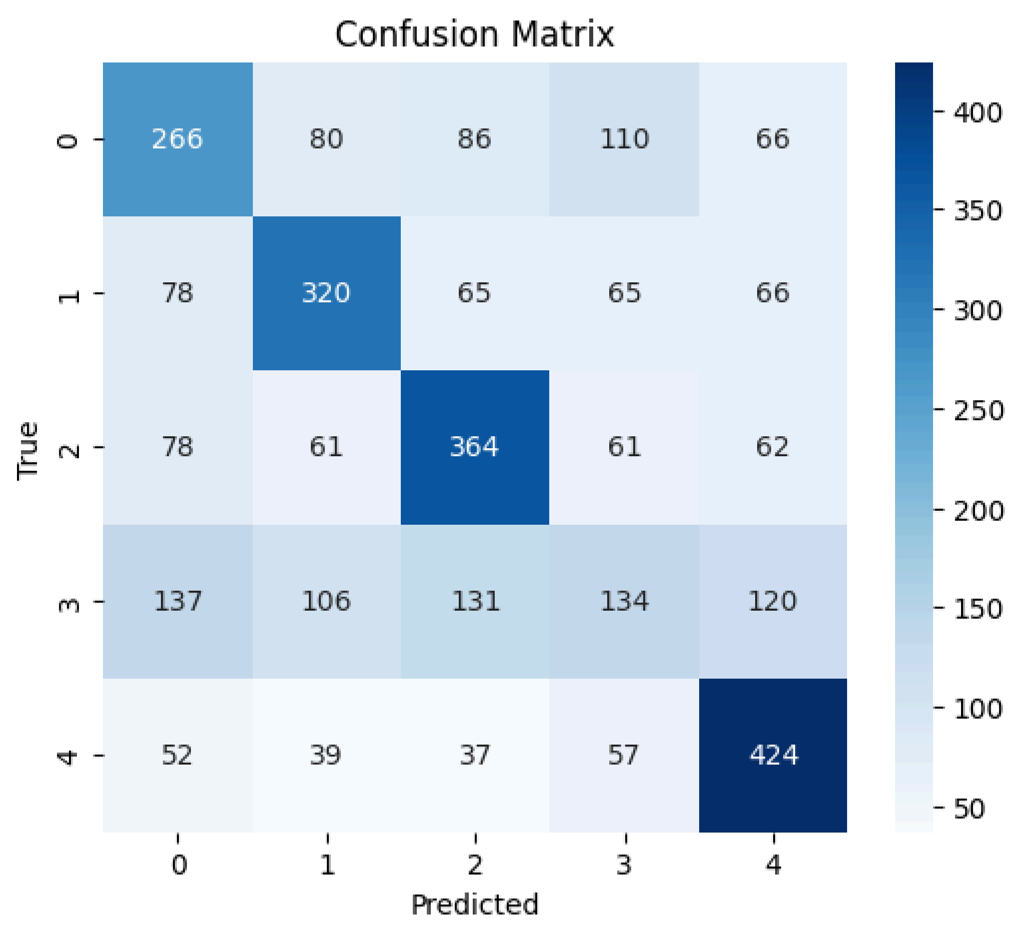
MLP

In [48]:
```
from sklearn.neural_network import MLPClassifier

mlp = MLPClassifier(random_state=1, max_iter=300)
mlp.fit(X_train, y_train)
```

Out[48]:
```
MLPClassifier(max_iter=300, random_state=1)
```

In [49]:
```
y_pred    = mlp.predict(X_test)

mlp_acc = accuracy_score(y_pred, y_test)
mlp_prec = precision_score(y_pred, y_test,average='weighted')
mlp_rec = recall_score(y_pred, y_test,average='weighted')
mlp_f1 = f1_score(y_pred, y_test,average='weighted')
```

