fase3_2

May 22, 2025

[11]:
```
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras import Model, Input
from tensorflow.keras.layers import Dense
from tensorflow.keras.models import load_model
import matplotlib.pyplot as plt

# ------------------------------------------------
# 1. Carregar dados reais (B1-F2) e sintéticos gerados na Fase 2
# ------------------------------------------------
# 1.1) Real
df_full = pd.read_csv("/home/darkcover/Documentos/Gan/Data/Real/trainingData.
 ↪csv")
wap_cols = [c for c in df_full.columns if c.startswith("WAP")]
df_full[wap_cols] = df_full[wap_cols].replace(100, -110)
df_real = df_full[(df_full.BUILDINGID==1)&(df_full.FLOOR==2)].copy()
present_waps = [c for c in wap_cols if (df_real[c] != -110).any()]  # ~190 WAPs␣
 ↪:contentReference[oaicite:1]{index=1}
df_real = df_real[present_waps + ["LONGITUDE","LATITUDE"]]
df_real.rename(columns={"LONGITUDE":"X","LATITUDE":"Y"}, inplace=True)

# 1.2) Sintéticos
df_gen = pd.read_csv("/home/darkcover/Documentos/Gan/Data/
 ↪df_generated_UJIndoorLoc.csv")   # 40 000×190 RSSI :contentReference[oaicite:
 ↪3]{index=3}

# ------------------------------------------------
# 2. Treinar modelo DNN para pseudo-rotulação
# ------------------------------------------------
X_real = df_real[present_waps].values.astype(np.float32)
y_real = df_real[["X","Y"]].values.astype(np.float32)

inp = Input(shape=(len(present_waps),))
x   = Dense(30, activation="relu")(inp)
x   = Dense(20, activation="relu")(x)
out = Dense(2, activation="linear")(x)
```

```
model_dnn = Model(inp, out, name="PseudoLabel_UJ")
model_dnn.compile(optimizer=tf.keras.optimizers.Adam(0.01), loss="mse")

model_dnn.fit(
    X_real, y_real,
    epochs=250, batch_size=100,
    validation_split=0.2, verbose=1
)
model_dnn.save("/home/darkcover/Documentos/Gan/Models/pseudo_label_model_UJ.
 ↪keras")                    #:contentReference[oaicite:5]{index=5}

# ------------------------------------------------
# 3. Predição de (X,Y) e D_score
# ------------------------------------------------
X_gen = df_gen[present_waps].values.astype(np.float32)
coords = model_dnn.predict(X_gen, verbose=1)
df_gen[["X","Y"]] = coords

disc = load_model("/home/darkcover/Documentos/Gan/Models/
 ↪discriminator_phase2_UJ.keras")
d_scores = disc.predict(X_gen, verbose=1).flatten()
df_gen["D_score"] = d_scores

# salvar com coordenadas + confiança
df_gen.to_csv("/home/darkcover/Documentos/Gan/Data/df_generated_with_coords.
 ↪csv", index=False)

# ------------------------------------------------
# 4. Seleção Inteligente (1 000 amostras = 10×10 zonas de 2 m)
# ------------------------------------------------
L, W = 20.0, 20.0
zone_size = 2.0
nx, ny = int(L/zone_size), int(W/zone_size)
num_zones = nx*ny
k = 1000 // num_zones  # 10 por zona

# atribuir zona
df_gen['zone_x'] = np.minimum((df_gen['X']//zone_size).astype(int), nx-1)
df_gen['zone_y'] = np.minimum((df_gen['Y']//zone_size).astype(int), ny-1)
df_gen['zone_id'] = df_gen['zone_x']*ny + df_gen['zone_y']

# top-k por zona
selected = (
    df_gen
    .groupby('zone_id', as_index=False)
    .apply(lambda g: g.nlargest(k, 'D_score'))
    .reset_index(drop=True)
```

```
)
selected.to_csv("/home/darkcover/Documentos/Gan/Data/df_selected_synthetic.
