In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import sys
import os
import optuna

sys.path.append(os.path.abspath(os.path.join('..')))

from src.utils import load_data, evaluate_model, compare_models

from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.preprocessing import StandardScaler
from sklearn.impute import SimpleImputer
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline
from sklearn.linear_model import LogisticRegression
from sklearn.neighbors import KNeighborsClassifier
from sklearn.svm import SVC
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.neural_network import MLPClassifier
from sklearn.metrics import confusion_matrix

optuna.logging.set_verbosity(optuna.logging.WARNING)
```

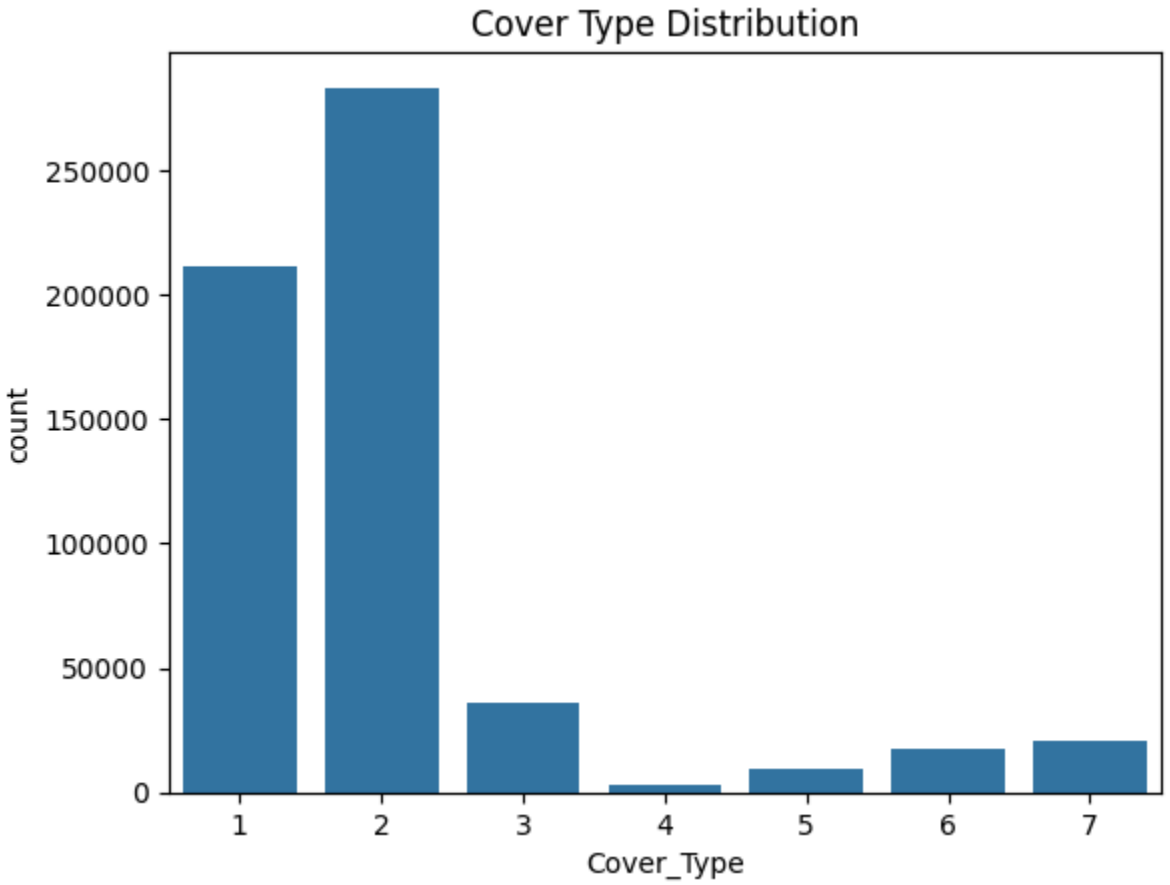
```
C:\Users\NIKHIL AGRAWAL\AppData\Roaming\Python\Python314\site-packages\tqdm\aut
o.py:21: TqdmWarning: IProgress not found. Please update jupyter and ipywidget
s. See https://ipywidgets.readthedocs.io/en/stable/user_install.html
  from .autonotebook import tqdm as notebook_tqdm
```

In [2]:
```
df = load_data('../data/raw/covtype.csv')
print(df.info())
target = 'Cover_Type'
```

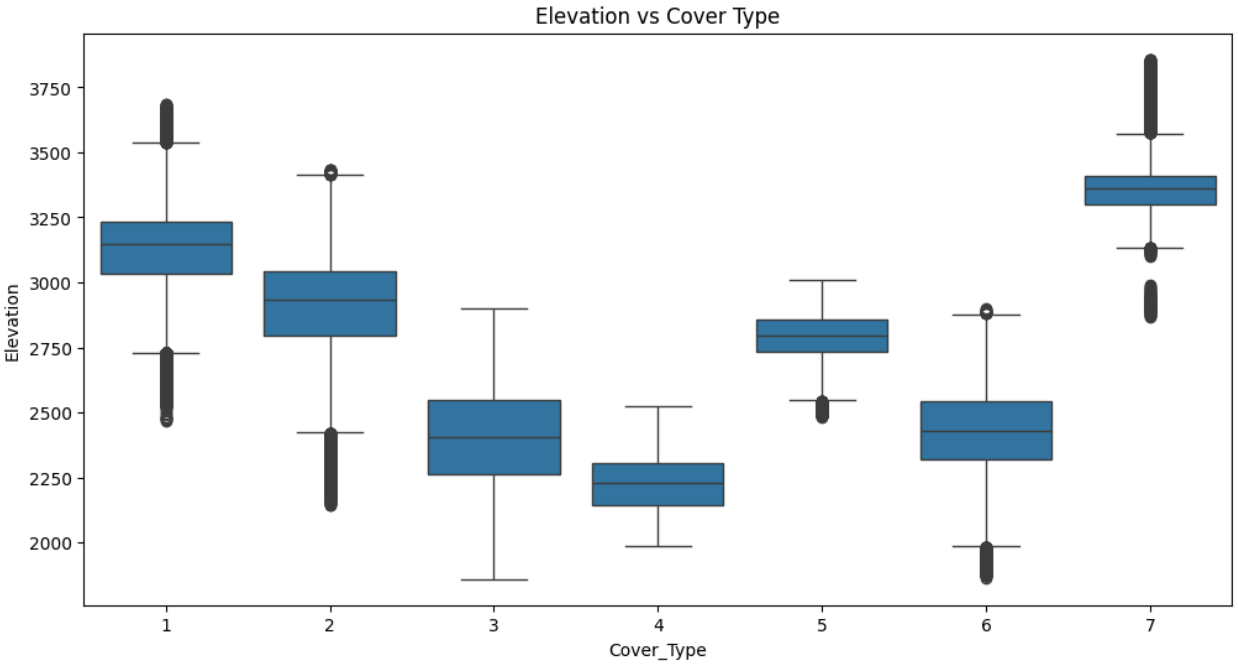
```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 581012 entries, 0 to 581011
Data columns (total 55 columns):
 #   Column                              Non-Null Count   Dtype
---  ------                              --------------   -----
 0   Elevation                           581012 non-null  int64
 1   Aspect                              581012 non-null  int64
 2   Slope                               581012 non-null  int64
 3   Horizontal_Distance_To_Hydrology    581012 non-null  int64
 4   Vertical_Distance_To_Hydrology      581012 non-null  int64
 5   Horizontal_Distance_To_Roadways     581012 non-null  int64
 6   Hillshade_9am                       581012 non-null  int64
 7   Hillshade_Noon                      581012 non-null  int64
 8   Hillshade_3pm                       581012 non-null  int64
 9   Horizontal_Distance_To_Fire_Points  581012 non-null  int64
 10  Wilderness_Area1                    581012 non-null  int64
 11  Wilderness_Area2                    581012 non-null  int64
 12  Wilderness_Area3                    581012 non-null  int64
 13  Wilderness_Area4                    581012 non-null  int64
 14  Soil_Type1                          581012 non-null  int64
 15  Soil_Type2                          581012 non-null  int64
 16  Soil_Type3                          581012 non-null  int64
 17  Soil_Type4                          581012 non-null  int64
 18  Soil_Type5                          581012 non-null  int64
 19  Soil_Type6                          581012 non-null  int64
 20  Soil_Type7                          581012 non-null  int64
 21  Soil_Type8                          581012 non-null  int64
 22  Soil_Type9                          581012 non-null  int64
 23  Soil_Type10                         581012 non-null  int64
 24  Soil_Type11                         581012 non-null  int64
 25  Soil_Type12                         581012 non-null  int64
 26  Soil_Type13                         581012 non-null  int64
 27  Soil_Type14                         581012 non-null  int64
 28  Soil_Type15                         581012 non-null  int64
 29  Soil_Type16                         581012 non-null  int64
 30  Soil_Type17                         581012 non-null  int64
 31  Soil_Type18                         581012 non-null  int64
 32  Soil_Type19                         581012 non-null  int64
 33  Soil_Type20                         581012 non-null  int64
 34  Soil_Type21                         581012 non-null  int64
 35  Soil_Type22                         581012 non-null  int64
 36  Soil_Type23                         581012 non-null  int64
 37  Soil_Type24                         581012 non-null  int64
 38  Soil_Type25                         581012 non-null  int64
 39  Soil_Type26                         581012 non-null  int64
 40  Soil_Type27                         581012 non-null  int64
 41  Soil_Type28                         581012 non-null  int64
 42  Soil_Type29                         581012 non-null  int64
 43  Soil_Type30                         581012 non-null  int64
 44  Soil_Type31                         581012 non-null  int64
 45  Soil_Type32                         581012 non-null  int64
 46  Soil_Type33                         581012 non-null  int64
 47  Soil_Type34                         581012 non-null  int64
 48  Soil_Type35                         581012 non-null  int64
```

```
 49  Soil_Type36                             581012 non-null  int64
 50  Soil_Type37                             581012 non-null  int64
 51  Soil_Type38                             581012 non-null  int64
 52  Soil_Type39                             581012 non-null  int64
 53  Soil_Type40                             581012 non-null  int64
 54  Cover_Type                              581012 non-null  int64
dtypes: int64(55)
memory usage: 243.8 MB
None
```

In [3]:
```
sns.countplot(x=target, data=df)
plt.title('Cover Type Distribution')
plt.show()
```



In [4]:
```
plt.figure(figsize=(12, 6))
sns.boxplot(x=target, y='Elevation', data=df)
plt.title('Elevation vs Cover Type')
plt.show()
```



In [5]:
```
if 'Id' in df.columns:
    df = df.drop('Id', axis=1)

X = df.drop(target, axis=1)
y = df[target]

numerical_cols = X.select_dtypes(include=['int64', 'float64']).columns

preprocessor = Pipeline(steps=[
    ('imputer', SimpleImputer(strategy='median')),
    ('scaler', StandardScaler())
])

print("Preprocessing data...")
X_processed = preprocessor.fit_transform(X)
X_train, X_test, y_train, y_test = train_test_split(X_processed, y, test_size=
```

```
Preprocessing data...
```

In [6]:
```
# Universal Subsampling for Tuning Phase
# We use a fixed subset of 20,000 samples for all hyperparameter searches to e
tuning_size = 20000
idx_tune = np.random.choice(len(X_train), size=tuning_size, replace=False)
X_tune = X_train[idx_tune]
y_tune = y_train.iloc[idx_tune]

print(f"Tuning on subset of {tuning_size} samples for speed.")
```

```
Tuning on subset of 20000 samples for speed.
```

In [7]:
```
# === 1. SVM Optimization ===
# def objective_svm(trial):
#     C = trial.suggest_float('C', 1e-3, 1e2, log=True)
```

```
#     # Limiting to RBF as it's generally best for non-linear tabular data
#     clf = SVC(C=C, kernel='rbf', gamma='scale', random_state=42)
#     score = cross_val_score(clf, X_tune, y_tune, cv=3, scoring='f1_weighted'
#     return score
#
# print("Tuning SVM...")
# study_svm = optuna.create_study(direction='maximize', sampler=optuna.sampler
# study_svm.optimize(objective_svm, n_trials=10) # Low trials due to high cost
# print("Best SVM Params:", study_svm.best_params)
# best_svm = SVC(**study_svm.best_params, kernel='rbf', random_state=42)

# Reverting to untuned model as requested
print("Skipping SVM Tuning (Reverted to Default)")
best_svm = SVC(kernel='rbf', random_state=42)
```

```
Skipping SVM Tuning (Reverted to Default)
```

In [8]:
```
# === 2. Random Forest Optimization ===
# def objective_rf(trial):
#     n_estimators = trial.suggest_int('n_estimators', 50, 300)
#     max_depth = trial.suggest_int('max_depth', 5, 30)
#     min_samples_split = trial.suggest_int('min_samples_split', 2, 20)
#     min_samples_leaf = trial.suggest_int('min_samples_leaf', 1, 10)
#
#     clf = RandomForestClassifier(
#         n_estimators=n_estimators,
#         max_depth=max_depth,
#         min_samples_split=min_samples_split,
#         min_samples_leaf=min_samples_leaf,
#         random_state=42,
#         n_jobs=-1
#     )
#     score = cross_val_score(clf, X_tune, y_tune, cv=3, scoring='f1_weighted'
#     return score
#
# print("Tuning Random Forest...")
# study_rf = optuna.create_study(direction='maximize', sampler=optuna.samplers
# study_rf.optimize(objective_rf, n_trials=15)
# print("Best RF Params:", study_rf.best_params)
# best_rf = RandomForestClassifier(**study_rf.best_params, random_state=42, n_

# Reverting to untuned model as requested
print("Skipping RF Tuning (Reverted to Default)")
best_rf = RandomForestClassifier(random_state=42, n_jobs=-1)
```

```
Skipping RF Tuning (Reverted to Default)
```

In [9]:
```
# === 3. KNN Optimization ===
# def objective_knn(trial):
#     n_neighbors = trial.suggest_int('n_neighbors', 3, 20)
#     weights = trial.suggest_categorical('weights', ['uniform', 'distance'])
#     p = trial.suggest_categorical('p', [1, 2]) # 1=Manhattan, 2=Euclidean
#
#     clf = KNeighborsClassifier(n_neighbors=n_neighbors, weights=weights, p=p
```

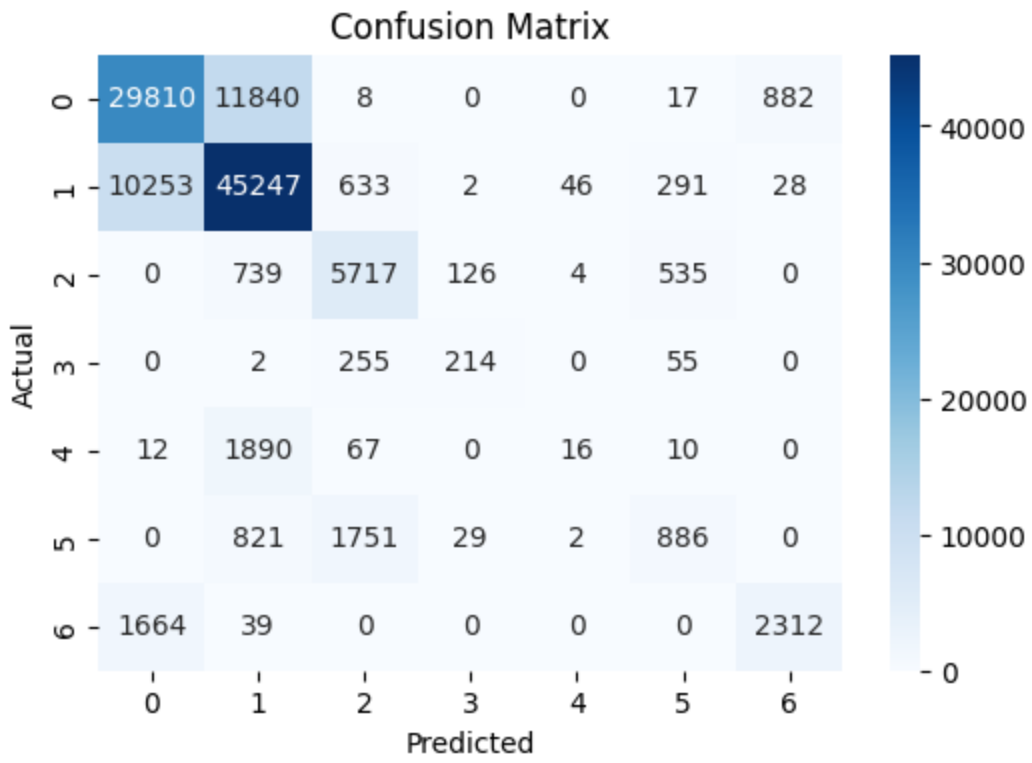
```
#     score = cross_val_score(clf, X_tune, y_tune, cv=3, scoring='f1_weighted'
#     return score
#
# print("Tuning KNN...")
# study_knn = optuna.create_study(direction='maximize', sampler=optuna.sampler
# study_knn.optimize(objective_knn, n_trials=15)
# print("Best KNN Params:", study_knn.best_params)
# best_knn = KNeighborsClassifier(**study_knn.best_params, n_jobs=-1)

# Reverting to untuned model as requested
print("Skipping KNN Tuning (Reverted to Default)")
best_knn = KNeighborsClassifier(n_jobs=-1)
```

```
Skipping KNN Tuning (Reverted to Default)
```

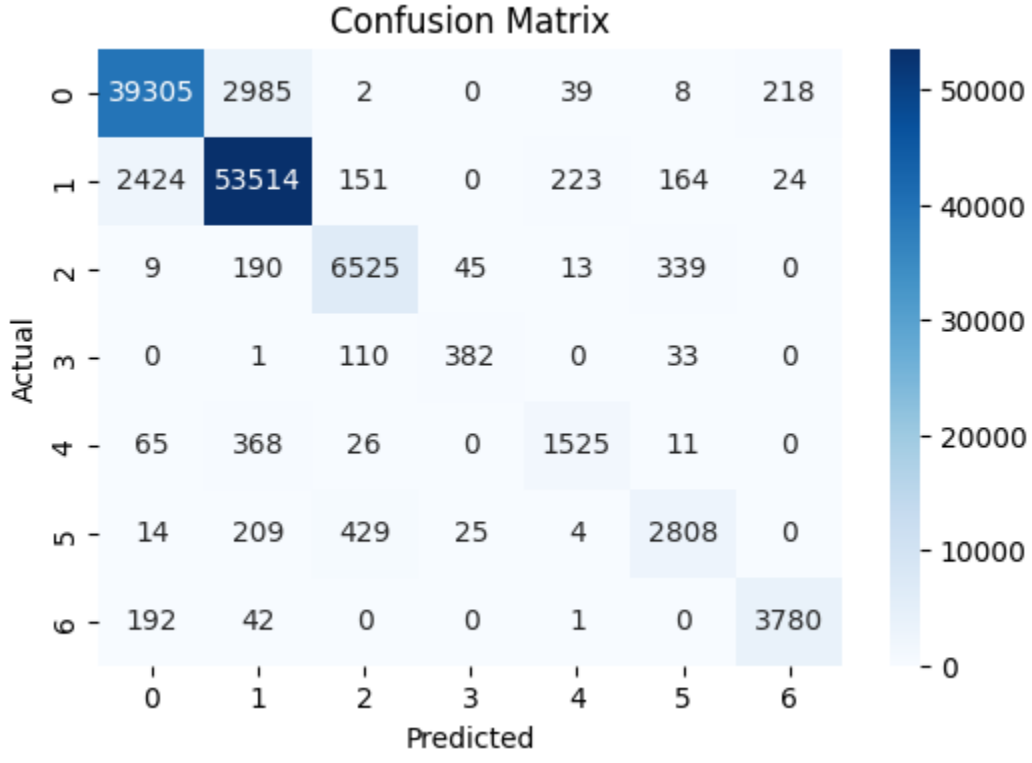
In [10]:

```
# Final Training Dictionary
models = {
    'Logistic Regression': LogisticRegression(random_state=42, max_iter=1000),
    'KNN': best_knn,
    'Decision Tree': DecisionTreeClassifier(random_state=42),
    'Random Forest': best_rf,
    'MLP': MLPClassifier(random_state=42, max_iter=200),
    'SVM': best_svm
}

results = {}
trained_models = {}

print("Starting Final Training...")
train_subset_size = 50000 # Use larger subset for final training to keep it re

for name, model in models.items():
    print(f"Training {name}...")

    # SVM and KNN can be very slow on 400k+ rows. We train on a larger subset
    # RF and Decision Tree can technically handle the full set, but for consis
    # You can increase train_subset_size if you have time/compute.
    if 'SVM' in name:
        idx = np.random.choice(len(X_train), size=train_subset_size, replace=F
        model.fit(X_train[idx], y_train.iloc[idx])
    else:
        model.fit(X_train, y_train)

    results[name] = evaluate_model(model, X_test, y_test, is_binary=False)
    trained_models[name] = model
```

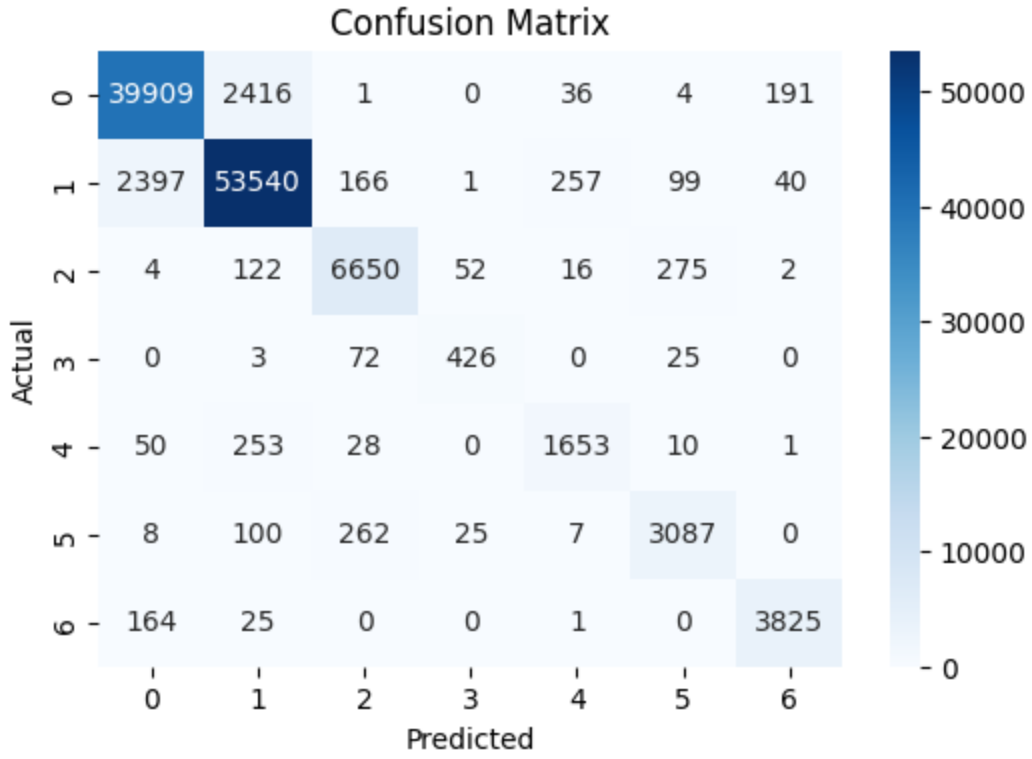
```
Starting Final Training...
Training Logistic Regression...
```



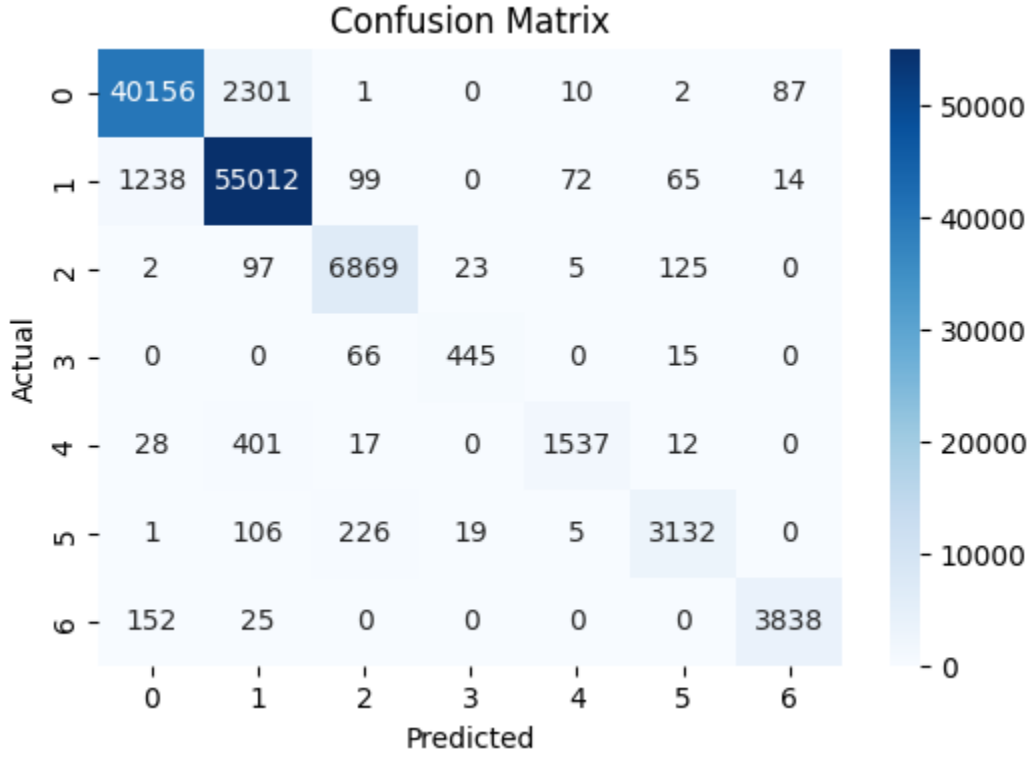

```
Training KNN...
```



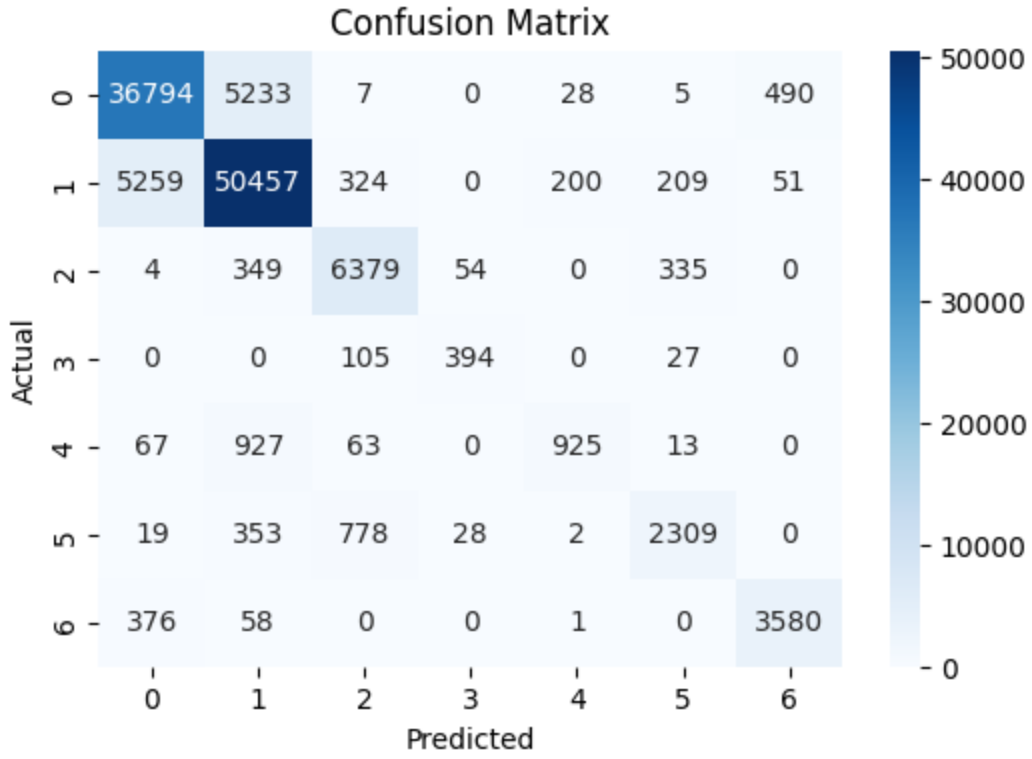

```
Training Decision Tree...
```



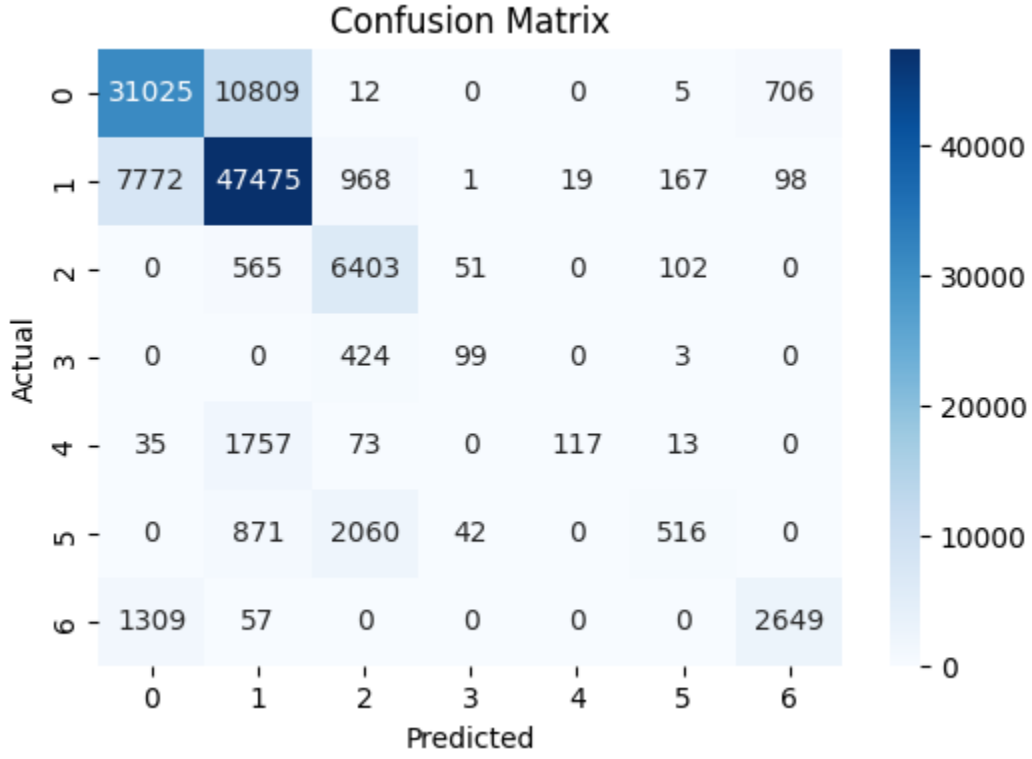

```
Training Random Forest...
```




```
Training MLP...
C:\Users\NIKHIL AGRAWAL\AppData\Roaming\Python\Python314\site-packages\sklearn\neural_network\_multilayer_perceptron.py:785: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (200) reached and the optimization hasn't converged yet.
  warnings.warn(
```




```
Training SVM...
```



In [11]:
```
df_results = compare_models(results)
print(df_results)
```

	Accuracy	Precision	Recall	F1
Random Forest	0.955130	0.955244	0.955130	0.954888
Decision Tree	0.938788	0.938763	0.938788	0.938771
KNN	0.928023	0.927756	0.928023	0.927785
MLP	0.867774	0.866978	0.867774	0.866310
SVM	0.759739	0.760484	0.759739	0.746773
Logistic Regression	0.724611	0.712554	0.724611	0.714467

In [12]:
```
best_model_name = df_results.index[0]
best_model = trained_models[best_model_name]

y_pred = best_model.predict(X_test)
cm = confusion_matrix(y_test, y_pred)

plt.figure(figsize=(10, 8))
sns.heatmap(cm, annot=True, fmt='d', cmap='viridis')
plt.title(f'Multiclass Confusion Matrix ({best_model_name})')
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.show()
```