Imports

```
import os
import warnings
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from PIL import Image

import torch
import torch.nn as nn
import torch.optim as optim
from torch.utils.data import Dataset, DataLoader
from torchvision import transforms

from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler

warnings.filterwarnings("ignore")

```

Configuration & Reproducibility

```
SEED = 42
BASE_PATH = "/kaggle/input/csiro-biomass"
IMG_SIZE = 224
BATCH_SIZE = 16
NUM_EPOCHS = 20
LEARNING_RATE = 1e-3
WEIGHT_DECAY = 1e-4

DEVICE = torch.device("cuda" if torch.cuda.is_available() else "cpu")

np.random.seed(SEED)
torch.manual_seed(SEED)
torch.cuda.manual_seed_all(SEED)
torch.backends.cudnn.deterministic = True
torch.backends.cudnn.benchmark = False

```

Load & Pivot Dataset

```
df = pd.read_csv(os.path.join(BASE_PATH, "train.csv"))

df = df.pivot_table(
    index="image_path",
    columns="target_name",
    values="target"
).reset_index()

df.fillna(0, inplace=True)

TARGET_COLUMNS = [
    'Dry_Green_g',
    'Dry_Dead_g',
    'Dry_Clover_g',
    'GDM_g',
    'Dry_Total_g'
]

print("Dataset shape:", df.shape)

```

```
Dataset shape: (357, 6)
```

Train / Validation Split & Target Scaling

```
train_df, val_df = train_test_split(
    df,
    test_size=0.2,
    random_state=SEED,
    shuffle=True
)

scaler = StandardScaler()
scaler.fit(train_df[TARGET_COLUMNS].values)

```

StandardScaler

```
StandardScaler()
```

Dataset Class

```
class BiomassDataset(Dataset):
    def __init__(self, df, image_dir, transform=None, scaler=None):
        self.df = df.copy()
        self.df["image_path"] = self.df["image_path"].apply(os.path.basename)
        self.samples = list(self.df.itertuples(index=False))
        self.image_dir = image_dir
        self.transform = transform
        self.scaler = scaler

    def __len__(self):
        return len(self.samples)

    def __getitem__(self, idx):
        row = self.samples[idx]
        img = Image.open(
            os.path.join(self.image_dir, row.image_path)
        ).convert("RGB")

        if self.transform:
            img = self.transform(img)

        target = np.array(
            [getattr(row, t) for t in TARGET_COLUMNS],
            dtype=np.float32
        )

        if self.scaler:
            target = self.scaler.transform(target.reshape(1, -1))[0]

        return img, torch.tensor(target)

```

Augmentation Strategies

```
augmentation_configs = {
    "no_aug": transforms.Compose([
        transforms.Resize((IMG_SIZE, IMG_SIZE)),
        transforms.ToTensor(),
        transforms.Normalize([0.485,0.456,0.406],[0.229,0.224,0.225])
    ]),

    "light_aug": transforms.Compose([
        transforms.Resize((IMG_SIZE, IMG_SIZE)),
        transforms.RandomHorizontalFlip(0.5),
        transforms.ToTensor(),
        transforms.Normalize([0.485,0.456,0.406],[0.229,0.224,0.225])
```

```
    ]),

    "medium_aug": transforms.Compose([
        transforms.Resize((IMG_SIZE, IMG_SIZE)),
        transforms.RandomHorizontalFlip(0.5),
        transforms.RandomRotation(15),
        transforms.ColorJitter(0.2,0.2,0.2),
        transforms.ToTensor(),
        transforms.Normalize([0.485,0.456,0.406],[0.229,0.224,0.225])
    ]),

    "strong_aug": transforms.Compose([
        transforms.Resize((IMG_SIZE, IMG_SIZE)),
        transforms.RandomHorizontalFlip(0.5),
        transforms.RandomVerticalFlip(0.3),
        transforms.RandomRotation(25),
        transforms.ColorJitter(0.3,0.3,0.3,0.05),
        transforms.RandomAffine(0, translate=(0.1,0.1), scale=(0.9,1.1)),
        transforms.ToTensor(),
        transforms.Normalize([0.485,0.456,0.406],[0.229,0.224,0.225])
    ])
}

```

Fixed Validation Transform

```
val_transform = transforms.Compose([
    transforms.Resize((IMG_SIZE, IMG_SIZE)),
    transforms.ToTensor(),
    transforms.Normalize([0.485,0.456,0.406],[0.229,0.224,0.225])
])

```

Weighted Loss

```
TARGET_WEIGHTS = torch.tensor([0.1,0.1,0.1,0.2,0.5], device=DEVICE)

class WeightedMSELoss(nn.Module):
    def __init__(self, weights):
        super().__init__()
        self.register_buffer("weights", weights)

    def forward(self, preds, targets):
        return ((preds - targets) ** 2 * self.weights).mean()

criterion = WeightedMSELoss(TARGET_WEIGHTS)

```

Weighted R^2 Metric

```
def weighted_r2_score(y_true, y_pred, weights):
    mean_y = y_true.mean(0, keepdim=True)
    ss_res = ((y_true - y_pred)**2).sum(0)
    ss_tot = ((y_true - mean_y)**2).sum(0)
    return (1 - (weights*ss_res).sum() /
            ((weights*ss_tot).sum() + 1e-8)).item()

```

CNN Architecture (Fixed)

```
class CNN(nn.Module):
    def __init__(self, num_filters=256, num_blocks=3, num_outputs=5):
        super().__init__()
```

```
        layers = []
        in_channels = 3

        for _ in range(num_blocks):
            layers += [
                nn.Conv2d(in_channels, num_filters, 3, padding=1),
                nn.BatchNorm2d(num_filters),
                nn.ReLU(inplace=True),
                nn.MaxPool2d(2)
            ]
            in_channels = num_filters

        layers.append(nn.AdaptiveAvgPool2d(1))
        self.features = nn.Sequential(*layers)
        self.regressor = nn.Linear(num_filters, num_outputs)

    def forward(self, x):
        x = self.features(x)
        return self.regressor(x.flatten(1))

```

One-Epoch Train / Eval Function

```
def run_epoch(model, loader, optimizer=None):
    training = optimizer is not None
    model.train() if training else model.eval()

    total_loss, total_r2, n = 0, 0, 0

    with torch.set_grad_enabled(training):
        for imgs, targets in loader:
            imgs, targets = imgs.to(DEVICE), targets.to(DEVICE)
            preds = model(imgs)
            loss = criterion(preds, targets)

            if training:
                optimizer.zero_grad()
                loss.backward()
                optimizer.step()

            b = imgs.size(0)
            total_loss += loss.item() * b
            total_r2 += weighted_r2_score(
                targets, preds, TARGET_WEIGHTS
            ) * b
            n += b

    return total_loss/n, total_r2/n

```

Augmentation Experiment Training Loop

```
results = {}

for aug_name, train_tf in augmentation_configs.items():
    print(f"\n==============================")
    print(f" Augmentation: {aug_name}")
    print(f"==============================")

    train_dataset = BiomassDataset(
        train_df, os.path.join(BASE_PATH,"train"),
        transform=train_tf, scaler=scaler
    )

    val_dataset = BiomassDataset(
        val_df, os.path.join(BASE_PATH,"train"),
        transform=val_transform, scaler=scaler
    )
```

```
    train_loader = DataLoader(train_dataset, BATCH_SIZE, shuffle=True, num_workers=2)
    val_loader = DataLoader(val_dataset, BATCH_SIZE, shuffle=False, num_workers=2)

    model = CNN().to(DEVICE)
    optimizer = optim.Adam(model.parameters(), lr=LEARNING_RATE, weight_decay=WEIGHT_DECAY)

    train_losses, val_losses = [], []
    train_r2s, val_r2s = [], []
    best_val_r2 = -1e9

    for epoch in range(NUM_EPOCHS):
        tr_l, tr_r2 = run_epoch(model, train_loader, optimizer)
        va_l, va_r2 = run_epoch(model, val_loader)

        train_losses.append(tr_l)
        val_losses.append(va_l)
        train_r2s.append(tr_r2)
        val_r2s.append(va_r2)

        best_val_r2 = max(best_val_r2, va_r2)

        print(
            f"Epoch {epoch+1} | "
            f"Train R²: {tr_r2:.4f} | "
            f"Val R²: {va_r2:.4f}"
        )

    results[aug_name] = {
        "avg_train_r2": np.mean(train_r2s),
        "avg_val_r2": np.mean(val_r2s),
        "best_val_r2": best_val_r2,
        "avg_val_loss": np.mean(val_losses),
        "val_r2s": val_r2s
    }

```

```
==============================
 Augmentation: no_aug
==============================
Epoch 1 | Train R²: -0.1831 | Val R²: -2.8216
Epoch 2 | Train R²: 0.0664 | Val R²: -0.0146
Epoch 3 | Train R²: 0.1576 | Val R²: 0.0411
Epoch 4 | Train R²: 0.1791 | Val R²: -0.1129
Epoch 5 | Train R²: 0.1808 | Val R²: 0.1225
Epoch 6 | Train R²: 0.0082 | Val R²: 0.0704
Epoch 7 | Train R²: 0.2041 | Val R²: 0.2345
Epoch 8 | Train R²: 0.1555 | Val R²: 0.1686
Epoch 9 | Train R²: 0.2101 | Val R²: 0.0803
Epoch 10 | Train R²: 0.1847 | Val R²: 0.0706
Epoch 11 | Train R²: 0.2255 | Val R²: -0.0399
Epoch 12 | Train R²: 0.1173 | Val R²: 0.0882
Epoch 13 | Train R²: 0.3186 | Val R²: 0.2098
Epoch 14 | Train R²: 0.2740 | Val R²: -0.9007
Epoch 15 | Train R²: 0.1864 | Val R²: -0.1540
Epoch 16 | Train R²: 0.2818 | Val R²: 0.1656
Epoch 17 | Train R²: 0.2715 | Val R²: 0.0951
Epoch 18 | Train R²: 0.2243 | Val R²: 0.2388
Epoch 19 | Train R²: 0.2616 | Val R²: 0.0219
Epoch 20 | Train R²: 0.2633 | Val R²: 0.2370

==============================
 Augmentation: light_aug
==============================
Epoch 1 | Train R²: -0.4480 | Val R²: -1.5534
Epoch 2 | Train R²: 0.0660 | Val R²: -0.3511
Epoch 3 | Train R²: 0.0683 | Val R²: 0.1712
Epoch 4 | Train R²: 0.1027 | Val R²: 0.0276
Epoch 5 | Train R²: 0.1635 | Val R²: 0.1569
Epoch 6 | Train R²: 0.1485 | Val R²: 0.1339
Epoch 7 | Train R²: 0.2036 | Val R²: 0.1470
Epoch 8 | Train R²: 0.1799 | Val R²: 0.0718
Epoch 9 | Train R²: 0.1425 | Val R²: 0.0635
Epoch 10 | Train R²: 0.1764 | Val R²: 0.0832
Epoch 11 | Train R²: 0.2306 | Val R²: 0.1085
Epoch 12 | Train R²: 0.1793 | Val R²: 0.2009
Epoch 13 | Train R²: 0.2249 | Val R²: 0.2300
Epoch 14 | Train R²: 0.2567 | Val R²: 0.1645
```

```
Epoch 15 | Train R²: 0.1710 | Val R²: 0.2055
Epoch 16 | Train R²: 0.2344 | Val R²: 0.1264
Epoch 17 | Train R²: 0.1023 | Val R²: 0.2457
Epoch 18 | Train R²: 0.0796 | Val R²: 0.2131
Epoch 19 | Train R²: 0.2690 | Val R²: -0.2056
Epoch 20 | Train R²: 0.1614 | Val R²: 0.2055

==============================
 Augmentation: medium_aug
==============================
Epoch 1 | Train R²: -0.3304 | Val R²: -0.1119
Epoch 2 | Train R²: 0.0460 | Val R²: -0.0194
Epoch 3 | Train R²: 0.0894 | Val R²: 0.1630
Epoch 4 | Train R²: 0.0306 | Val R²: 0.0947
Epoch 5 | Train R²: 0.0684 | Val R²: 0.1261
Epoch 6 | Train R²: 0.0060 | Val R²: 0.1705
```

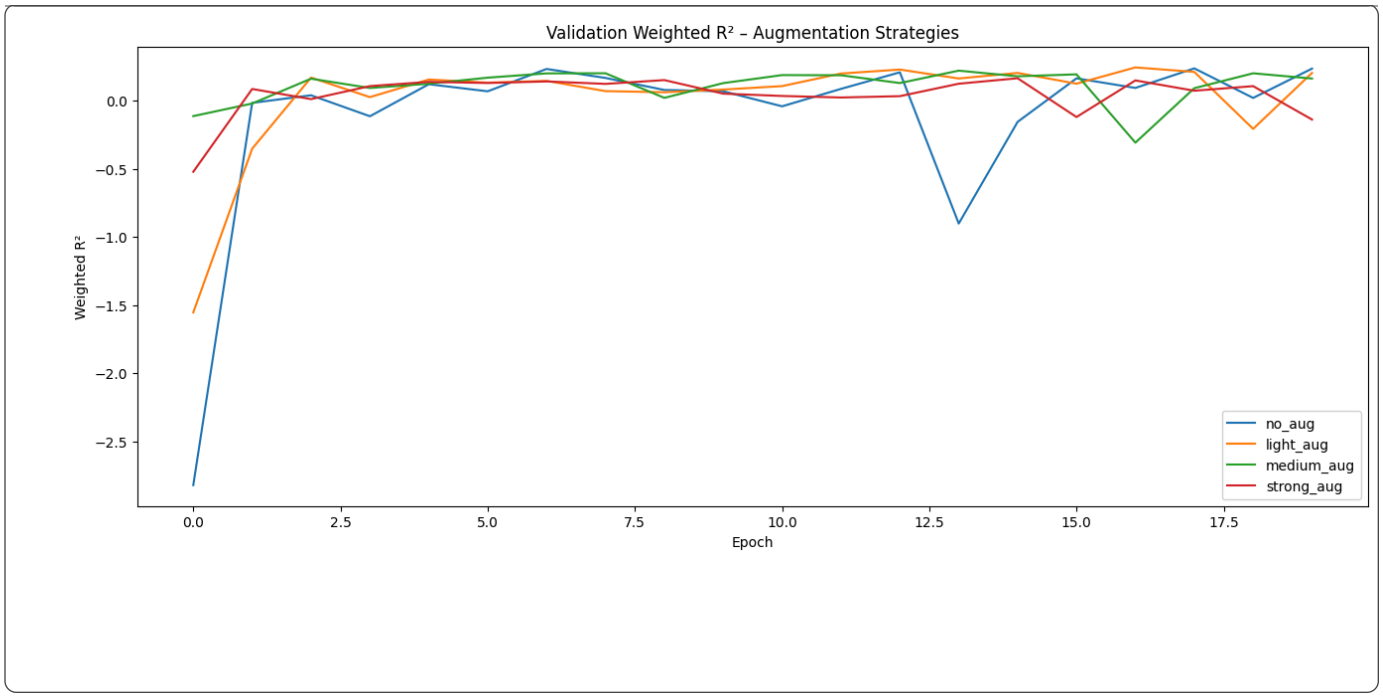
Summary Table

```
summary_df = pd.DataFrame([
    {
        "Augmentation": k,
        "Avg Val R²": results[k]["avg_val_r2"],
        "Best Val R²": results[k]["best_val_r2"],
        "Avg Val Loss": results[k]["avg_val_loss"]
    }
    for k in results
]).sort_values("Avg Val R²", ascending=False)

display(summary_df)

```

	Augmentation	Avg Val R²	Best Val R²	Avg Val Loss
2	medium_aug	0.112023	0.222104	0.120532
3	strong_aug	0.044965	0.166239	0.131189
1	light_aug	0.022247	0.245681	0.127315
0	no_aug	-0.109971	0.238753	0.140283

Validation R^2 Plot

```
plt.figure(figsize=(16,6))
for k in results:
    plt.plot(results[k]["val_r2s"], label=k)
plt.title("Validation Weighted R² – Augmentation Strategies")
plt.xlabel("Epoch")
plt.ylabel("Weighted R²")
plt.legend()
plt.show()

```


Validation Weighted R² – Augmentation Strategies
Weighted R²
Epoch
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
no_aug
light_aug
medium_aug
strong_aug