TABLE 5. Performance Comparison (Mean Train Accuracy, Test Accuracy, and F1-Score) of Imbalanced vs. Balanced Sampling Methods. The base performance for each model is reported on imbalanced data (IB), with the values in square brackets indicating the difference when applying balanced-oversampling (BDO), balanced-undersampling (BDU), and balanced-hybridsampling (BDH).

Method	Mean Train Accuracy IB [BDO, BDU, BDH]	Test Accuracy IB [BDO, BDU, BDH]	F1-Score IB [BDO, BDU, BDH]
Without hyper-parameter Tuning (WHT)			
Autoencoder	94.12 [+0.68, +1.28, +1.73]	95.15 [+1.05, +0.27, +0.63]	1.15 [+0.30, -0.75, -0.69]
Decision Trees	99.10 [-6.60, -7.10, -7.70]	99.95 [-9.66, -10.09, -9.35]	6.56 [-5.57, -5.57, -5.55]
Gaussian Naive Bayes	98.45 [-8.25, -8.95, -7.95]	99.82 [-10.02, -11.07, -9.97]	26.30 [-23.72, -25.41, -25.31]
Isolation Forest	95.60 [-4.10, -5.40, -3.60]	94.55 [-3.65, -4.85, -2.75]	13.48 [-9.40, -12.48, -12.49]
KNN	99.88 [-0.88, -8.88, -0.68]	99.95 [-0.19, -9.21, -0.32]	99.94 [-87.50, -98.95, -90.93]
LightGBM	99.20 [-1.40, -8.15, -1.10]	99.94 [-4.59, -8.94, -2.04]	15.86 [-14.31, -14.78, -14.37]
Random Forest	98.30 [-0.30, -1.20, -0.30]	99.10 [-1.60, -2.75, -1.70]	31.10 [+7.32, -1.72, +3.97]
Robust Covariance	90.52 [-0.42, -0.12, +1.08]	90.10 [-0.90, -0.30, +0.60]	6.44 [-5.65, -5.57, -5.41]
XGBoost	98.50 [-3.10, -7.16, -3.50]	99.91 [-4.91, -9.14, -5.31]	52.10 [-50.32, -51.05, -51.09]
ADMXGB	**99.96** [-0.16, -0.30, -0.35]	99.67 [**+0.13**, -0.05, +0.06]	31.02 [**+11.38**, -1.73, +6.51]
With hyper-parameter Tuning (HT) - Grid Search			
Autoencoder	94.50 [+0.20, +0.70, +1.10]	95.59 [0.00, -0.15, -0.06]	1.26 [-0.75, -0.83, -0.71]
Decision Trees	99.30 [-4.20, -6.50, -2.00]	99.95 [-3.38, -8.16, -2.57]	22.55 [-20.91, -21.40, -22.53]
Gaussian Naive Bayes	98.60 [-8.10, -8.80, -7.50]	99.84 [-9.74, -10.59, -9.54]	31.36 [-27.56, -30.37, -30.34]
Isolation Forest	96.10 [-3.70, -5.20, -3.10]	95.12 [-3.32, -4.72, -2.67]	16.68 [-11.73, -15.58, -15.50]
KNN	99.90 [-0.80, -8.10, -0.65]	99.95 [-0.10, -7.89, -0.29]	16.42 [+0.52, -15.32, -6.89]
LightGBM	99.40 [-0.80, -8.75, -1.00]	99.95 [-2.80, -8.37, -1.85]	28.73 [-26.46, -27.62, -26.37]
Random Forest	99.20 [-0.40, -1.00, -0.50]	99.40 [-1.20, -1.90, -1.00]	36.38 [+5.28, -5.02, -0.22]
Robust Covariance	91.10 [+0.40, -0.30, +1.10]	90.80 [+0.10, -0.70, +0.70]	8.40 [-7.57, -7.51, -7.40]
XGBoost	98.00 [-1.90, -3.06, -2.10]	99.50 [-3.60, -4.56, -3.70]	54.35 [-51.98, +40.84, -53.25]
ADMXGB	99.93 [-0.01, -0.15, **+0.03**]	99.92 [-0.02, -0.12, **+0.04**]	18.39 [+81.51, +81.42, **+81.58**]
With hyper-parameter Tuning (HT) - Random Search			
Autoencoder	94.70 [+0.20, +0.60, +1.10]	95.35 [+0.78, +0.64, +0.36]	1.36 [-0.70, -0.75, -0.58]
Decision Trees	99.25 [-4.15, -6.15, -1.95]	99.95 [-3.38, -8.24, -2.57]	20.66 [-19.03, -19.53, -18.56]
Gaussian Naive Bayes	98.55 [-7.90, -8.65, -7.35]	99.82 [-9.62, -10.72, -9.22]	31.63 [-27.59, -30.72, -30.57]
Isolation Forest	95.90 [-3.30, -4.90, -2.65]	95.33 [-3.23, -4.73, -2.63]	15.13 [-10.00, -13.99, -13.91]
KNN	99.88 [-0.68, -8.03, -0.60]	99.95 [-0.10, -7.89, -0.29]	15.76 [+1.17, -14.66, -6.23]
LightGBM	99.40 [-1.15, -8.75, -0.90]	99.95 [-3.03, -8.43, -1.75]	25.02 [-22.85, -23.91, -22.56]
Random Forest	98.80 [+0.10, -0.50, 0.00]	99.30 [-1.00, -1.65, -0.80]	34.50 [+8.18, -2.37, +2.16]
Robust Covariance	91.00 [+0.60, +0.10, +1.60]	90.78 [+0.32, -0.28, +1.02]	7.49 [-6.60, -6.50, -6.38]
XGBoost	98.10 [-1.75, -3.40, -2.90]	99.70 [-3.75, -4.99, -4.70]	54.10 [-51.64, +40.88, -52.99]
ADMXGB	99.93 [-0.02, -0.16, **+0.03**]	99.93 [-0.03, -0.13, **+0.03**]	12.71 [+87.19, +87.10, **+87.25**]
With hyper-parameter Tuning (HT) - HyperOPT			
Autoencoder	94.95 [+0.25, +0.65, +0.95]	95.70 [+0.10, +0.40, +0.10]	1.42 [-0.70, -0.77, -0.60]
Decision Trees	99.15 [-3.25, -5.95, -1.75]	99.92 [-3.02, -7.97, -2.32]	24.02 [-22.21, -22.83, -21.86]
Gaussian Naive Bayes	98.65 [-7.55, -8.45, -7.25]	99.86 [-9.36, -10.41, -9.06]	33.30 [-28.96, -32.35, -32.19]
Isolation Forest	96.25 [-3.25, -4.90, -2.65]	95.85 [-3.35, -5.00, -2.85]	16.53 [-10.96, -15.37, -15.25]
KNN	99.85 [-0.60, -7.80, -0.55]	99.90 [0.00, -7.84, -0.20]	17.67 [-0.13, -16.57, -8.00]
LightGBM	99.95 [-1.61, -1.08, -1.15]	99.94 [-3.14, -8.44, -1.44]	18.39 [-16.40, -17.30, -15.83]
Random Forest	99.40 [-0.40, -1.00, -0.50]	99.65 [-1.25, -1.75, -1.05]	40.43 [+2.99, -7.75, -3.10]
Robust Covariance	91.35 [+0.65, +0.15, +1.65]	90.90 [+0.55, 0.00, +1.20]	8.21 [-7.28, -7.18, -7.06]
XGBoost	91.13 [+4.01, +3.80, +4.17]	91.11 [+0.02, +0.20, +3.99]	1.07 [0.00, -0.02, +0.06]
ADMXGB	99.65 [+0.27, +0.12, **+0.30**]	99.68 [+0.22, +0.08, **+0.28**]	21.52 [+78.39, +78.24, **+78.44**]