  ↪csv", index=False)
```

```
Epoch 1/250
12/12             3s 30ms/step -
loss: 11821125730304.0000 - val_loss: 11749446123520.0000
Epoch 2/250
12/12             0s 11ms/step -
loss: 11694933803008.0000 - val_loss: 11436867715072.0000
Epoch 3/250
12/12             0s 11ms/step -
loss: 11282134597632.0000 - val_loss: 10630062931968.0000
Epoch 4/250
12/12             0s 11ms/step -
loss: 10294076112896.0000 - val_loss: 9002108846080.0000
Epoch 5/250
12/12             0s 12ms/step -
loss: 8421872500736.0000 - val_loss: 6378962288640.0000
Epoch 6/250
12/12             0s 13ms/step -
loss: 5594443939840.0000 - val_loss: 3155409764352.0000
Epoch 7/250
12/12             0s 11ms/step -
loss: 2434006253568.0000 - val_loss: 637365846016.0000
Epoch 8/250
12/12             0s 11ms/step -
loss: 355688906752.0000 - val_loss: 4432541184.0000
Epoch 9/250
12/12             0s 11ms/step -
loss: 33785382912.0000 - val_loss: 69494423552.0000
Epoch 10/250
12/12             0s 11ms/step -
loss: 56117698560.0000 - val_loss: 4683898880.0000
Epoch 11/250
12/12             0s 11ms/step -
loss: 3291883520.0000 - val_loss: 6135585280.0000
Epoch 12/250
12/12             0s 11ms/step -
loss: 4830894080.0000 - val_loss: 3770299648.0000
Epoch 13/250
12/12             0s 10ms/step -
loss: 2131415552.0000 - val_loss: 1451561728.0000
Epoch 14/250
12/12             0s 10ms/step -
loss: 1421660544.0000 - val_loss: 1435903104.0000
Epoch 15/250
12/12             0s 12ms/step -
```

```
loss: 1452767616.0000 - val_loss: 1537308928.0000
Epoch 16/250
12/12            0s 10ms/step -
loss: 1358554880.0000 - val_loss: 1621566592.0000
Epoch 17/250
12/12            0s 11ms/step -
loss: 1327240576.0000 - val_loss: 1565458176.0000
Epoch 18/250
12/12            0s 11ms/step -
loss: 1385733376.0000 - val_loss: 1518996096.0000
Epoch 19/250
12/12            0s 11ms/step -
loss: 1444157440.0000 - val_loss: 1544569344.0000
Epoch 20/250
12/12            0s 13ms/step -
loss: 1394344448.0000 - val_loss: 1552564864.0000
Epoch 21/250
12/12            0s 11ms/step -
loss: 1346098304.0000 - val_loss: 1541730944.0000
Epoch 22/250
12/12            0s 14ms/step -
loss: 1381743872.0000 - val_loss: 1552942464.0000
Epoch 23/250
12/12            0s 17ms/step -
loss: 1440544896.0000 - val_loss: 1542195328.0000
Epoch 24/250
12/12            0s 11ms/step -
loss: 1187185536.0000 - val_loss: 1548562944.0000
Epoch 25/250
12/12            0s 12ms/step -
loss: 1325497600.0000 - val_loss: 1531553664.0000
Epoch 26/250
12/12            0s 14ms/step -
loss: 1335135488.0000 - val_loss: 1542153856.0000
Epoch 27/250
12/12            0s 11ms/step -
loss: 1284353280.0000 - val_loss: 1562755840.0000
Epoch 28/250
12/12            0s 13ms/step -
loss: 1295922176.0000 - val_loss: 1551929216.0000
Epoch 29/250
12/12            0s 11ms/step -
loss: 1435904768.0000 - val_loss: 1518398080.0000
Epoch 30/250
12/12            0s 11ms/step -
loss: 1284737152.0000 - val_loss: 1528762752.0000
Epoch 31/250
12/12            0s 10ms/step -
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loss: 1339010816.0000 - val_loss: 1521275264.0000
Epoch 32/250
12/12            0s 14ms/step -
loss: 1394191744.0000 - val_loss: 1528633600.0000
Epoch 33/250
12/12            0s 11ms/step -
loss: 1338977920.0000 - val_loss: 1525582592.0000
Epoch 34/250
12/12            0s 11ms/step -
loss: 1175326592.0000 - val_loss: 1496711296.0000
Epoch 35/250
12/12            0s 13ms/step -
loss: 1295245056.0000 - val_loss: 1514114304.0000
Epoch 36/250
12/12            0s 12ms/step -
loss: 1258831232.0000 - val_loss: 1542867840.0000
Epoch 37/250
12/12            0s 30ms/step -
loss: 1317022976.0000 - val_loss: 1516204800.0000
Epoch 38/250
12/12            0s 17ms/step -
loss: 1381184000.0000 - val_loss: 1527587072.0000