In [50]:
```
cm = confusion_matrix(y_test, y_pred)

# Plot Confusion Matrix
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```



In [51]:
```
print(classification_report(y_test, y_pred))
```

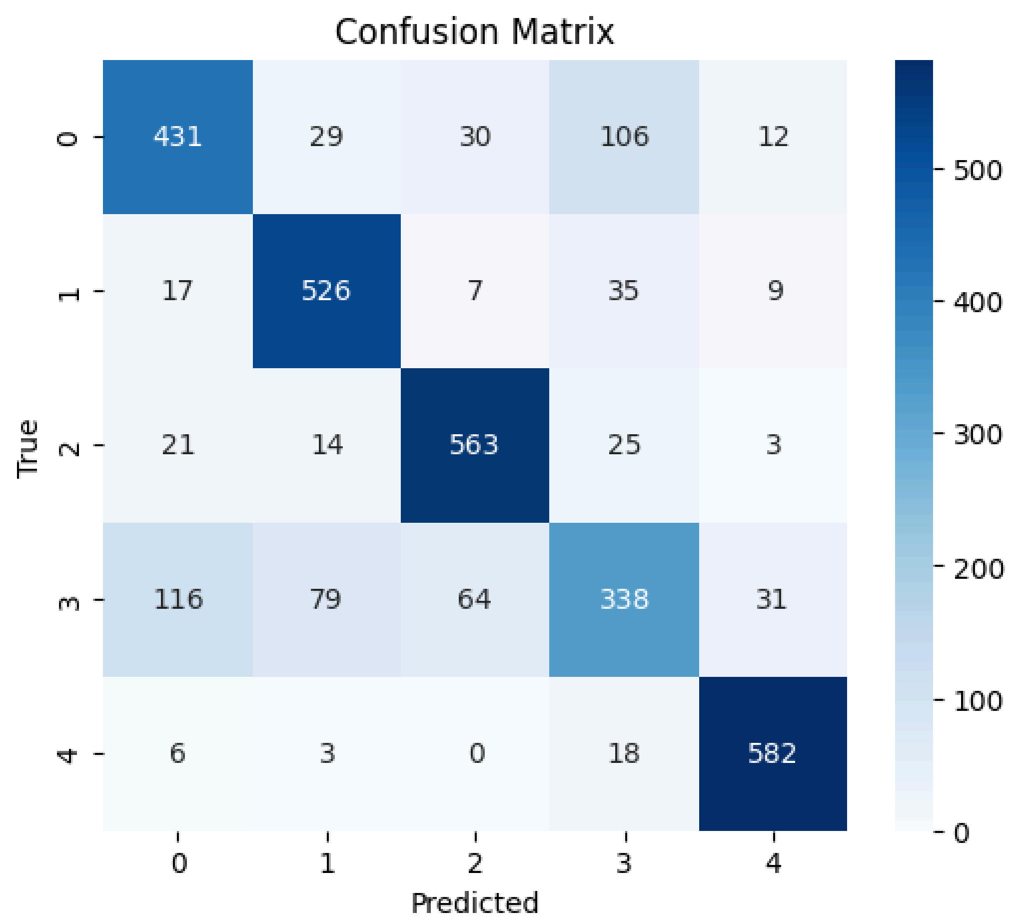
```
              precision    recall  f1-score   support

           0       0.44      0.44      0.44       608
           1       0.53      0.54      0.53       594
           2       0.53      0.58      0.56       626
           3       0.31      0.21      0.25       628
           4       0.57      0.70      0.63       609

    accuracy                           0.49      3065
   macro avg       0.48      0.49      0.48      3065
weighted avg       0.48      0.49      0.48      3065
```

In [52]:
```
storeResults('MLP',mlp_acc,mlp_prec,mlp_rec,mlp_f1)
```

XGBoost

In [53]:
```
from xgboost import XGBClassifier

xgb = XGBClassifier(use_label_encoder=False, eval_metric='mlogloss')
xgb.fit(X_train, y_train)

y_pred = xgb.predict(X_test)

xgb_acc = accuracy_score(y_pred, y_test)
xgb_prec = precision_score(y_pred, y_test,average='weighted')
xgb_rec = recall_score(y_pred, y_test,average='weighted')
xgb_f1 = f1_score(y_pred, y_test,average='weighted')
```

In [54]:
```
cm = confusion_matrix(y_test, y_pred)

# Plot Confusion Matrix
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```



In [55]:
```
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.73      0.71      0.72       608
           1       0.81      0.89      0.84       594
           2       0.85      0.90      0.87       626
           3       0.65      0.54      0.59       628
           4       0.91      0.96      0.93       609

    accuracy                           0.80      3065
   macro avg       0.79      0.80      0.79      3065
weighted avg       0.79      0.80      0.79      3065
```

In [56]:
```
storeResults('XGBoost',xgb_acc,xgb_prec,xgb_rec,xgb_f1)
```

Ensemble

In [57]:
```
from sklearn.model_selection import GridSearchCV
from sklearn.ensemble import AdaBoostClassifier, VotingClassifier, BaggingClassifier
```

In [58]:
```
rf = RandomForestClassifier(random_state=42, n_jobs=-1)

param_grid_rf = {
    "n_estimators": [100, 200, 300],
    "max_depth": [None, 10, 20],
    "min_samples_split": [2, 5, 10],
    "min_samples_leaf": [1, 2, 4],
    "max_features": ["sqrt", "log2"]
}

grid_rf = GridSearchCV(rf, param_grid_rf, cv=3, scoring="accuracy", n_jobs=-1, verbose=2)
grid_rf.fit(X_train, y_train)
print("Best RF params:", grid_rf.best_params_)
print("Best RF score:", grid_rf.best_score_)
```

```
Fitting 3 folds for each of 162 candidates, totalling 486 fits
Best RF params: {'max_depth': None, 'max_features': 'sqrt', 'min_samples_leaf': 1, 'min_samples_split': 5, 'n_estimators': 300}
Best RF score: 0.7050340733814556
```

In [59]:
```
best_rf = grid_rf.best_estimator_
```

In [60]:
```
brf = BaggingClassifier(
    base_estimator=best_rf,
    random_state=42,
    n_jobs=-1
)
```

In [61]:
```
ext = VotingClassifier(
    estimators=[('RF', best_rf), ('BagRF', brf)],
    voting='soft'
)
```

In [62]:
```
ext.fit(X_train, y_train)
```

Out[62]:
```
VotingClassifier(estimators=[('RF',
                              RandomForestClassifier(max_features='sqrt',
                                                     min_samples_split=5,
                                                     n_estimators=300,
                                                     n_jobs=-1,
                                                     random_state=42)),
                             ('BagRF',
                              BaggingClassifier(base_estimator=RandomForestClassifier(max_features='sqrt',
                                                                                      min_samples_split=5,
                                                                                      n_estimators=300,
                                                                                      n_jobs=-1,
                                                                                      random_state=42),
                                                n_jobs=-1, random_state=42))],
                 voting='soft')
```

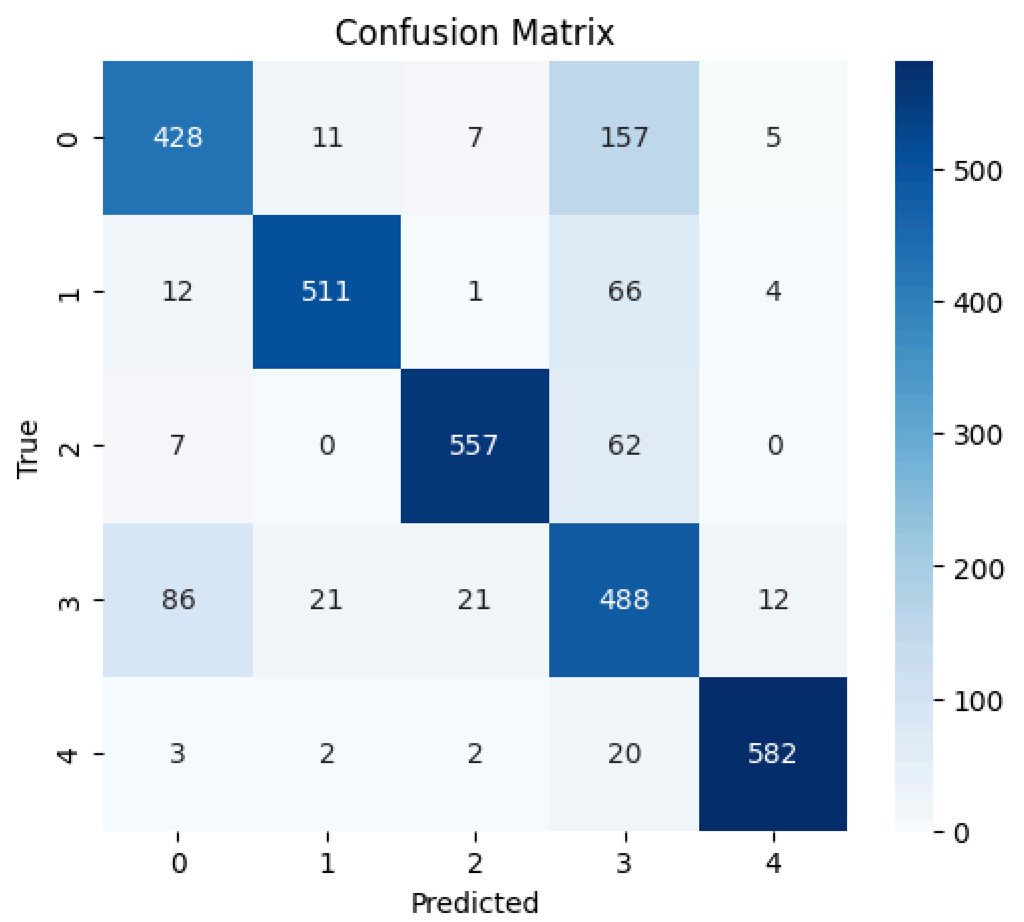
In [63]:
```
y_pred = ext.predict(X_test)
```

In [64]:
```
ext_acc = accuracy_score(y_pred, y_test)
ext_prec = precision_score(y_pred, y_test,average='weighted')
ext_rec = recall_score(y_pred, y_test,average='weighted')
ext_f1 = f1_score(y_pred, y_test,average='macro')
```

In [65]:
```
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.80      0.70      0.75       608
           1       0.94      0.86      0.90       594
           2       0.95      0.89      0.92       626
           3       0.62      0.78      0.69       628
           4       0.97      0.96      0.96       609

    accuracy                           0.84      3065
   macro avg       0.85      0.84      0.84      3065
weighted avg       0.85      0.84      0.84      3065
```

In [66]:
```
cm = confusion_matrix(y_test, y_pred)

# Plot Confusion Matrix
plt.figure(figsize=(6, 5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```



In [67]:
```
storeResults('Ensemble Model',ext_acc,ext_prec,ext_rec,ext_f1)
```

Comparison

In [68]:
```
result = pd.DataFrame({ 'ML Model' : ML_Model,
                        'Accuracy' : accuracy,
                        'Macro F1 score' : f1score,
                        'Recall'   : recall,
                        'Precision': precision,

                      })
```

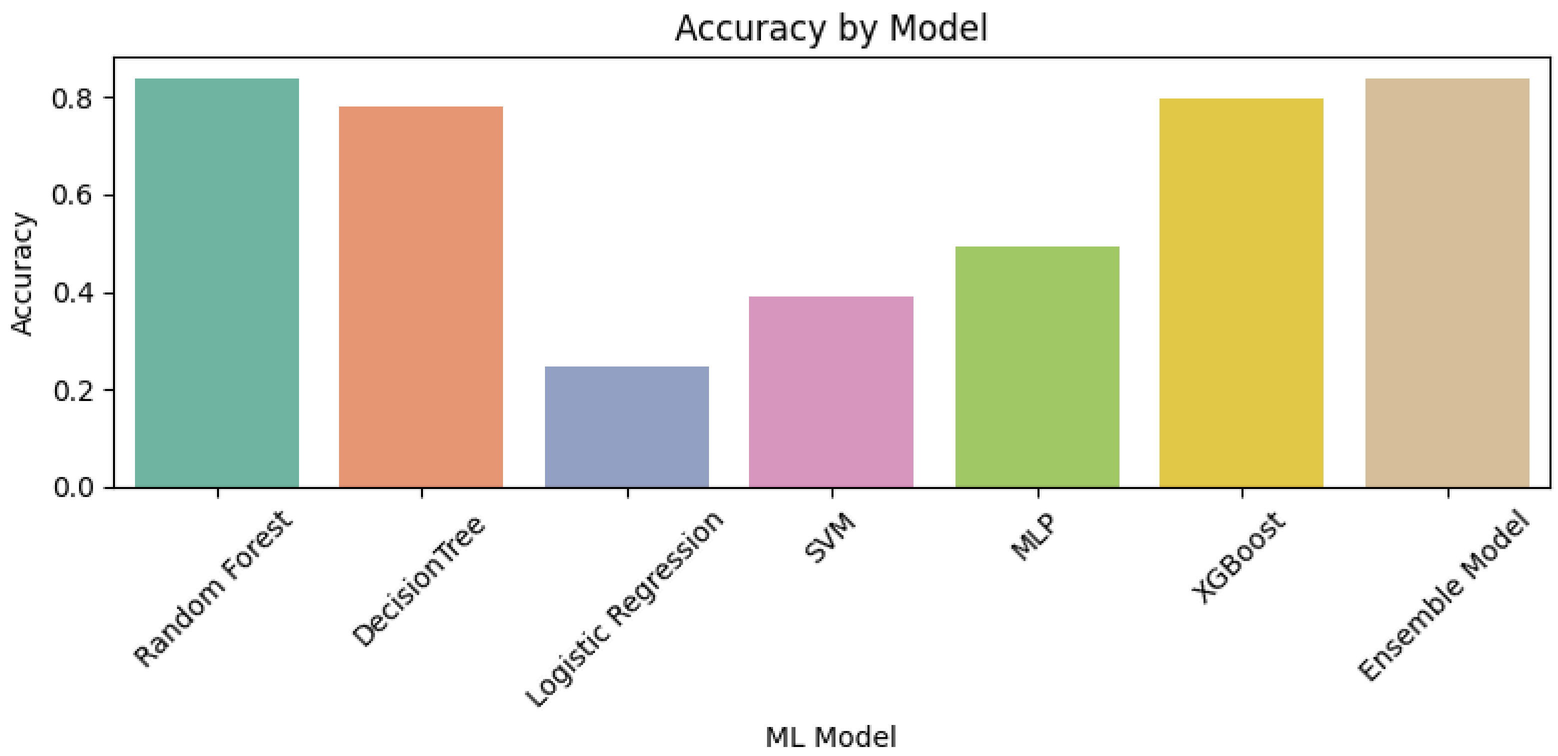
In [69]:
```
result
```

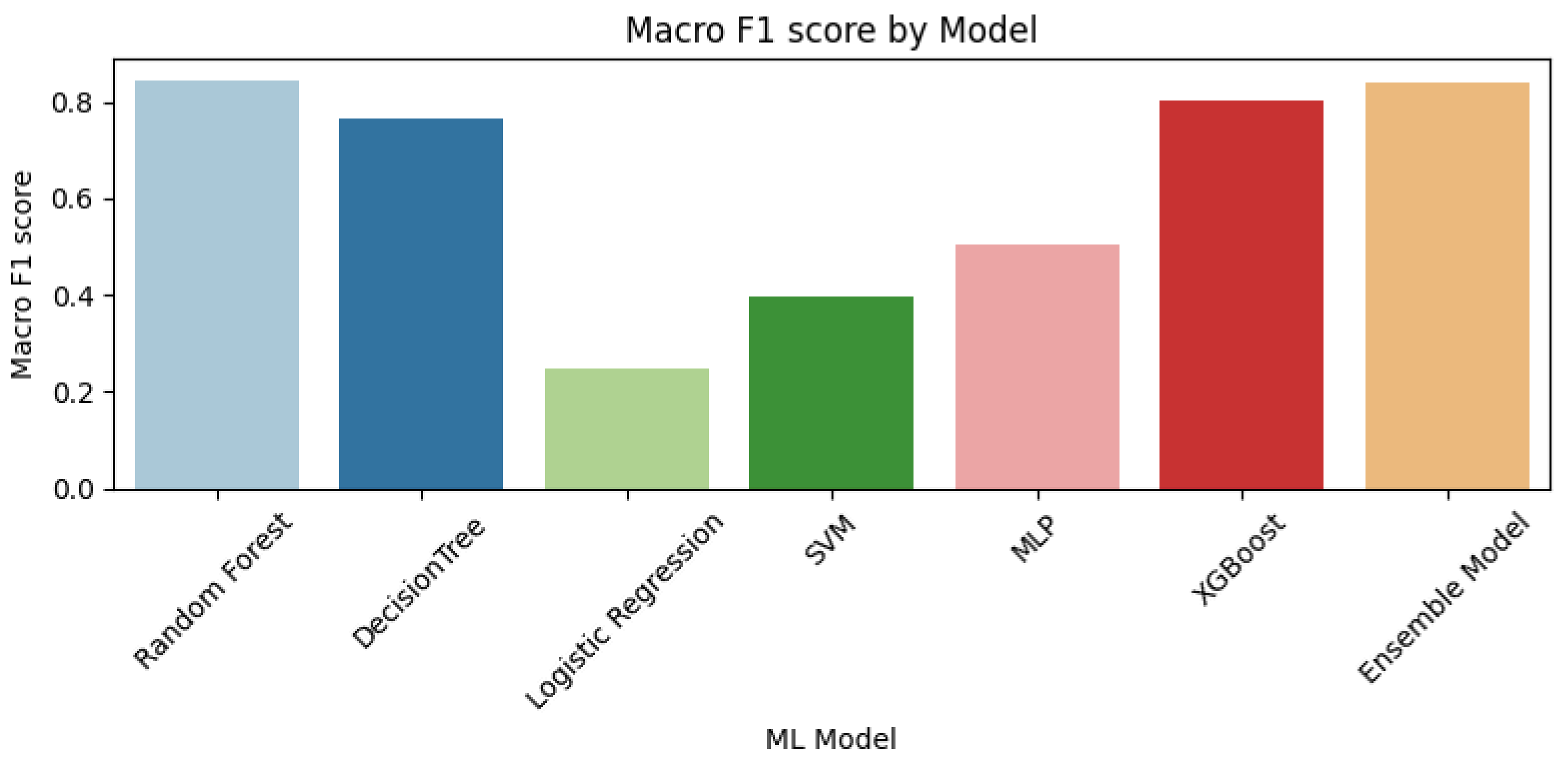
Out[69]:

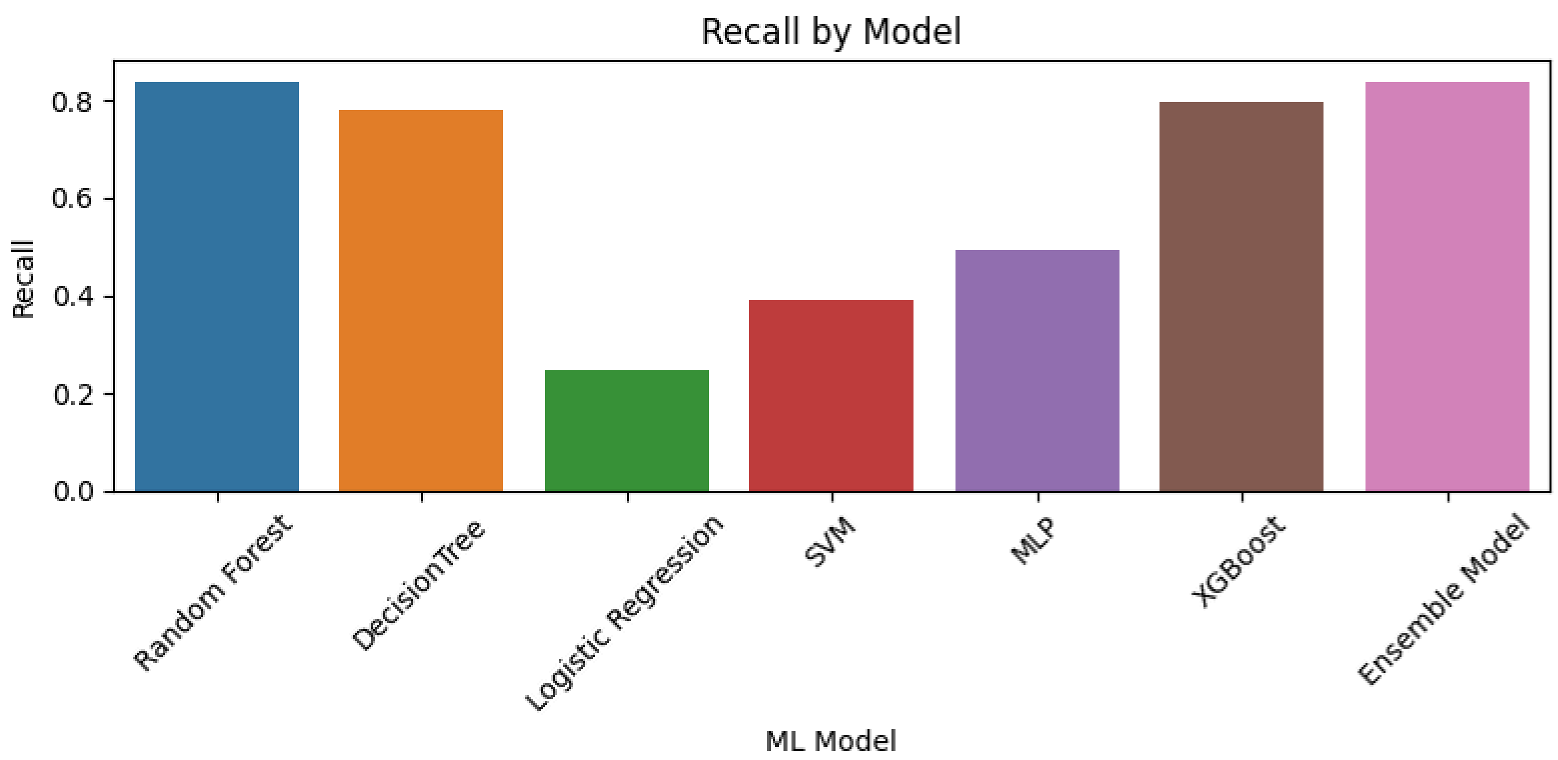
	ML Model	Accuracy	Macro F1 score	Recall	Precision
0	Random Forest	0.840	0.846	0.840	0.841
1	DecisionTree	0.779	0.767	0.779	0.818
2	Logistic Regression	0.244	0.248	0.244	0.260
3	SVM	0.388	0.398	0.388	0.414
4	MLP	0.492	0.503	0.492	0.521
5	XGBoost	0.796	0.801	0.796	0.810
6	Ensemble Model	0.837	0.842	0.837	0.836

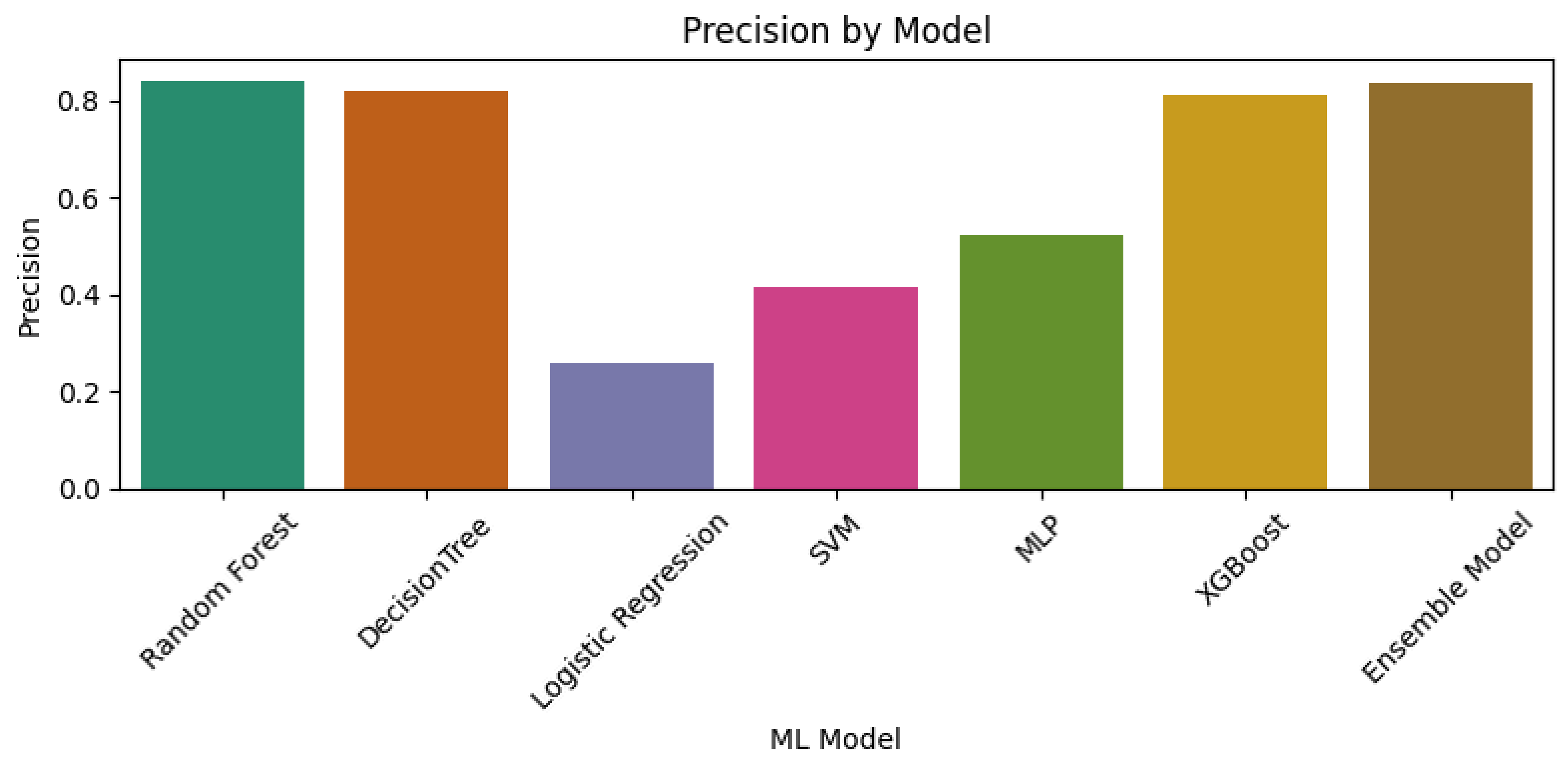
Graph

In [71]:
```
palettes = ['Set2', 'Paired', 'tab10', 'Dark2']

import matplotlib.pyplot as plt
import seaborn as sns

for metric, pal in zip(['Accuracy','Macro F1 score','Recall','Precision'], palettes):
    plt.figure(figsize=(8, 4))
    sns.barplot(data=result, x='ML Model', y=metric, palette=sns.color_palette(pal))
    plt.title(f'{metric} by Model')
    plt.xticks(rotation=45)
    plt.tight_layout()
    plt.show()
```









Models

In [78]:
```
import joblib

filename = 'Models/model.sav'
joblib.dump(ext, filename)
```

Out[78]: ['Models/model.sav']

In [79]:
```
filename = 'Models/model_rf.sav'
joblib.dump(rf, filename)
```

Out[79]: ['Models/model_rf.sav']

In [ ]: