KhavrRF\_Micro\_modeltune\_Cu\_RS\_Landsat

Random Forest

47 samples

11 predictors

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.3210276 0.07004662 0.2603704

6 0.3232101 0.07057026 0.2620075

11 0.3273369 0.06296453 0.2655794

RMSE was used to select the optimal model using the smallest value.

The final value used for the model was mtry = 2.

goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Landsat\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.7407602 0.7824442 0.02090188 0.1445748 0.0008690355

> # externalvalidation

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Landsat\_External , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.4464203 -0.1340829 0.1169442 0.3419711 0.1230687

> #training

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Landsat\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 50.4

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Landsat\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 0.1061178

> ##testing

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Landsat\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 117.4

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Landsat\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 0.2995407

KhavrRF\_Micro\_modeltune\_Cu\_RS\_Sentinel

Random Forest

47 samples

16 predictors

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.3005875 0.11081297 0.2504101

9 0.3063338 0.08496068 0.2533900

16 0.3103066 0.07971518 0.2547733

RMSE was used to select the optimal model using the smallest value.

The final value used for the model was mtry = 2.

goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Sentinel\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.78167 0.818619 0.01760343 0.1326779 -0.0004241702

> # externalvalidation

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Sentinel\_External, plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.4088237 -0.128392 0.1139045 0.3374974 0.09087416

#training

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Sentinel\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 46.2

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Sentinel\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 0.09881171

> ##testing

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Sentinel\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 115.8

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Sentinel\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 0.2700053

KhavrRF\_Micro\_modeltune\_Cu\_RS\_Landsat\_Sentinel

Random Forest

47 samples

27 predictors

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.3142010 0.03228492 0.2581388

14 0.3183807 0.04091687 0.2606716

27 0.3174806 0.04555192 0.2591779

RMSE was used to select the optimal model using the smallest value.

The final value used for the model was mtry = 2.

goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Landsat\_Sentinel\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.7633255 0.8015959 0.0190825 0.1381394 0.001170979

> # externalvalidation

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Landsat\_Sentinel\_External, plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.3575866 -0.1062412 0.109762 0.3313034 0.1006176

nrmse(KhavrRF\_Micro\_Cu\_RS\_Landsat\_Sentinel\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 48.1

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Landsat\_Sentinel\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 0.1012051

> ##testing

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Landsat\_Sentinel\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 113.7

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Landsat\_Sentinel\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 0.2744934

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| --- |
| KhavrRF\_Micro\_modeltune\_Cu\_RS\_Topographic  Random Forest  47 samples  34 predictors  No pre-processing  Resampling: Bootstrapped (25 reps)  Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...  Resampling results across tuning parameters:  mtry RMSE Rsquared MAE  2 0.3117175 0.08051042 0.2644297  18 0.3234746 0.06508513 0.2725551  34 0.3263580 0.06198129 0.2742648  RMSE was used to select the optimal model using the smallest value.  The final value used for the model was mtry = 2.  goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Topographic\_Internal , plot.it = TRUE)  R2 concordance MSE RMSE bias  1 0.7606429 0.79655 0.01929879 0.1389201 -0.0007704823  > # externalvalidation  > KhavrRF\_Micro\_Cu\_RS\_Topographic\_External <- predict(KhavrRF\_Micro\_Cu\_RS\_Topographic, newdata = RF\_Micro\_Scenario\_models\_dataset[-Training\_RF\_Micro\_scenario, ])  > goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Topographic\_External, plot.it = TRUE)  R2 concordance MSE RMSE bias  1 -0.2523454 -0.05623944 0.1012531 0.3182029 0.09929508  > #training  > nrmse(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 48.4  > MAPE(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 0.1024235  > ##testing  > nrmse(KhavrRF\_Micro\_Cu\_RS\_Topographic\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 109.2  > MAPE(KhavrRF\_Micro\_Cu\_RS\_Topographic\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 0.2648211 |
|  |
| |  | | --- | | > | |

KhavrRF\_Micro\_modeltune\_Cu\_RS\_Topographic\_Climate

Random Forest

47 samples

38 predictors

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.2973806 0.03673288 0.2417790

20 0.2923239 0.05835808 0.2366494

38 0.2949493 0.06575750 0.2376130

RMSE was used to select the optimal model using the smallest value.

The final value used for the model was mtry = 20.

goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.8481486 0.8761796 0.01224342 0.11065 0.0006723546

> # externalvalidation

>

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_External, plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.2749567 0.0411218 0.1030813 0.3210627 0.09009879

> #training

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 38.6

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 0.07956731

> ##testing

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 110.2

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 0.2652613

KhavrRF\_Micro\_modeltune\_Cu\_RS\_Topographic\_Climate\_Soil

Random Forest

47 samples

41 predictors

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.3039818 0.06714956 0.2469974

21 0.2975632 0.07201056 0.2377117

41 0.3036590 0.06819791 0.2399558

RMSE was used to select the optimal model using the smallest value.

The final value used for the model was mtry = 21.

goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Soil\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.8510907 0.8788954 0.0120062 0.1095728 0.001600411

> # externalvalidation

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Soil\_External, plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.3176847 -0.008664123 0.1065359 0.3263983 0.08440705

> #training

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Soil\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 38.2

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Soil\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 0.07867737

> ##testing

> nrmse(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Soil\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 112

> MAPE(KhavrRF\_Micro\_Cu\_RS\_Topographic\_Climate\_Soil\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 0.2683772

KhavrRF\_Micro\_modeltune\_Cu\_Topographic

Random Forest

47 samples

7 predictor

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.3312797 0.06445024 0.2765348

4 0.3376400 0.06037743 0.2824277

7 0.3428940 0.05803499 0.2864338

RMSE was used to select the optimal model using the smallest value.

The final value used for the model was mtry = 2.

goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Topographic\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.7171043 0.7577616 0.02280921 0.1510272 0.001504527

> # externalvalidation

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Topographic\_External, plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.01517443 0.171247 0.08207766 0.286492 0.1118002

> #training

> nrmse(KhavrRF\_Micro\_Cu\_Topographic\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 52.6

> MAPE(KhavrRF\_Micro\_Cu\_Topographic\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])

[1] 0.1119815

> ##testing

> nrmse(KhavrRF\_Micro\_Cu\_Topographic\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 98.3

> MAPE(KhavrRF\_Micro\_Cu\_Topographic\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])

[1] 0.241834

KhavrRF\_Micro\_modeltune\_Cu\_Climate

Random Forest

47 samples

4 predictor

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.3007506 0.1397684 0.2292634

3 0.3057392 0.1338725 0.2332088

4 0.3114137 0.1270669 0.2371096

goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Climate\_External, plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.05041654 0.2935156 0.08492701 0.2914224 0.09952927

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Climate\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.792042 0.842029 0.01676716 0.1294881 0.002618522

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Climate\_External, plot.it = TRUE)

R2 concordance MSE RMSE bias

1 -0.05041654 0.2935156 0.08492701 0.2914224 0.09952927

|  |
| --- |
| #training  > nrmse(KhavrRF\_Micro\_Cu\_Climate\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 45.1  > MAPE(KhavrRF\_Micro\_Cu\_Climate\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 0.08927432  > ##testing  > nrmse(KhavrRF\_Micro\_Cu\_Climate\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 100  > MAPE(KhavrRF\_Micro\_Cu\_Climate\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 0.2661946 |
|  |
| |  | | --- | | > | |

KhavrRF\_Micro\_modeltune\_Cu\_Soil

Random Forest

47 samples

3 predictor

No pre-processing

Resampling: Bootstrapped (25 reps)

Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...

Resampling results across tuning parameters:

mtry RMSE Rsquared MAE

2 0.3096995 0.08729003 0.2431410

3 0.3149149 0.08719316 0.2464069

RMSE was used to select the optimal model using the smallest value.

The final value used for the model was mtry = 2.

# Internal validation

>

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Soil\_Internal , plot.it = TRUE)

R2 concordance MSE RMSE bias

1 0.7587609 0.8166547 0.01945054 0.1394652 0.0006848936

> # externalvalidation

>

> goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Soil\_External, plot.it = TRUE)

|  |
| --- |
|  |
| |  | | --- | | >  #training  > nrmse(KhavrRF\_Micro\_Cu\_Soil\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 48.6  > MAPE(KhavrRF\_Micro\_Cu\_Soil\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 0.09924074  > ##testing  > nrmse(KhavrRF\_Micro\_Cu\_Soil\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 108.3  > MAPE(KhavrRF\_Micro\_Cu\_Soil\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 0.2731079  KhavrRF\_Micro\_modeltune\_Cu\_Rec\_Fea\_Elimination  Random Forest  47 samples  39 predictors  No pre-processing  Resampling: Bootstrapped (25 reps)  Summary of sample sizes: 47, 47, 47, 47, 47, 47, ...  Resampling results across tuning parameters:  mtry RMSE Rsquared MAE  2 0.2920352 0.06678091 0.2341926  20 0.2844244 0.11028017 0.2246251  39 0.2908461 0.10124916 0.2282860  # Internal validation  > KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_Internal <- predict(KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination, newdata = RF\_Micro\_Scenario\_models\_dataset[Training\_RF\_Micro\_scenario, ])  > goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_Internal , plot.it = TRUE)  R2 concordance MSE RMSE bias  1 0.8603963 0.8864587 0.01125592 0.1060939 -0.001964071  > # externalvalidation  > KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_External <- predict(KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination, newdata = RF\_Micro\_Scenario\_models\_dataset[-Training\_RF\_Micro\_scenario, ])  > goof(observed = RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario], predicted = KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_External, plot.it = TRUE)  R2 concordance MSE RMSE bias  1 -0.3045413 0.008606855 0.1054732 0.3247664 0.087082  > #training  > nrmse(KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 37  > MAPE(KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_Internal, RF\_Micro\_Scenario\_models\_dataset$Cu[Training\_RF\_Micro\_scenario])  [1] 0.07596936  > ##testing  > nrmse(KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 111.5  > MAPE(KhavrRF\_Micro\_Cu\_Rec\_Fea\_Elimination\_External, RF\_Micro\_Scenario\_models\_dataset$Cu[-Training\_RF\_Micro\_scenario])  [1] 0.2643515 | |