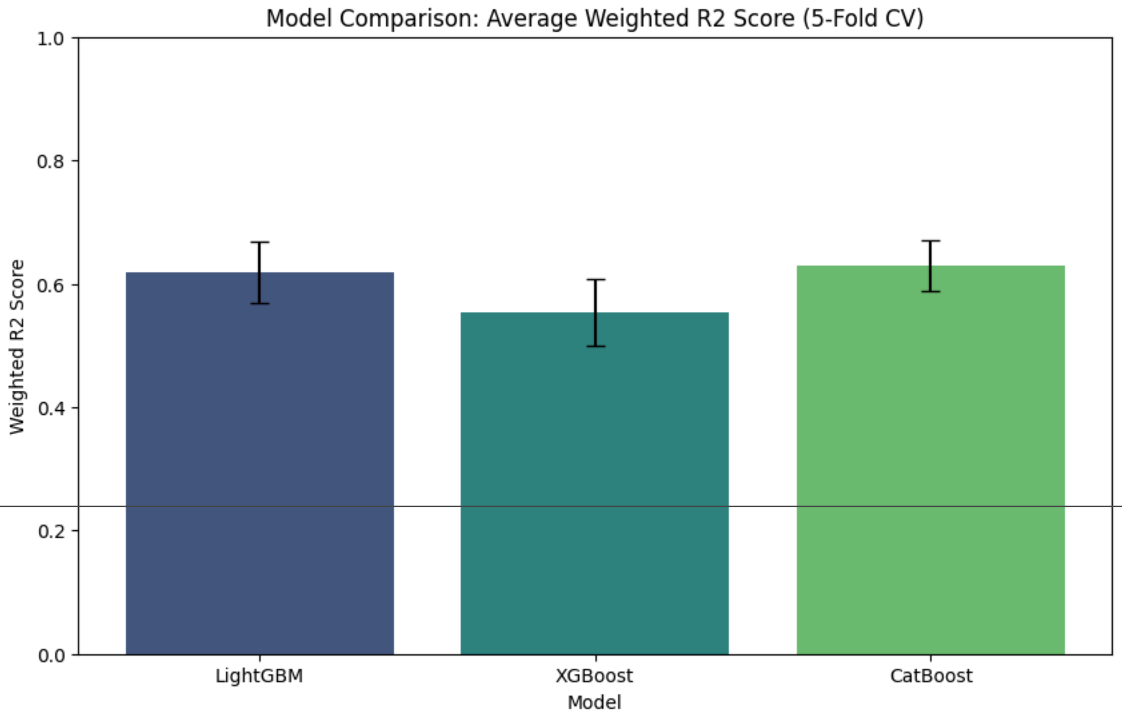
```python
import os, torch, numpy as np, pandas as pd
from pathlib import Path
from PIL import Image
from tqdm import tqdm
from sklearn.svm import SVR
from sklearn.multioutput import MultiOutputRegressor
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import KFold, GridSearchCV
from sklearn.metrics import make_scorer
from transformers import AutoImageProcessor, AutoModel
import torchvision.transforms as transforms

# --- CONFIGURATION ---
CFG = {
    "base_path": Path("/kaggle/input/csiro-biomass"),
    "model_path": "/kaggle/input/dinov2/pytorch/large/1",
    "device": torch.device("cuda" if torch.cuda.is_available() else "cpu"),
    "n_splits": 5,
    "seed": 42
}

TARGETS = ['Dry_Green_g', 'Dry_Dead_g', 'Dry_Clover_g', 'GDM_g', 'Dry_Total_g']
# Official competition weights: Dry_Total_g (0.5), GDM_g (0.2), Others (0.1)
COMP_WEIGHTS = np.array([0.1, 0.1, 0.1, 0.2, 0.5])
MEAN, STD = [0.485, 0.456, 0.406], [0.229, 0.224, 0.225]
```

```
2026-01-10 12:47:39.035482: E external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:467] Unable to register cuFFT factory: Att
WARNING: All log messages before absl::InitializeLog() is called are written to STDERR
E0000 00:00:1768049259.218180      55 cuda_dnn.cc:8579] Unable to register cuDNN factory: Attempting to register factory for plu
E0000 00:00:1768049259.268875      55 cuda_blas.cc:1407] Unable to register cuBLAS factory: Attempting to register factory for p
W0000 00:00:1768049259.692194      55 computation_placer.cc:177] computation placer already registered. Please check linkage and
W0000 00:00:1768049259.692239      55 computation_placer.cc:177] computation placer already registered. Please check linkage and
W0000 00:00:1768049259.692242      55 computation_placer.cc:177] computation placer already registered. Please check linkage and
W0000 00:00:1768049259.692244      55 computation_placer.cc:177] computation placer already registered. Please check linkage and
```

```python
def weighted_r2_metric(y_true, y_pred):
    """Calculates Global Weighted R2 based on competition rules."""
    ss_res = np.sum(COMP_WEIGHTS * np.sum((y_true - y_pred)**2, axis=0))
    global_mean = np.average(np.mean(y_true, axis=0), weights=COMP_WEIGHTS)
    ss_tot = np.sum(COMP_WEIGHTS * np.sum((y_true - global_mean)**2, axis=0))
    return 1 - (ss_res / ss_tot)

weighted_scorer = make_scorer(weighted_r2_metric, greater_is_better=True)

def extract_dense_features(df, model):
    """Extracts patch-based embeddings from DINOv2 (Dense Methodology)."""
    tta_transforms = [
        transforms.Compose([transforms.ToTensor(), transforms.Resize((224, 224)), transforms.Normalize(MEAN, STD)]
        transforms.Compose([transforms.RandomHorizontalFlip(p=1.0), transforms.ToTensor(), transforms.Resize((224,
    ]
    unique_paths = df['image_path'].unique()
    all_feats = []

    with torch.no_grad():
        for path in tqdm(unique_paths, desc="GPU Feature Extraction"):
            img = Image.open(CFG["base_path"] / path).convert("RGB")
            # Average patch features (ignoring CLS token at index 0)
            tta_results = [model(aug(img).unsqueeze(0).to(CFG["device"])).last_hidden_state[:, 1:, :].mean(dim=1).
            all_feats.append(np.mean(tta_results, axis=0))

    return np.vstack(all_feats), unique_paths
```

```python
import os, torch, numpy as np, pandas as pd
import warnings
import matplotlib.pyplot as plt
import seaborn as sns
from pathlib import Path
from PIL import Image
from tqdm import tqdm
from lightgbm import LGBMRegressor
from xgboost import XGBRegressor
from catboost import CatBoostRegressor
from sklearn.multioutput import MultiOutputRegressor
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import KFold
from sklearn.metrics import r2_score
from transformers import AutoModel
import torchvision.transforms as transforms

# --- SILENCE WARNINGS ---
warnings.filterwarnings("ignore", category=SyntaxWarning)
warnings.filterwarnings("ignore", category=UserWarning)
os.environ['TF_CPP_MIN_LOG_LEVEL'] = '3'

# --- CONFIGURATION ---
CFG = {
    "base_path": Path("/kaggle/input/csiro-biomass"),
    "model_path": "/kaggle/input/dinov2/pytorch/large/1",
    "device": torch.device("cuda" if torch.cuda.is_available() else "cpu"),
    "n_splits": 5,
    "seed": 42
}

TARGETS = ['Dry_Green_g', 'Dry_Dead_g', 'Dry_Clover_g', 'GDM_g', 'Dry_Total_g']
COMP_WEIGHTS = np.array([0.1, 0.1, 0.1, 0.2, 0.5])
MEAN, STD = [0.485, 0.456, 0.406], [0.229, 0.224, 0.225]

# --- 1. METRICS ---
def weighted_r2_metric(y_true, y_pred):
    # Calculate R2 for each target
    r2_scores = []
    for i in range(y_true.shape[1]):
        r2_scores.append(r2_score(y_true[:, i], y_pred[:, i]))
    # Apply competition weights
    return np.sum(np.array(r2_scores) * COMP_WEIGHTS)

# --- 2. FEATURE EXTRACTION ---
def extract_dense_features(df, model):
    tta_transforms = [
        transforms.Compose([transforms.ToTensor(), transforms.Resize((224, 224)), transforms.Normalize(MEAN, STD)
        transforms.Compose([transforms.RandomHorizontalFlip(p=1.0), transforms.ToTensor(), transforms.Resize((224
    ]
    unique_paths = df['image_path'].unique()
    all_feats = []
    with torch.no_grad():
        for path in tqdm(unique_paths, desc="GPU Feature Extraction"):
            img = Image.open(CFG["base_path"] / path).convert("RGB")
            tta_results = [model(aug(img).unsqueeze(0).to(CFG["device"])).last_hidden_state[:, 1:, :].mean(dim=1)
            all_feats.append(np.mean(tta_results, axis=0))

    feat_matrix = np.vstack(all_feats)
    feat_cols = [f"feat_{i}" for i in range(feat_matrix.shape[1])]
    return pd.DataFrame(feat_matrix, columns=feat_cols), unique_paths

# --- 3. PIPELINE ---
def run_pipeline():
    model_dir = os.path.abspath(CFG["model_path"])
    model = AutoModel.from_pretrained(model_dir, local_files_only=True, trust_remote_code=True).to(CFG["device"])

    # Data Preparation
    train_df = pd.read_csv(CFG["base_path"] / "train.csv")
    train_p = train_df.pivot_table(index="image_path", columns="target_name", values="target").reset_index()
    X_train_df, _ = extract_dense_features(train_p, model)
    Y_train_log = np.log1p(train_p[TARGETS].values)

    scaler = StandardScaler()
    X_train_scaled = pd.DataFrame(scaler.fit_transform(X_train_df), columns=X_train_df.columns)

    # Model Definitions
    models_to_test = {
        "LightGBM": MultiOutputRegressor(LGBMRegressor(n_estimators=200, learning_rate=0.05, verbosity=-1, random_
        "XGBoost": MultiOutputRegressor(XGBRegressor(n_estimators=200, learning_rate=0.05, random_state=CFG["seed
        "CatBoost": MultiOutputRegressor(CatBoostRegressor(n_estimators=200, learning_rate=0.05, verbose=0, rando
    }

    cv_results = []
    kf = KFold(n_splits=CFG["n_splits"], shuffle=True, random_state=CFG["seed"])

    # --- CROSS VALIDATION LOOP ---
    for name, regressor in models_to_test.items():
        print(f"\nEvaluating {name}...")
        fold_scores = []

        for fold, (train_idx, val_idx) in enumerate(kf.split(X_train_scaled, Y_train_log)):
            X_tr, X_vl = X_train_scaled.iloc[train_idx], X_train_scaled.iloc[val_idx]
            y_tr, y_vl = Y_train_log[train_idx], Y_train_log[val_idx]

            regressor.fit(X_tr, y_tr)
            preds = regressor.predict(X_vl)

            # Use competition weighted R2 metric
            score = weighted_r2_metric(y_vl, preds)
            fold_scores.append(score)
            print(f" Fold {fold+1} Weighted R2: {score:.4f}")

        avg_score = np.mean(fold_scores)
        std_score = np.std(fold_scores)
        cv_results.append({"Model": name, "Avg_R2": avg_score, "Std_R2": std_score})
        print(f"Average {name} Weighted R2: {avg_score:.4f} (+/- {std_score:.4f})")

    # --- RESULTS VISUALIZATION ---
    res_df = pd.DataFrame(cv_results)
    plt.figure(figsize=(10, 6))
    sns.barplot(x="Model", y="Avg_R2", data=res_df, palette="viridis")
    plt.errorbar(x=res_df["Model"], y=res_df["Avg_R2"], yerr=res_df["Std_R2"], fmt='none', c='black', capsize=5)
    plt.title("Model Comparison: Average Weighted R2 Score (5-Fold CV)")
    plt.ylabel("Weighted R2 Score")
    plt.ylim(0, 1.0)
    plt.savefig("model_comparison.png")
    print("\nChart saved to model_comparison.png")

    # --- FINAL PREDICTIONS (Using best model) ---
    best_model_name = res_df.loc[res_df["Avg_R2"].idxmax(), "Model"]
    print(f"\nFinal Inference using {best_model_name}")

    final_regressor = models_to_test[best_model_name]
    final_regressor.fit(X_train_scaled, Y_train_log)

    test_df = pd.read_csv(CFG["base_path"] / "test.csv")
    test_uniq = pd.DataFrame({'image_path': test_df['image_path'].unique()})
    X_test_df, test_ids = extract_dense_features(test_uniq, model)
    X_test_scaled = pd.DataFrame(scaler.transform(X_test_df), columns=X_test_df.columns)

    test_preds_log = final_regressor.predict(X_test_scaled)
    avg_preds = np.maximum(np.expm1(test_preds_log), 0)

    # Submission
    final_rows = []
    for i, path in enumerate(test_ids):
        image_id = Path(path).stem
        for j, target_name in enumerate(TARGETS):
            final_rows.append({"sample_id": f"{image_id}__{target_name}", "target": avg_preds[i, j]})

    pd.DataFrame(final_rows).to_csv("submission.csv", index=False)
    print("Submission saved to submission.csv")

if __name__ == "__main__":
    run_pipeline()
```

```
/usr/local/lib/python3.12/dist-packages/sqlalchemy/orm/query.py:195: SyntaxWarning: "is not" with 'tuple' literal. Did you mean
  if entities is not ():
GPU Feature Extraction: 100%|██████████| 357/357 [01:13<00:00,  4.84it/s]

Evaluating LightGBM...
 Fold 1 Weighted R2: 0.5807
 Fold 2 Weighted R2: 0.6072
 Fold 3 Weighted R2: 0.7106
 Fold 4 Weighted R2: 0.6237
 Fold 5 Weighted R2: 0.5682
Average LightGBM Weighted R2: 0.6181 (+/- 0.0502)

Evaluating XGBoost...
 Fold 1 Weighted R2: 0.5319
 Fold 2 Weighted R2: 0.5610
 Fold 3 Weighted R2: 0.6550
 Fold 4 Weighted R2: 0.5169
 Fold 5 Weighted R2: 0.5046
Average XGBoost Weighted R2: 0.5539 (+/- 0.0539)

Evaluating CatBoost...
 Fold 1 Weighted R2: 0.6191
 Fold 2 Weighted R2: 0.6285
 Fold 3 Weighted R2: 0.6873
 Fold 4 Weighted R2: 0.6492
 Fold 5 Weighted R2: 0.5604
Average CatBoost Weighted R2: 0.6289 (+/- 0.0415)

Chart saved to model_comparison.png

Final Inference using CatBoost
/tmp/ipykernel_55/1591067300.py:112: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `x` variable to `hue` and set

  sns.barplot(x="Model", y="Avg_R2", data=res_df, palette="viridis")
GPU Feature Extraction: 100%|██████████| 1/1 [00:00<00:00,  3.41it/s]
Submission saved to submission.csv
```


Model Comparison: Average Weighted R2 Score (5-Fold CV)
Weighted R2 Score
LightGBM
XGBoost
CatBoost
Model