Epoch 39/250
12/12            0s 17ms/step -
loss: 1406986112.0000 - val_loss: 1515336448.0000
Epoch 40/250
12/12            0s 12ms/step -
loss: 1271159680.0000 - val_loss: 1518564864.0000
Epoch 41/250
12/12            0s 10ms/step -
loss: 1268127616.0000 - val_loss: 1473149056.0000
Epoch 42/250
12/12            0s 12ms/step -
loss: 1288209152.0000 - val_loss: 1505884672.0000
Epoch 43/250
12/12            0s 10ms/step -
loss: 1230949760.0000 - val_loss: 1527820160.0000
Epoch 44/250
12/12            0s 10ms/step -
loss: 1330612352.0000 - val_loss: 1484304768.0000
Epoch 45/250
12/12            0s 11ms/step -
loss: 1415599232.0000 - val_loss: 1512286720.0000
Epoch 46/250
12/12            0s 10ms/step -
loss: 1289804800.0000 - val_loss: 1537957888.0000
Epoch 47/250
12/12            0s 11ms/step -
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loss: 1353890944.0000 - val_loss: 1522492160.0000
Epoch 48/250
12/12            0s 11ms/step -
loss: 1334820736.0000 - val_loss: 1487499136.0000
Epoch 49/250
12/12            0s 11ms/step -
loss: 1370687104.0000 - val_loss: 1486514432.0000
Epoch 50/250
12/12            0s 10ms/step -
loss: 1338198272.0000 - val_loss: 1483123456.0000
Epoch 51/250
12/12            0s 10ms/step -
loss: 1217737472.0000 - val_loss: 1480951296.0000
Epoch 52/250
12/12            0s 11ms/step -
loss: 1310816128.0000 - val_loss: 1470834560.0000
Epoch 53/250
12/12            0s 10ms/step -
loss: 1383381120.0000 - val_loss: 1466945664.0000
Epoch 54/250
12/12            0s 10ms/step -
loss: 1235101056.0000 - val_loss: 1484679808.0000
Epoch 55/250
12/12            0s 18ms/step -
loss: 1291668352.0000 - val_loss: 1495298176.0000
Epoch 56/250
12/12            0s 11ms/step -
loss: 1249147520.0000 - val_loss: 1462872320.0000
Epoch 57/250
12/12            0s 10ms/step -
loss: 1327681152.0000 - val_loss: 1483620608.0000
Epoch 58/250
12/12            0s 10ms/step -
loss: 1214098048.0000 - val_loss: 1475745152.0000
Epoch 59/250
12/12            0s 11ms/step -
loss: 1344478080.0000 - val_loss: 1477428608.0000
Epoch 60/250
12/12            0s 10ms/step -
loss: 1292239872.0000 - val_loss: 1475943808.0000
Epoch 61/250
12/12            0s 10ms/step -
loss: 1302522496.0000 - val_loss: 1489378944.0000
Epoch 62/250
12/12            0s 11ms/step -
loss: 1252274176.0000 - val_loss: 1448485504.0000
Epoch 63/250
12/12            0s 11ms/step -
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loss: 1210284544.0000 - val_loss: 1482618752.0000
Epoch 64/250
12/12            0s 10ms/step -
loss: 1224398336.0000 - val_loss: 1445371136.0000
Epoch 65/250
12/12            0s 11ms/step -
loss: 1278023936.0000 - val_loss: 1458355072.0000
Epoch 66/250
12/12            0s 10ms/step -
loss: 1280632960.0000 - val_loss: 1469121920.0000
Epoch 67/250
12/12            0s 11ms/step -
loss: 1292196224.0000 - val_loss: 1458057472.0000
Epoch 68/250
12/12            0s 10ms/step -
loss: 1291245696.0000 - val_loss: 1441170048.0000
Epoch 69/250
12/12            0s 11ms/step -
loss: 1377096448.0000 - val_loss: 1476396672.0000
Epoch 70/250
12/12            0s 10ms/step -
loss: 1250580096.0000 - val_loss: 1454212992.0000
Epoch 71/250
12/12            0s 11ms/step -
loss: 1327602432.0000 - val_loss: 1423644544.0000
Epoch 72/250
12/12            0s 11ms/step -
loss: 1281182336.0000 - val_loss: 1461246464.0000
Epoch 73/250
12/12            0s 11ms/step -
loss: 1217371264.0000 - val_loss: 1421895296.0000
Epoch 74/250
12/12            0s 10ms/step -
loss: 1204784640.0000 - val_loss: 1434458240.0000
Epoch 75/250
12/12            0s 11ms/step -
loss: 1227967488.0000 - val_loss: 1459366784.0000
Epoch 76/250
12/12            0s 10ms/step -
loss: 1204781056.0000 - val_loss: 1467856128.0000
Epoch 77/250
12/12            0s 11ms/step -
loss: 1207777408.0000 - val_loss: 1416283008.0000
Epoch 78/250
12/12            0s 11ms/step -
loss: 1227794560.0000 - val_loss: 1447147904.0000
Epoch 79/250
12/12            0s 24ms/step -
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loss: 1351383552.0000 - val_loss: 1421209088.0000
Epoch 80/250
12/12             0s 10ms/step -
loss: 1201980288.0000 - val_loss: 1461341568.0000
Epoch 81/250
12/12             0s 10ms/step -
loss: 1236407040.0000 - val_loss: 1410868608.0000
Epoch 82/250
12/12             0s 10ms/step -
loss: 1309560448.0000 - val_loss: 1422832640.0000
Epoch 83/250
12/12             0s 11ms/step -
loss: 1225887104.0000 - val_loss: 1408290944.0000
Epoch 84/250
12/12             0s 10ms/step -
loss: 1244954368.0000 - val_loss: 1416310016.0000
Epoch 85/250
12/12             0s 10ms/step -
loss: 1257765120.0000 - val_loss: 1415318784.0000
Epoch 86/250
12/12             0s 11ms/step -
loss: 1182648576.0000 - val_loss: 1391701632.0000
Epoch 87/250
12/12             0s 11ms/step -
loss: 1181315968.0000 - val_loss: 1416086144.0000
Epoch 88/250
12/12             0s 10ms/step -
loss: 1280235008.0000 - val_loss: 1397289600.0000
Epoch 89/250
12/12             0s 10ms/step -
loss: 1294597248.0000 - val_loss: 1424905600.0000
Epoch 90/250
12/12             0s 10ms/step -
loss: 1320516992.0000 - val_loss: 1402949760.0000
Epoch 91/250
12/12             0s 12ms/step -
loss: 1333885312.0000 - val_loss: 1386031104.0000
Epoch 92/250
12/12             0s 10ms/step -
loss: 1178346112.0000 - val_loss: 1412083072.0000
Epoch 93/250
12/12             0s 11ms/step -
loss: 1190767744.0000 - val_loss: 1373356544.0000
Epoch 94/250
12/12             0s 10ms/step -
loss: 1203112320.0000 - val_loss: 1403592960.0000
Epoch 95/250
12/12             0s 11ms/step -
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loss: 1272323712.0000 - val_loss: 1371292160.0000
Epoch 96/250
12/12            0s 10ms/step -
loss: 1215879424.0000 - val_loss: 1396479488.0000
Epoch 97/250
12/12            0s 10ms/step -
loss: 1124198784.0000 - val_loss: 1376752256.0000
Epoch 98/250
12/12            0s 11ms/step -
loss: 1146043264.0000 - val_loss: 1370930048.0000
Epoch 99/250
12/12            0s 11ms/step -
loss: 1270665984.0000 - val_loss: 1391031296.0000
Epoch 100/250
12/12            0s 10ms/step -
loss: 1186797056.0000 - val_loss: 1354082432.0000
Epoch 101/250
12/12            0s 10ms/step -
loss: 1187070464.0000 - val_loss: 1363309568.0000
Epoch 102/250
12/12            0s 11ms/step -
loss: 1156782592.0000 - val_loss: 1360887424.0000
Epoch 103/250
12/12            0s 11ms/step -
loss: 1184460288.0000 - val_loss: 1356830848.0000
Epoch 104/250
12/12            0s 10ms/step -
loss: 1230513792.0000 - val_loss: 1374621312.0000
Epoch 105/250
12/12            0s 11ms/step -
loss: 1227921280.0000 - val_loss: 1353616768.0000
Epoch 106/250
12/12            0s 11ms/step -
loss: 1237669760.0000 - val_loss: 1367338240.0000
Epoch 107/250
12/12            0s 10ms/step -
loss: 1121799680.0000 - val_loss: 1342680320.0000
Epoch 108/250
12/12            0s 11ms/step -
loss: 1164164352.0000 - val_loss: 1347270784.0000
Epoch 109/250
12/12            0s 10ms/step -
loss: 1131243136.0000 - val_loss: 1339825152.0000
Epoch 110/250
12/12            0s 11ms/step -
loss: 1196226176.0000 - val_loss: 1337557504.0000
Epoch 111/250
12/12            0s 10ms/step -
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loss: 1198385280.0000 - val_loss: 1365396608.0000
Epoch 112/250
12/12            0s 11ms/step -
loss: 1227887744.0000 - val_loss: 1321152640.0000
Epoch 113/250
12/12            0s 10ms/step -
loss: 1244901376.0000 - val_loss: 1358645760.0000
Epoch 114/250
12/12            0s 10ms/step -
loss: 1190183808.0000 - val_loss: 1315092608.0000
Epoch 115/250
12/12            0s 10ms/step -
loss: 1218214784.0000 - val_loss: 1335833216.0000
Epoch 116/250
12/12            0s 12ms/step -
loss: 1109022592.0000 - val_loss: 1320521472.0000
Epoch 117/250
12/12            0s 11ms/step -
loss: 1257390080.0000 - val_loss: 1320896128.0000
Epoch 118/250
12/12            0s 10ms/step -
loss: 1138699904.0000 - val_loss: 1327959808.0000
Epoch 119/250
12/12            0s 11ms/step -
loss: 1035445248.0000 - val_loss: 1296239872.0000
Epoch 120/250
12/12            0s 18ms/step -
loss: 1196465792.0000 - val_loss: 1328130304.0000
Epoch 121/250
12/12            0s 10ms/step -
loss: 1180300032.0000 - val_loss: 1307115776.0000
Epoch 122/250
12/12            0s 10ms/step -
loss: 1113031296.0000 - val_loss: 1302682496.0000
Epoch 123/250
12/12            0s 10ms/step -
loss: 1163534208.0000 - val_loss: 1320623360.0000
Epoch 124/250
12/12            0s 11ms/step -
loss: 1209185664.0000 - val_loss: 1302860544.0000
Epoch 125/250
12/12            0s 11ms/step -
loss: 1243038336.0000 - val_loss: 1321038720.0000
Epoch 126/250
12/12            0s 10ms/step -
loss: 1072806336.0000 - val_loss: 1272131456.0000
Epoch 127/250
12/12            0s 11ms/step -
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```
loss: 1125135872.0000 - val_loss: 1309985536.0000
Epoch 128/250
12/12            0s 10ms/step -
loss: 1161094528.0000 - val_loss: 1289011968.0000
Epoch 129/250
12/12            0s 17ms/step -
loss: 1119024256.0000 - val_loss: 1288774272.0000
Epoch 130/250
12/12            0s 14ms/step -
loss: 1111980416.0000 - val_loss: 1272762752.0000
Epoch 131/250
12/12            0s 10ms/step -
loss: 1131213056.0000 - val_loss: 1284154496.0000
Epoch 132/250
12/12            0s 10ms/step -
loss: 1144383488.0000 - val_loss: 1295398784.0000
Epoch 133/250
12/12            0s 10ms/step -
loss: 1115837568.0000 - val_loss: 1271689600.0000
Epoch 134/250
12/12            0s 10ms/step -
loss: 1086776704.0000 - val_loss: 1272075264.0000
Epoch 135/250
12/12            0s 10ms/step -
loss: 1031638400.0000 - val_loss: 1269587712.0000
Epoch 136/250
12/12            0s 11ms/step -
loss: 1163720960.0000 - val_loss: 1272215936.0000
Epoch 137/250
12/12            0s 11ms/step -
loss: 1140239872.0000 - val_loss: 1267256064.0000
Epoch 138/250
12/12            0s 11ms/step -
loss: 1063352512.0000 - val_loss: 1250539008.0000
Epoch 139/250
12/12            0s 10ms/step -
loss: 1079614464.0000 - val_loss: 1263288704.0000
Epoch 140/250
12/12            0s 13ms/step -
loss: 1060639168.0000 - val_loss: 1251678080.0000
Epoch 141/250
12/12            0s 11ms/step -
loss: 1105408384.0000 - val_loss: 1238285696.0000
Epoch 142/250
12/12            0s 11ms/step -
loss: 1170570880.0000 - val_loss: 1256027904.0000
Epoch 143/250
12/12            0s 10ms/step -
```

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loss: 1051963520.0000 - val_loss: 1227569152.0000
Epoch 144/250
12/12            0s 10ms/step -
loss: 1121336064.0000 - val_loss: 1258813824.0000
Epoch 145/250
12/12            0s 10ms/step -
loss: 1087337472.0000 - val_loss: 1229208320.0000
Epoch 146/250
12/12            0s 10ms/step -
loss: 1071183744.0000 - val_loss: 1227620992.0000
Epoch 147/250
12/12            0s 10ms/step -
loss: 1136542464.0000 - val_loss: 1243032960.0000
Epoch 148/250
12/12            0s 11ms/step -
loss: 1081383168.0000 - val_loss: 1214736512.0000
Epoch 149/250
12/12            0s 11ms/step -
loss: 1093211392.0000 - val_loss: 1240239104.0000
Epoch 150/250
12/12            0s 11ms/step -
loss: 1114293504.0000 - val_loss: 1221773696.0000
Epoch 151/250
12/12            0s 10ms/step -
loss: 1134534656.0000 - val_loss: 1214185984.0000
Epoch 152/250
12/12            0s 11ms/step -
loss: 1064322816.0000 - val_loss: 1226336256.0000
Epoch 153/250
12/12            0s 11ms/step -
loss: 1084058880.0000 - val_loss: 1204364672.0000
Epoch 154/250
12/12            0s 27ms/step -
loss: 1054210240.0000 - val_loss: 1195871360.0000
Epoch 155/250
12/12            0s 12ms/step -
loss: 999930432.0000 - val_loss: 1246494080.0000
Epoch 156/250
12/12            0s 13ms/step -
loss: 1067959360.0000 - val_loss: 1198473728.0000
Epoch 157/250
12/12            0s 14ms/step -
loss: 1006617088.0000 - val_loss: 1191570432.0000
Epoch 158/250
12/12            0s 12ms/step -
loss: 1063783360.0000 - val_loss: 1212609536.0000
Epoch 159/250
12/12            0s 10ms/step -
```

```
loss: 1103948416.0000 - val_loss: 1190610048.0000
Epoch 160/250
12/12            0s 10ms/step -
loss: 945140416.0000 - val_loss: 1180348928.0000
Epoch 161/250
12/12            0s 10ms/step -
loss: 1030850624.0000 - val_loss: 1199040128.0000
Epoch 162/250
12/12            0s 10ms/step -
loss: 1086534528.0000 - val_loss: 1192679168.0000
Epoch 163/250
12/12            0s 10ms/step -
loss: 1004252160.0000 - val_loss: 1176673664.0000
Epoch 164/250
12/12            0s 10ms/step -
loss: 1040039616.0000 - val_loss: 1171837568.0000
Epoch 165/250
12/12            0s 11ms/step -
loss: 1019734336.0000 - val_loss: 1195496960.0000
Epoch 166/250
12/12            0s 11ms/step -
loss: 1027359424.0000 - val_loss: 1166891392.0000
Epoch 167/250
12/12            0s 10ms/step -
loss: 1055435520.0000 - val_loss: 1179108352.0000
Epoch 168/250
12/12            0s 10ms/step -
loss: 991102144.0000 - val_loss: 1160248960.0000
Epoch 169/250
12/12            0s 10ms/step -
loss: 1001505728.0000 - val_loss: 1172981760.0000
Epoch 170/250
12/12            0s 10ms/step -
loss: 974665344.0000 - val_loss: 1155425664.0000
Epoch 171/250
12/12            0s 11ms/step -
loss: 1023173632.0000 - val_loss: 1163089152.0000
Epoch 172/250
12/12            0s 10ms/step -
loss: 999692608.0000 - val_loss: 1150186112.0000
Epoch 173/250
12/12            0s 10ms/step -
loss: 958365760.0000 - val_loss: 1149737856.0000
Epoch 174/250
12/12            0s 10ms/step -
loss: 1029921344.0000 - val_loss: 1143641088.0000
Epoch 175/250
12/12            0s 11ms/step -
```

```
loss: 1038665536.0000 - val_loss: 1168137600.0000
Epoch 176/250
12/12            0s 10ms/step -
loss: 1009490816.0000 - val_loss: 1139046912.0000
Epoch 177/250
12/12            0s 16ms/step -
loss: 1052036544.0000 - val_loss: 1143738624.0000
Epoch 178/250
12/12            0s 12ms/step -
loss: 990144704.0000 - val_loss: 1135267456.0000
Epoch 179/250
12/12            0s 10ms/step -
loss: 950951552.0000 - val_loss: 1144118400.0000
Epoch 180/250
12/12            0s 10ms/step -
loss: 1008327808.0000 - val_loss: 1129157248.0000
Epoch 181/250
12/12            0s 20ms/step -
loss: 938052288.0000 - val_loss: 1126308992.0000
Epoch 182/250
12/12            0s 10ms/step -
loss: 1021100160.0000 - val_loss: 1138139648.0000
Epoch 183/250
12/12            0s 11ms/step -
loss: 911541568.0000 - val_loss: 1118516480.0000
Epoch 184/250
12/12            0s 10ms/step -
loss: 1054077440.0000 - val_loss: 1117360896.0000
Epoch 185/250
12/12            0s 11ms/step -
loss: 881228736.0000 - val_loss: 1113607552.0000
Epoch 186/250
12/12            0s 11ms/step -
loss: 954608256.0000 - val_loss: 1116156544.0000
Epoch 187/250
12/12            0s 11ms/step -
loss: 987932160.0000 - val_loss: 1112454144.0000
Epoch 188/250
12/12            0s 11ms/step -
loss: 999079104.0000 - val_loss: 1112052736.0000
Epoch 189/250
12/12            0s 11ms/step -
loss: 952347904.0000 - val_loss: 1102062464.0000
Epoch 190/250
12/12            0s 10ms/step -
loss: 964508928.0000 - val_loss: 1099132928.0000
Epoch 191/250
12/12            0s 10ms/step -
```

```
loss: 893160128.0000 - val_loss: 1106216192.0000
Epoch 192/250
12/12            0s 10ms/step -
loss: 912642240.0000 - val_loss: 1098627072.0000
Epoch 193/250
12/12            0s 11ms/step -
loss: 909476416.0000 - val_loss: 1091635712.0000
Epoch 194/250
12/12            0s 10ms/step -
loss: 913288512.0000 - val_loss: 1087810816.0000
Epoch 195/250
12/12            0s 10ms/step -
loss: 952859520.0000 - val_loss: 1090801024.0000
Epoch 196/250
12/12            0s 11ms/step -
loss: 929929664.0000 - val_loss: 1095329408.0000
Epoch 197/250
12/12            0s 11ms/step -
loss: 859605440.0000 - val_loss: 1095166336.0000
Epoch 198/250
12/12            0s 10ms/step -
loss: 957714688.0000 - val_loss: 1082812032.0000
Epoch 199/250
12/12            0s 11ms/step -
loss: 973707456.0000 - val_loss: 1076443904.0000
Epoch 200/250
12/12            0s 10ms/step -
loss: 1026845440.0000 - val_loss: 1071727040.0000
Epoch 201/250
12/12            0s 12ms/step -
loss: 887828544.0000 - val_loss: 1107300992.0000
Epoch 202/250
12/12            0s 12ms/step -
loss: 987968192.0000 - val_loss: 1077546112.0000
Epoch 203/250
12/12            0s 10ms/step -
loss: 913371264.0000 - val_loss: 1089324544.0000
Epoch 204/250
12/12            0s 10ms/step -
loss: 889719040.0000 - val_loss: 1063845312.0000
Epoch 205/250
12/12            0s 10ms/step -
loss: 870806592.0000 - val_loss: 1062348608.0000
Epoch 206/250
12/12            0s 10ms/step -
loss: 943767296.0000 - val_loss: 1060736576.0000
Epoch 207/250
12/12            0s 13ms/step -
```

```
loss: 953309248.0000 - val_loss: 1062189824.0000
Epoch 208/250
12/12            0s 11ms/step -
loss: 925741696.0000 - val_loss: 1065158464.0000
Epoch 209/250
12/12            0s 10ms/step -
loss: 872905280.0000 - val_loss: 1053633024.0000
Epoch 210/250
12/12            0s 11ms/step -
loss: 888000128.0000 - val_loss: 1053812800.0000
Epoch 211/250
12/12            0s 10ms/step -
loss: 916785920.0000 - val_loss: 1039434432.0000
Epoch 212/250
12/12            0s 10ms/step -
loss: 860489024.0000 - val_loss: 1037257216.0000
Epoch 213/250
12/12            0s 13ms/step -
loss: 897487552.0000 - val_loss: 1035805824.0000
Epoch 214/250
12/12            0s 11ms/step -
loss: 828967744.0000 - val_loss: 1042990336.0000
Epoch 215/250
12/12            0s 10ms/step -
loss: 868911296.0000 - val_loss: 1029946944.0000
Epoch 216/250
12/12            0s 11ms/step -
loss: 876213504.0000 - val_loss: 1030206720.0000
Epoch 217/250
12/12            0s 10ms/step -
loss: 887197120.0000 - val_loss: 1035668928.0000
Epoch 218/250
12/12            0s 10ms/step -
loss: 983117952.0000 - val_loss: 1018776896.0000
Epoch 219/250
12/12            0s 10ms/step -
loss: 894887936.0000 - val_loss: 1016087104.0000
Epoch 220/250
12/12            0s 11ms/step -
loss: 893643776.0000 - val_loss: 1026124800.0000
Epoch 221/250
12/12            0s 10ms/step -
loss: 918571904.0000 - val_loss: 1021319808.0000
Epoch 222/250
12/12            0s 10ms/step -
loss: 901581824.0000 - val_loss: 1019983552.0000
Epoch 223/250
12/12            0s 10ms/step -
```

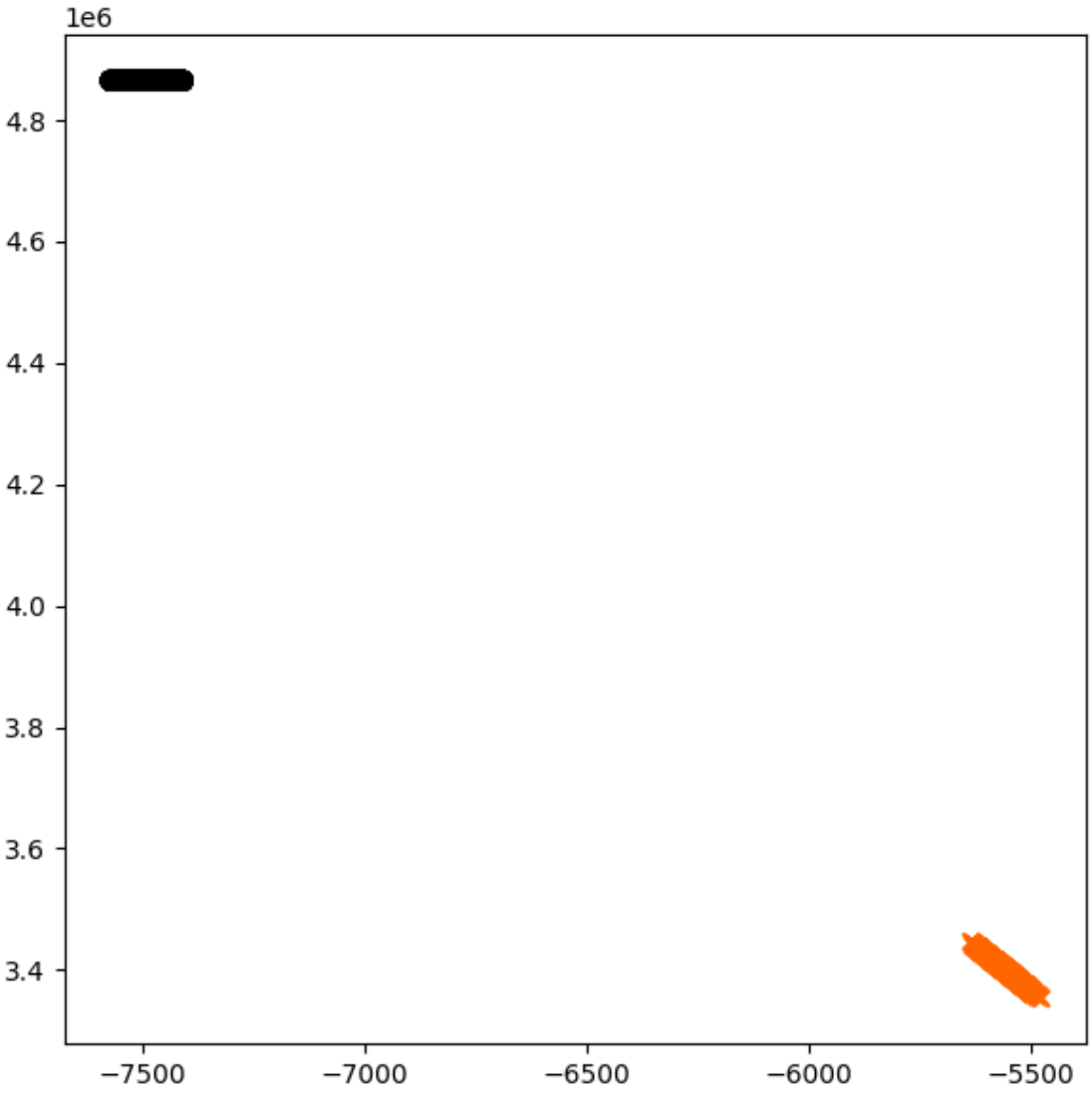
```
loss: 794922176.0000 - val_loss: 1053148672.0000
Epoch 224/250
12/12            0s 10ms/step -
loss: 819604928.0000 - val_loss: 1019803136.0000
Epoch 225/250
12/12            0s 10ms/step -
loss: 761526464.0000 - val_loss: 1004337472.0000
Epoch 226/250
12/12            0s 11ms/step -
loss: 809238336.0000 - val_loss: 996903296.0000
Epoch 227/250
12/12            0s 11ms/step -
loss: 784989632.0000 - val_loss: 1046302400.0000
Epoch 228/250
12/12            0s 10ms/step -
loss: 855480576.0000 - val_loss: 990323136.0000
Epoch 229/250
12/12            0s 10ms/step -
loss: 844307776.0000 - val_loss: 996755520.0000
Epoch 230/250
12/12            0s 11ms/step -
loss: 817896128.0000 - val_loss: 984509184.0000
Epoch 231/250
12/12            0s 10ms/step -
loss: 778596608.0000 - val_loss: 993085952.0000
Epoch 232/250
12/12            0s 10ms/step -
loss: 865754432.0000 - val_loss: 983181120.0000
Epoch 233/250
12/12            0s 11ms/step -
loss: 817406976.0000 - val_loss: 998801152.0000
Epoch 234/250
12/12            0s 16ms/step -
loss: 852506240.0000 - val_loss: 984861056.0000
Epoch 235/250
12/12            0s 11ms/step -
loss: 807011520.0000 - val_loss: 969619136.0000
Epoch 236/250
12/12            0s 11ms/step -
loss: 772992896.0000 - val_loss: 973058560.0000
Epoch 237/250
12/12            0s 10ms/step -
loss: 823752320.0000 - val_loss: 992325632.0000
Epoch 238/250
12/12            0s 13ms/step -
loss: 792573504.0000 - val_loss: 1042313344.0000
Epoch 239/250
12/12            0s 10ms/step -
```

```
loss: 840164352.0000 - val_loss: 961217664.0000
Epoch 240/250
12/12            0s 10ms/step -
loss: 805045056.0000 - val_loss: 978490240.0000
Epoch 241/250
12/12            0s 11ms/step -
loss: 826736448.0000 - val_loss: 1008062208.0000
Epoch 242/250
12/12            0s 10ms/step -
loss: 829668480.0000 - val_loss: 953182720.0000
Epoch 243/250
12/12            0s 11ms/step -
loss: 822981056.0000 - val_loss: 956496000.0000
Epoch 244/250
12/12            0s 10ms/step -
loss: 773466240.0000 - val_loss: 944106368.0000
Epoch 245/250
12/12            0s 11ms/step -
loss: 852404160.0000 - val_loss: 1058906368.0000
Epoch 246/250
12/12            0s 10ms/step -
loss: 718135232.0000 - val_loss: 969855680.0000
Epoch 247/250
12/12            0s 11ms/step -
loss: 764650432.0000 - val_loss: 955250816.0000
Epoch 248/250
12/12            0s 10ms/step -
loss: 796829568.0000 - val_loss: 991175680.0000
Epoch 249/250
12/12            0s 10ms/step -
loss: 747341952.0000 - val_loss: 966584768.0000
Epoch 250/250
12/12            0s 10ms/step -
loss: 766836928.0000 - val_loss: 938350144.0000
1250/1250            2s 2ms/step
1250/1250            3s 2ms/step
```

```
/tmp/ipykernel_175749/1549680210.py:76: DeprecationWarning:
DataFrameGroupBy.apply operated on the grouping columns. This behavior is
deprecated, and in a future version of pandas the grouping columns will be
excluded from the operation. Either pass `include_groups=False` to exclude the
groupings or explicitly select the grouping columns after groupby to silence
this warning.
  .apply(lambda g: g.nlargest(k, 'D_score'))
```

[12]:
```
# ------------------------------------------------
# 5. Visualizações finais
# ------------------------------------------------
```

```
# 5.1) Cobertura espacial (Figura 6 estilo artigo)
fig, ax = plt.subplots(figsize=(6,6))
# reais: círculos vazados
ax.scatter(df_real['X'], df_real['Y'],
           facecolors='none', edgecolors='black', s=50, label='Real')
# sintéticos: xis laranja
ax.scatter(selected['X'], selected['Y'],
           marker='x', c='#FF6600', s=40, label='Sintéticas Selecionadas')
# grid 1 m fino
#for c in np.arange(0, L+1, 1):
#    ax.axvline(c, linestyle=':', linewidth=0.5, color='gray', zorder=0)
#    ax.axhline(c, linestyle=':', linewidth=0.5, color='gray', zorder=0)
# delimitações 2 m zonas
#for c in np.arange(0, L+zone_size, zone_size):
#    ax.axvline(c, linestyle='--', linewidth=1, color='gray', zorder=0)
#    ax.axhline(c, linestyle='--', linewidth=1, color='gray', zorder=0)
#ax.set_xlim(0, L); ax.set_ylim(0, W)
#ax.set_aspect('equal', 'box')
#ax.set_xticks(np.arange(0, L+1, 2))
#ax.set_yticks(np.arange(0, W+1, 2))
#ax.set_xlabel("X (m)"); ax.set_ylabel("Y (m)")
#ax.legend(frameon=False, loc='upper right')
#ax.set_title("Cobertura Espacial - Real vs. Sintéticas", pad=12)
plt.tight_layout()
plt.show()
```


1e6
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
−7500
−7000
−6500
−6000
−5500

[ ]: