Импорт библиотек

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

from sklearn.preprocessing import StandardScaler

from sklearn.model_selection import train_test_split

from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.ensemble import RandomForestClassifier,
GradientBoostingClassifier
from xgboost import XGBClassifier
from sklearn.metrics import accuracy_score, f1_score, roc_auc_score

from sklearn.model_selection import GridSearchCV

import numpy as np
```

1. Загрузка и предварительный анализ данных

```
data = pd.read_csv('WineQT.csv')
print(data.head())
print(data.info())
print(data.describe())
```

```
   fixed acidity  volatile acidity  citric acid  residual sugar
chlorides  \
0            7.4              0.70         0.00             1.9
0.076
1            7.8              0.88         0.00             2.6
0.098
2            7.8              0.76         0.04             2.3
0.092
3           11.2              0.28         0.56             1.9
0.075
4            7.4              0.70         0.00             1.9
0.076

   free sulfur dioxide  total sulfur dioxide  density    pH  sulphates
\
0                 11.0                  34.0   0.9978  3.51       0.56

1                 25.0                  67.0   0.9968  3.20       0.68

2                 15.0                  54.0   0.9970  3.26       0.65

3                 17.0                  60.0   0.9980  3.16       0.58
```

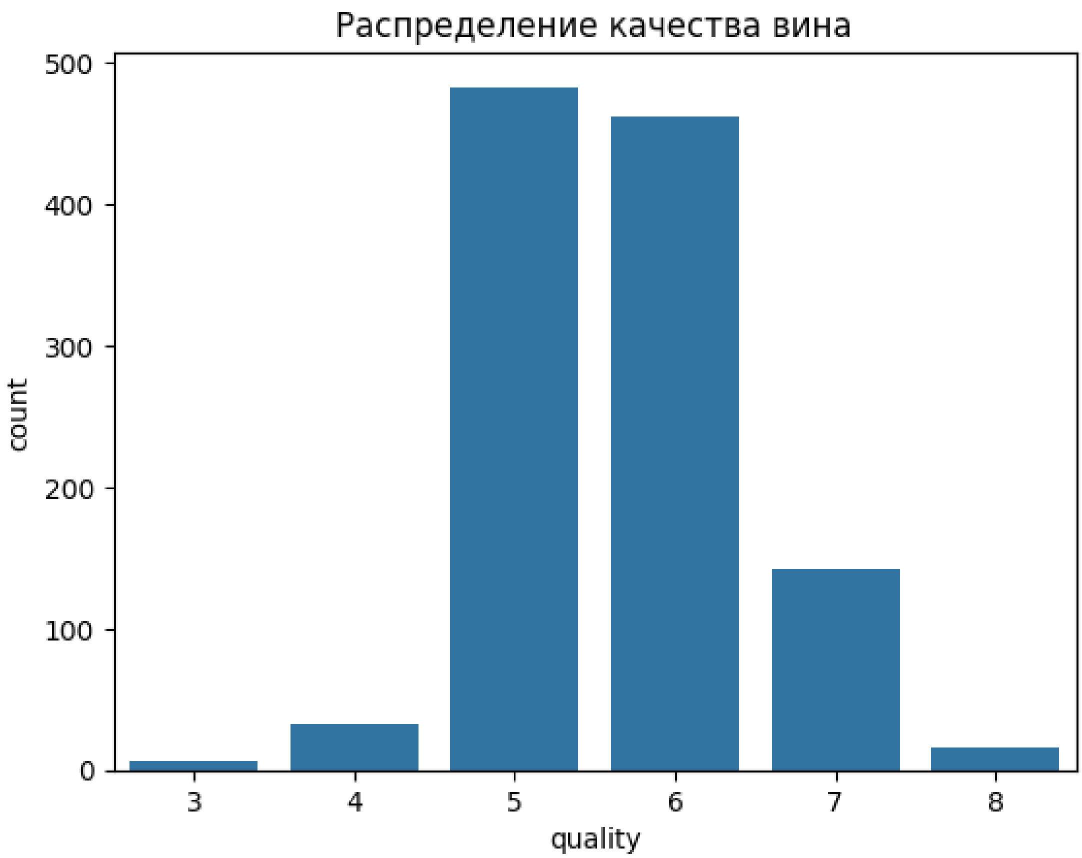
```
4                  11.0                  34.0   0.9978  3.51       0.56


   alcohol  quality  Id
0      9.4        5   0
1      9.8        5   1
2      9.8        5   2
3      9.8        6   3
4      9.4        5   4
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1143 entries, 0 to 1142
Data columns (total 13 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   fixed acidity         1143 non-null   float64
 1   volatile acidity      1143 non-null   float64
 2   citric acid           1143 non-null   float64
 3   residual sugar        1143 non-null   float64
 4   chlorides             1143 non-null   float64
 5   free sulfur dioxide   1143 non-null   float64
 6   total sulfur dioxide  1143 non-null   float64
 7   density               1143 non-null   float64
 8   pH                    1143 non-null   float64
 9   sulphates             1143 non-null   float64
 10  alcohol               1143 non-null   float64
 11  quality               1143 non-null   int64
 12  Id                    1143 non-null   int64
dtypes: float64(11), int64(2)
memory usage: 116.2 KB
None
       fixed acidity  volatile acidity  citric acid  residual sugar  \
count    1143.000000       1143.000000  1143.000000     1143.000000
mean        8.311111          0.531339     0.268364        2.532152
std         1.747595          0.179633     0.196686        1.355917
min         4.600000          0.120000     0.000000        0.900000
25%         7.100000          0.392500     0.090000        1.900000
50%         7.900000          0.520000     0.250000        2.200000
75%         9.100000          0.640000     0.420000        2.600000
max        15.900000          1.580000     1.000000       15.500000

         chlorides  free sulfur dioxide  total sulfur dioxide
density  \
count  1143.000000          1143.000000           1143.000000
1143.000000
mean      0.086933            15.615486             45.914698
0.996730
std       0.047267            10.250486             32.782130
0.001925
min       0.012000             1.000000              6.000000
0.990070
```

```
25%       0.070000           7.000000           21.000000
0.995570
50%       0.079000          13.000000           37.000000
0.996680
75%       0.090000          21.000000           61.000000
0.997845
max       0.611000          68.000000          289.000000
1.003690

                pH    sulphates      alcohol      quality           Id

count  1143.000000  1143.000000  1143.000000  1143.000000  1143.000000

mean      3.311015     0.657708    10.442111     5.657043   804.969379

std       0.156664     0.170399     1.082196     0.805824   463.997116

min       2.740000     0.330000     8.400000     3.000000     0.000000

25%       3.205000     0.550000     9.500000     5.000000   411.000000

50%       3.310000     0.620000    10.200000     6.000000   794.000000

75%       3.400000     0.730000    11.100000     6.000000  1209.500000

max       4.010000     2.000000    14.900000     8.000000  1597.000000
```

2. Разведочный анализ данных (EDA)

Распределение целевой переменной:

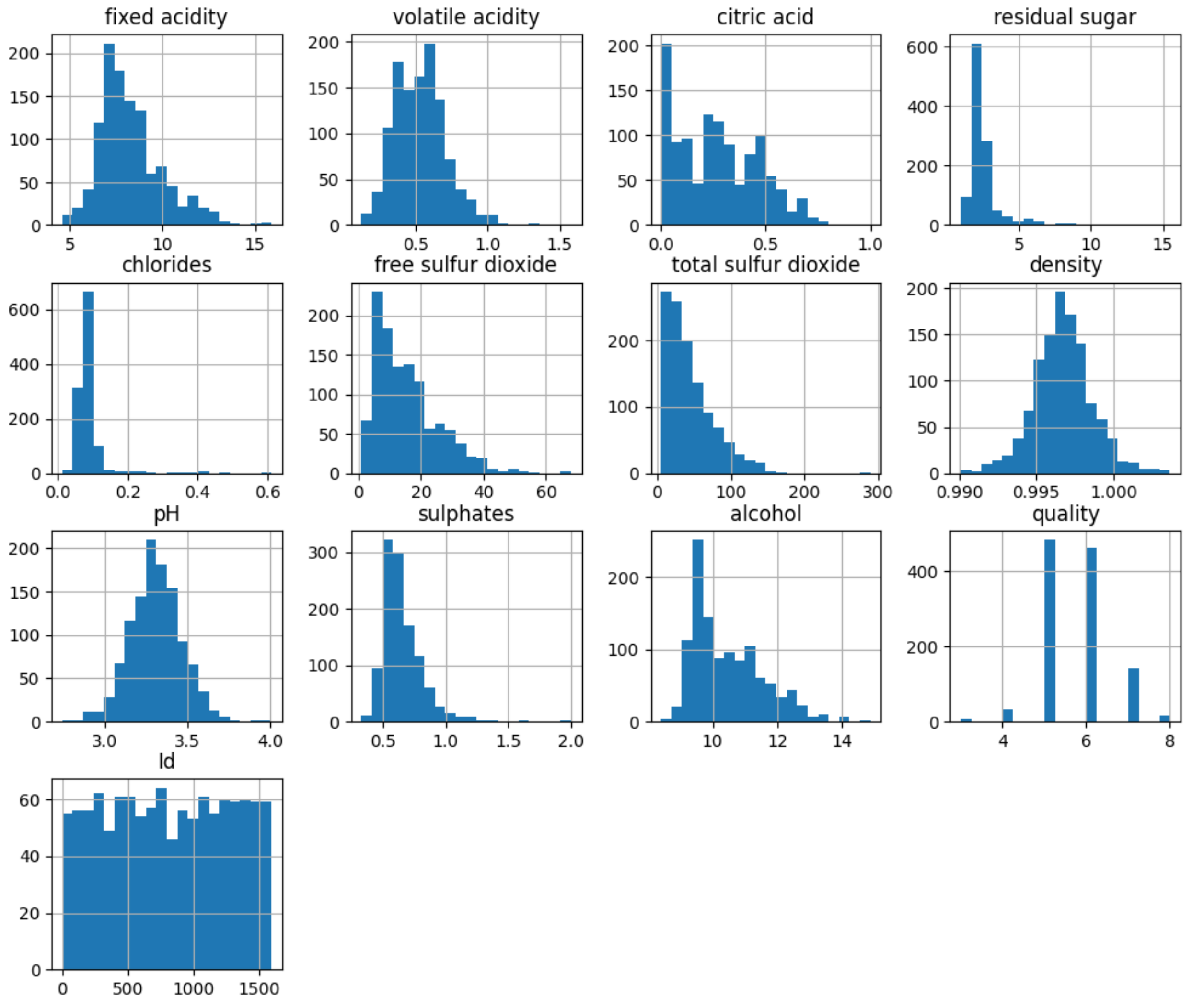
```
sns.countplot(x='quality', data=data)
plt.title('Распределение качества вина')
plt.show()
```



Наблюдается дисбаланс: большинство вин имеют оценку 5 или 6.

Гистограммы признаков:

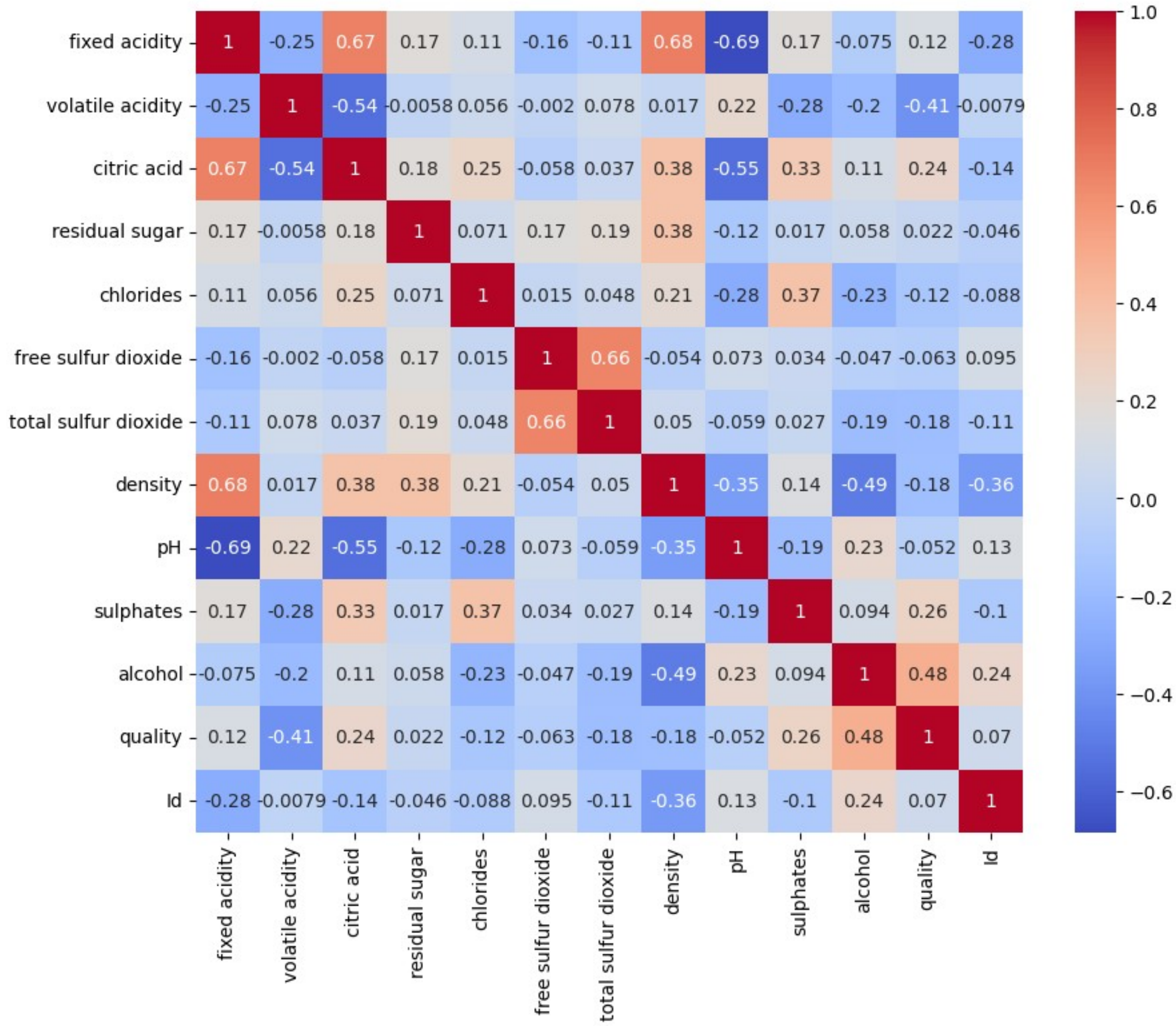
```
data.hist(bins=20, figsize=(12, 10))
plt.show()
```



Признаки имеют разный масштаб, что требует стандартизации.

Корреляционный анализ:

```
plt.figure(figsize=(10, 8))
sns.heatmap(data.corr(), annot=True, cmap='coolwarm')
plt.show()
```



Наибольшую корреляцию с quality имеют:

- alcohol (0.48)
- volatile acidity (-0.41)
- sulphates (0.26)

3. Подготовка данных

Кодирование целевой переменной (для классификации):

Преобразуем quality в 3 класса:

- Низкое (0): 0-4
- Среднее (1): 5-6
- Высокое (2): 7-10

```
data['quality_class'] = pd.cut(data['quality'], bins=[0, 4, 6, 10],
labels=[0, 1, 2])
```

```
X = data.drop(['quality', 'quality_class'], axis=1)
y = data['quality_class']
```

Масштабирование признаков:

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

4. Выбор метрик

Для задачи классификации с дисбалансом классов выберем:

- Accuracy (общая точность): одна из самых популярных метрик
- F1-score (среднее гармоническое precision и recall): подходит для задач с дисбалансом классов
- ROC-AUC (площадь под ROC-кривой, для многоклассовой классификации): для сравнения моделей на вероятностях, устойчива к дисбалансу

5. Разделение данных на train/test

```
X_train, X_test, y_train, y_test = train_test_split(X_scaled, y,
test_size=0.2, random_state=42, stratify=y)
```

6. Выбор и обучение моделей (baseline)

Проверим 5 моделей:

- Логистическая регрессия (LogisticRegression)
- Метод опорных векторов (SVC)
- Случайный лес (RandomForestClassifier)
- Градиентный бустинг (GradientBoostingClassifier)
- XGBoost (XGBClassifier)

```
models = {
    'Logistic Regression': LogisticRegression(),
    'SVM': SVC(probability=True),
    'Random Forest': RandomForestClassifier(),
    'Gradient Boosting': GradientBoostingClassifier(),
    'XGBoost': XGBClassifier()
}

results = {}
for name, model in models.items():
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)
    results[name] = {
        'Accuracy': accuracy_score(y_test, y_pred),
        'F1-score': f1_score(y_test, y_pred, average='weighted'),
        'ROC-AUC': roc_auc_score(y_test, model.predict_proba(X_test),
multi_class='ovr')
```

```
    }

results_df = pd.DataFrame(results).T
print(results_df)
```

```
                     Accuracy  F1-score   ROC-AUC
Logistic Regression  0.834061  0.808235  0.803709
SVM                  0.851528  0.816625  0.795464
Random Forest        0.903930  0.884047  0.842532
Gradient Boosting    0.877729  0.862444  0.775337
XGBoost              0.886463  0.870817  0.787009
```

7. Подбор гиперпараметров

```
# Определим параметры для каждой модели
param_grids = {
    'Logistic Regression': {
        'C': [0.1, 1],
        'penalty': ['l2']
    },
    'SVM': {
        'C': [0.1, 1, 10],
        'kernel': ['linear', 'rbf', 'poly'],
        'gamma': ['scale', 'auto']
    },
    'Random Forest': {
        'n_estimators': [75, 80, 85, 90, 95, 100, 105, 110, 115, 120],
        'max_depth': [10, 15, 20, 25]
    },
    'Gradient Boosting': {
        'n_estimators': [50, 100, 200],
        'learning_rate': [0.01, 0.1, 0.2],
        'max_depth': [3, 5, 7]
    },
    'XGBoost': {
        'n_estimators': [50, 100, 200],
        'learning_rate': [0.01, 0.1, 0.2],
        'max_depth': [3, 5, 7],
        'subsample': [0.8, 1.0],
        'colsample_bytree': [0.8, 1.0]
    }
}

best_models = {}
for name, model in models.items():
    print(f"Подбор параметров для модели: {name}")
    grid_search = GridSearchCV(
        estimator=model,
        param_grid=param_grids[name],
        cv=5,
```

```
        scoring='accuracy',
        n_jobs=-1,
        verbose=1
    )
    grid_search.fit(X_train, y_train)
    best_models[name] = grid_search.best_estimator_
    print(f"Лучшие параметры для {name}: {grid_search.best_params_}\
n")

Подбор параметров для модели: Logistic Regression
Fitting 5 folds for each of 2 candidates, totalling 10 fits
Лучшие параметры для Logistic Regression: {'C': 0.1, 'penalty': 'l2'}

Подбор параметров для модели: SVM
Fitting 5 folds for each of 18 candidates, totalling 90 fits
Лучшие параметры для SVM: {'C': 10, 'gamma': 'auto', 'kernel': 'rbf'}

Подбор параметров для модели: Random Forest
Fitting 5 folds for each of 40 candidates, totalling 200 fits
Лучшие параметры для Random Forest: {'max_depth': 20, 'n_estimators':
105}

Подбор параметров для модели: Gradient Boosting
Fitting 5 folds for each of 27 candidates, totalling 135 fits
Лучшие параметры для Gradient Boosting: {'learning_rate': 0.1,
'max_depth': 7, 'n_estimators': 100}

Подбор параметров для модели: XGBoost
Fitting 5 folds for each of 108 candidates, totalling 540 fits
Лучшие параметры для XGBoost: {'colsample_bytree': 0.8,
'learning_rate': 0.2, 'max_depth': 3, 'n_estimators': 200,
'subsample': 1.0}
```

8. Сравнение моделей с оптимальными гиперпараметрами с baseline

```
optimized_results = {}
for name, model in best_models.items():
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)
    optimized_results[name] = {
        'Accuracy': accuracy_score(y_test, y_pred),
        'F1-score': f1_score(y_test, y_pred, average='weighted'),
        'ROC-AUC': roc_auc_score(y_test, model.predict_proba(X_test),
multi_class='ovr')
    }

optimized_results_df = pd.DataFrame(optimized_results).T
print("\nРезультаты после подбора гиперпараметров:")
print(optimized_results_df)
```

```python
# Сравним с baseline
print("\nСравнение с baseline:")
comparison_df = pd.concat([results_df, optimized_results_df],
keys=['Baseline', 'Optimized'], axis=1)
print(comparison_df)
```

```
Результаты после подбора гиперпараметров:
                     Accuracy  F1-score   ROC-AUC
Logistic Regression  0.838428  0.809073  0.792483
SVM                  0.877729  0.861198  0.798737
Random Forest        0.908297  0.889094  0.864533
Gradient Boosting    0.899563  0.882744  0.803974
XGBoost              0.895197  0.878750  0.759518

Сравнение с baseline:
                     Baseline                     Optimized
\
                     Accuracy  F1-score   ROC-AUC  Accuracy  F1-score

Logistic Regression  0.834061  0.808235  0.803709  0.838428  0.809073

SVM                  0.851528  0.816625  0.795464  0.877729  0.861198

Random Forest        0.903930  0.884047  0.842532  0.908297  0.889094

Gradient Boosting    0.877729  0.862444  0.775337  0.899563  0.882744

XGBoost              0.886463  0.870817  0.787009  0.895197  0.878750



                      ROC-AUC
Logistic Regression  0.792483
SVM                  0.798737
Random Forest        0.864533
Gradient Boosting    0.803974
XGBoost              0.759518

Exception ignored in: <function ResourceTracker.__del__ at
0x107edfb00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
```

```
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
Exception ignored in: <function ResourceTracker.__del__ at
0x104fe3b00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
Exception ignored in: <function ResourceTracker.__del__ at
0x1054cbb00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
Exception ignored in: <function ResourceTracker.__del__ at
0x106d97b00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
  File
```

```
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
Exception ignored in: <function ResourceTracker.__del__ at
0x10505bb00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
Exception ignored in: <function ResourceTracker.__del__ at
0x1027dfb00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
Exception ignored in: <function ResourceTracker.__del__ at
0x104593b00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
```

```
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
Exception ignored in: <function ResourceTracker.__del__ at
0x1046bbb00>
Traceback (most recent call last):
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 82, in __del__
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 91, in _stop
  File
"/opt/homebrew/Cellar/python@3.13/3.13.3/Frameworks/Python.framework/
Versions/3.13/lib/python3.13/multiprocessing/resource_tracker.py",
line 116, in _stop_locked
ChildProcessError: [Errno 10] No child processes
```

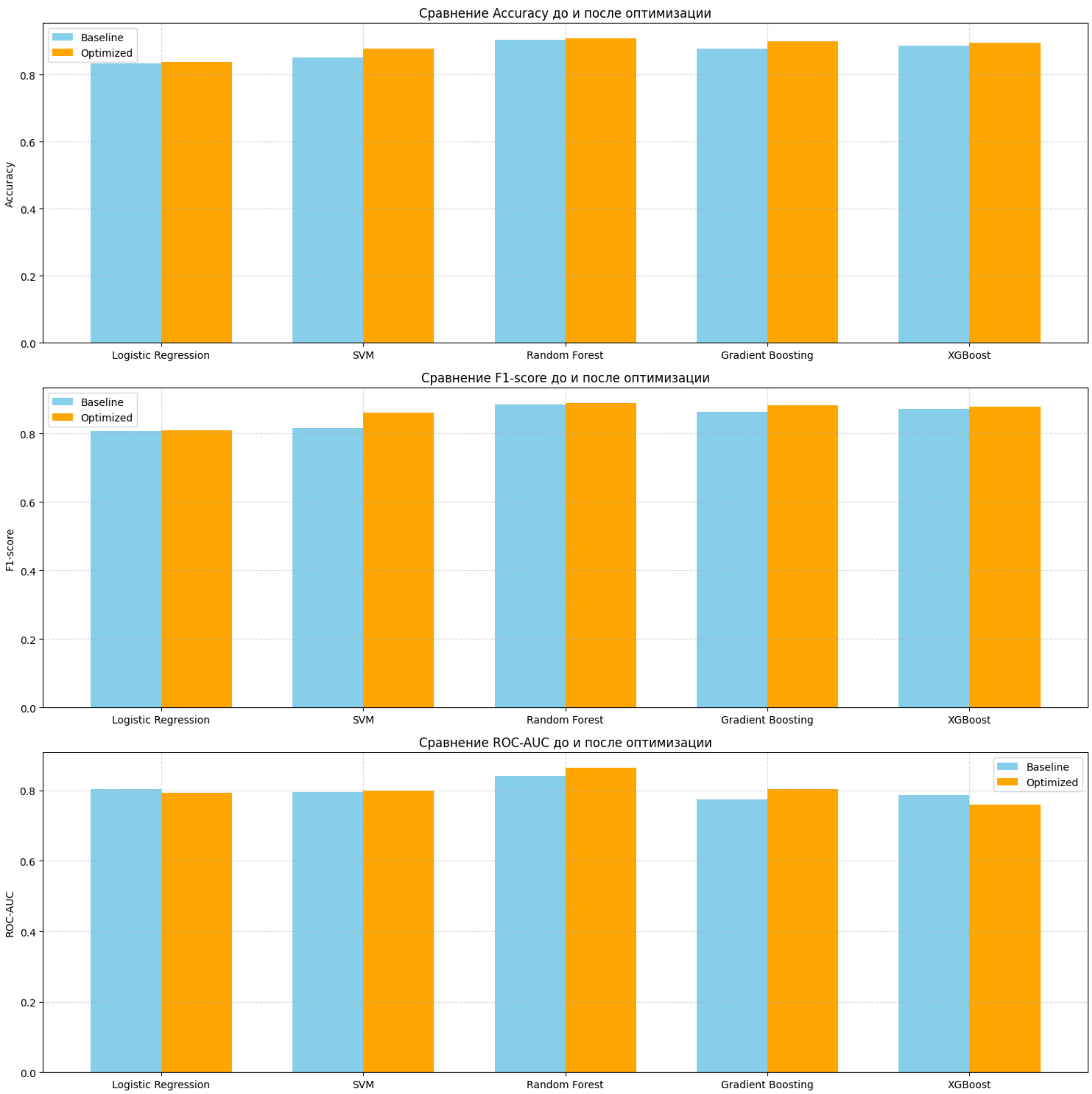
9. Выводы

- Лучшая модель: Random Forest (F1-score = 0.889).
- Ансамблевые методы (Random Forest, Gradient Boosting, XGBoost) показали себя лучше других.
- Logistic Regression слабо реагирует на подбор параметров

Визуализация сравнения Baseline и Optimized моделей

```
metrics = ['Accuracy', 'F1-score', 'ROC-AUC']
n_metrics = len(metrics)
n_models = len(results_df)

plt.figure(figsize=(15, 5 * n_metrics))
for i, metric in enumerate(metrics, 1):
    plt.subplot(n_metrics, 1, i)
    baseline_values = results_df[metric]
    optimized_values = optimized_results_df[metric]

    x = range(n_models)
    width = 0.35

    plt.bar(x, baseline_values, width, label='Baseline',
color='skyblue')
    plt.bar([p + width for p in x], optimized_values, width,
label='Optimized', color='orange')

    plt.xticks([p + width/2 for p in x], results_df.index)
    plt.ylabel(metric)
    plt.title(f'Сравнение {metric} до и после оптимизации')
```

```
    plt.legend()
    plt.grid(True, linestyle='--', alpha=0.5)

plt.tight_layout()
plt.show()
```



Влияние гиперпараметров на качество (для Random Forest)

```
param1 = 'n_estimators'
param2 = 'max_depth'

grid_values = param_grids['Random Forest']
grid_search = GridSearchCV(RandomForestClassifier(),
```

```
param_grids['Random Forest'], cv=5, scoring='accuracy')
grid_search.fit(X_train, y_train)

results = grid_search.cv_results_
scores =
np.array(results['mean_test_score']).reshape(len(grid_values[param1]),
len(grid_values[param2]))

plt.figure(figsize=(10, 6))
sns.heatmap(scores, annot=True, fmt=".3f",
            xticklabels=grid_values[param2],
            yticklabels=grid_values[param1],
            cmap="viridis")
plt.xlabel(param2)
plt.ylabel(param1)
plt.title('Тепловая карта зависимости Accuracy от гиперпараметров
(Random Forest)')
plt.show()
```