



JPL YIP Fall 2023

Classification of UAVSAR Polarimetric Data for Wildfire and Soil Moisture Monitoring

3340 - Radar Science And Engineering

Presented by Wen Tao Lin
Mentors: Yunling Lou, Karen An, Charles Z. Marshak



Jet Propulsion Laboratory
California Institute of Technology

This document has been reviewed and determined
not to contain export controlled technical data.

Background – Fire Monitoring

- Summer Product
 - Automate fire perimeter and burn severity mapping
 - Motivations
 - Improve results from the optical-based fire mapping
 - Reduce manual efforts
 - Real Time monitoring aid disaster response

Background – SMAPVEX12

- A 2012 validation experiment for the Soil Moisture Active Passive (SMAP) mission launched in 2015
 - Development and Evaluation of the SMAP algorithms for pre-launch
- Our usage
 - Field data for forested and agricultural sites
 - UAVSAR data for the same sites

Project Objectives

- Fire Monitoring:
 - Improve upon the summer product with the additional data from new flight direction
- Smapvex12:
 - Establish relationship between fuel moisture and PolSAR data

Fire Monitoring

Existing Procedure – after RTC

Multiple steps through multiple Jupyter Notebooks

- prone to confusion (outputs vs. inputs)

Fire Perimeter Generation

- 1) Crop the raster image by a circle
- 2) Preprocess the cropped image and perform superpixel segmentation
- 3) Generate the fire perimeter map

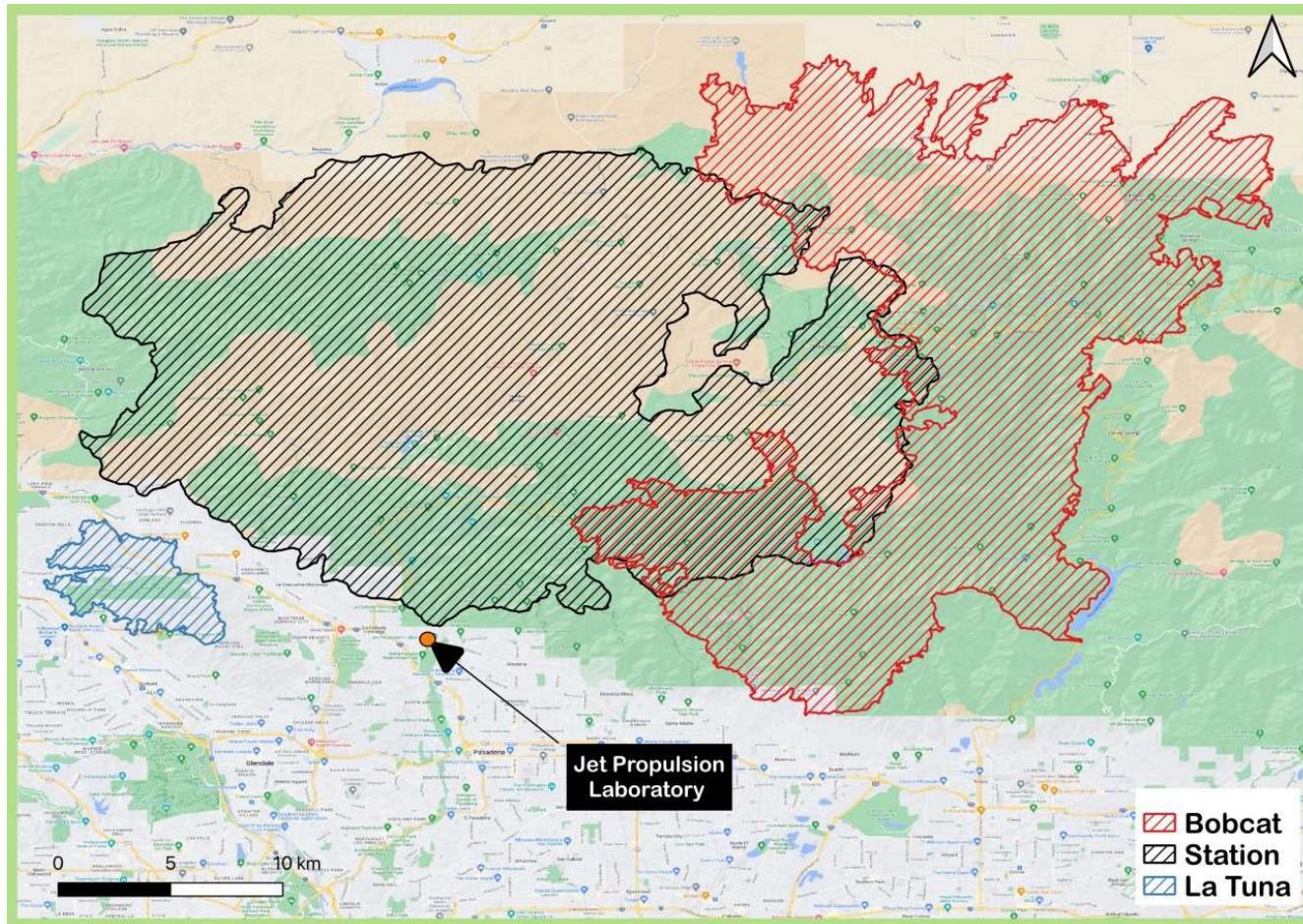
Burn Severity Map Generation

- 1) Crop the raster image by a fire perimeter in GeoJSON or shapefile
- 2) Generate the burn severity map

What are we adding?

- Utilize both directions of a flight area
- Multiple perimeter selection based on usage
- One-step function for perimeter and burn severity

Field of Study



*will only be studying the
La Tuna Fire and the
southern half of Bobcat
Fire due to data
limitation*

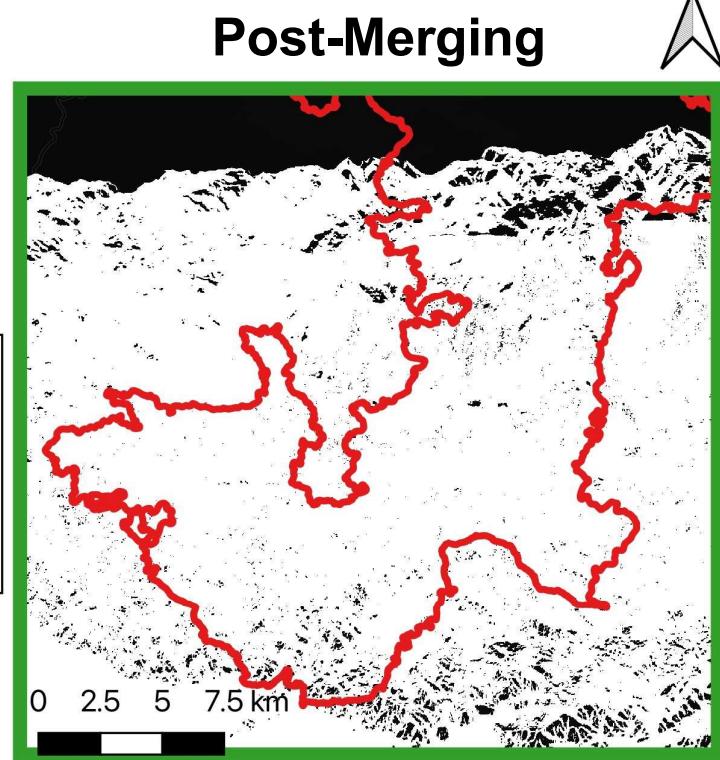
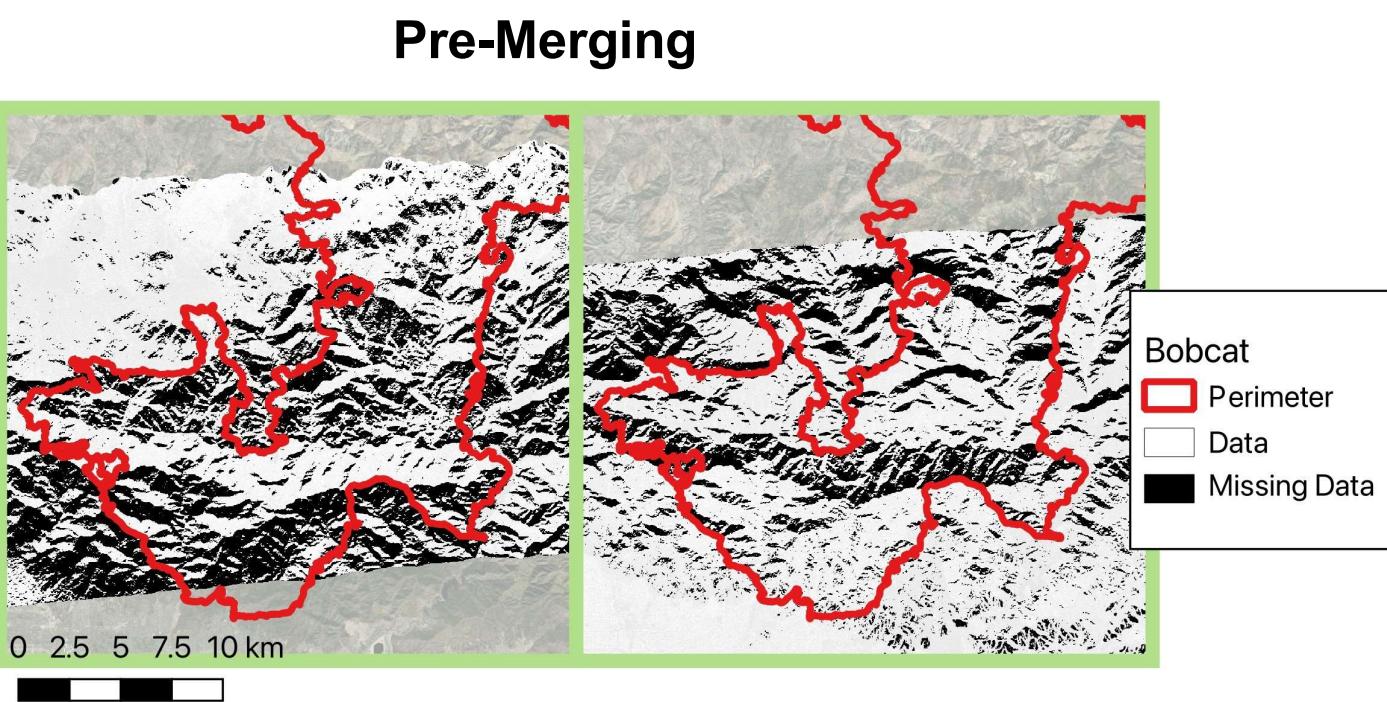
Merging Approaches

- Weighted by Incidence Angle
 - Handles outlier
 - Utilizes both pixels, accounting for noise
- Averaging
 - More affected by outliers
- Lowest Incidence Angle
 - Increased resolution at lower incidence angle

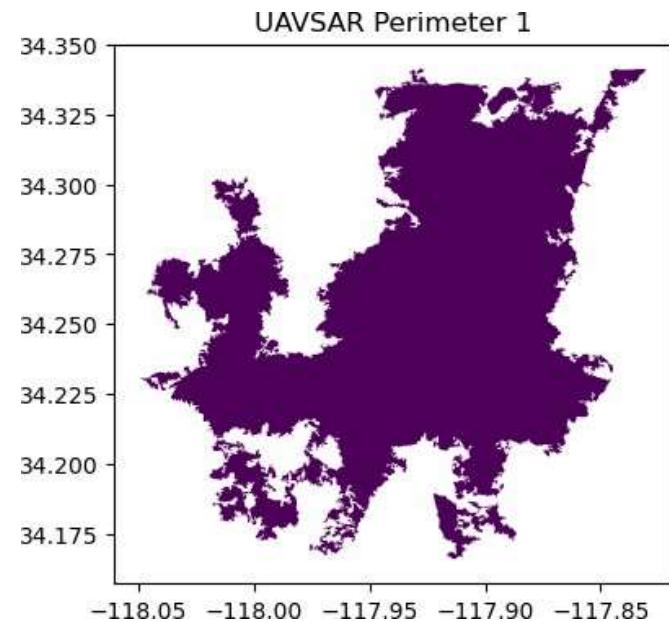
Resampling Approach

- Bilinear
 - Smoother image
- Nearest
 - Computationally efficient
- Difference depend on the original images
- Default to Bilinear, but user can specific

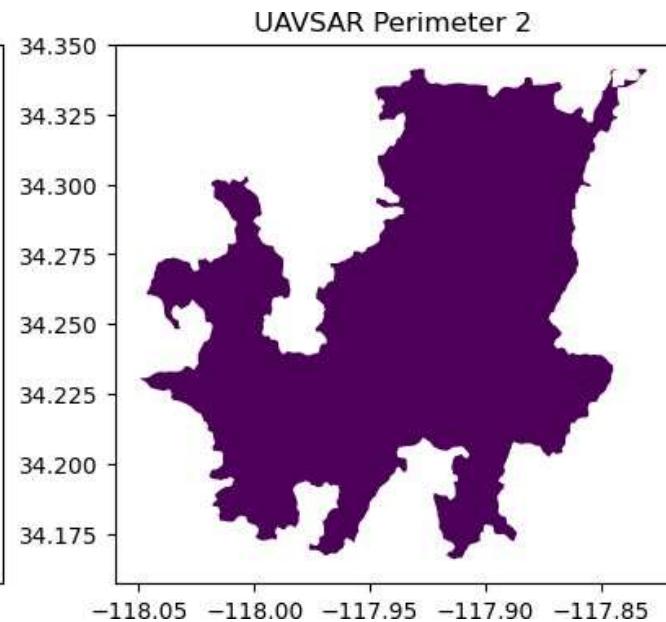
Merging Result



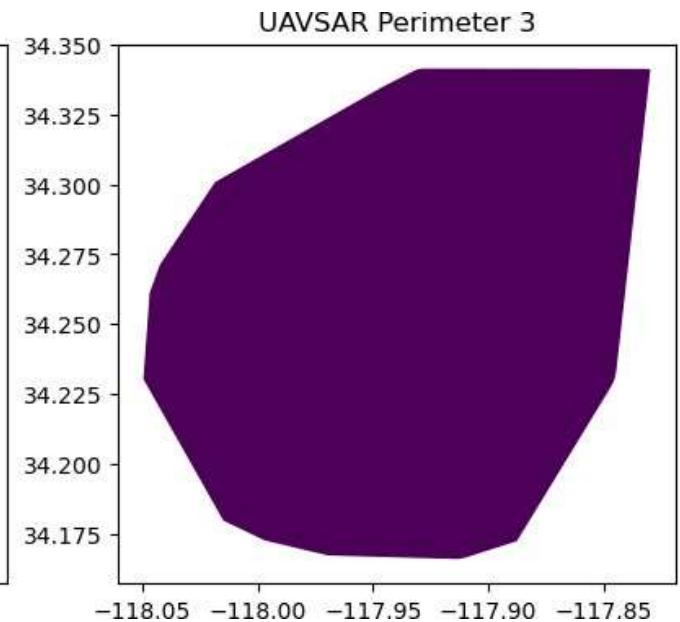
Perimeter Selection



Closing circles



Concave Hull



Convex Hull

Improved User Friendliness

- Less overall actions required by the user → easier to use
- Similar level of customization

Only need a folder with:

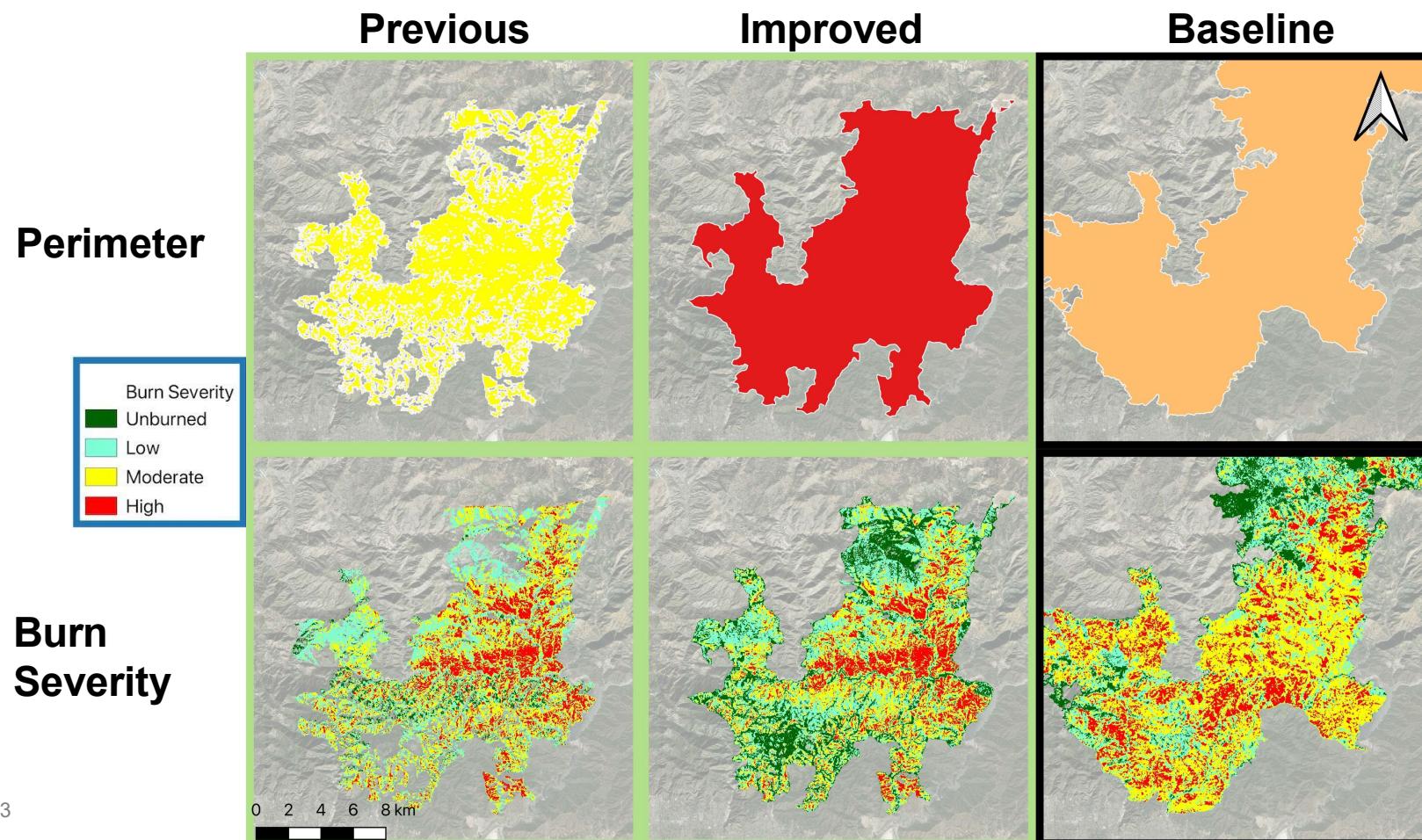
- 1) all the cropped incidence angle raw files
- 2) all the cropped RTC files (HVHV)

Name
> baseline
SanAnd_08525_18076_003_181011_HVHV_RTC_cropped_35km.tif
SanAnd_08525_18076_003_181011_L090_CX_01_inc_35km.tif
SanAnd_08525_21065_014_211117_HVHV_RTC_cropped_35km.tif
SanAnd_08525_21065_014_211117_L090_CX_01_inc_35km.tif
<input checked="" type="checkbox"/> SanAnd_26526_18076_002_181011_HVHV_RTC_cropped_35km.tif
SanAnd_26526_18076_002_181011_L090_CX_01_inc_35km.tif
SanAnd_26526_21065_013_211117_HVHV_RTC_cropped_35km.tif
SanAnd_26526_21065_013_211117_L090_CX_01_inc_35km.tif

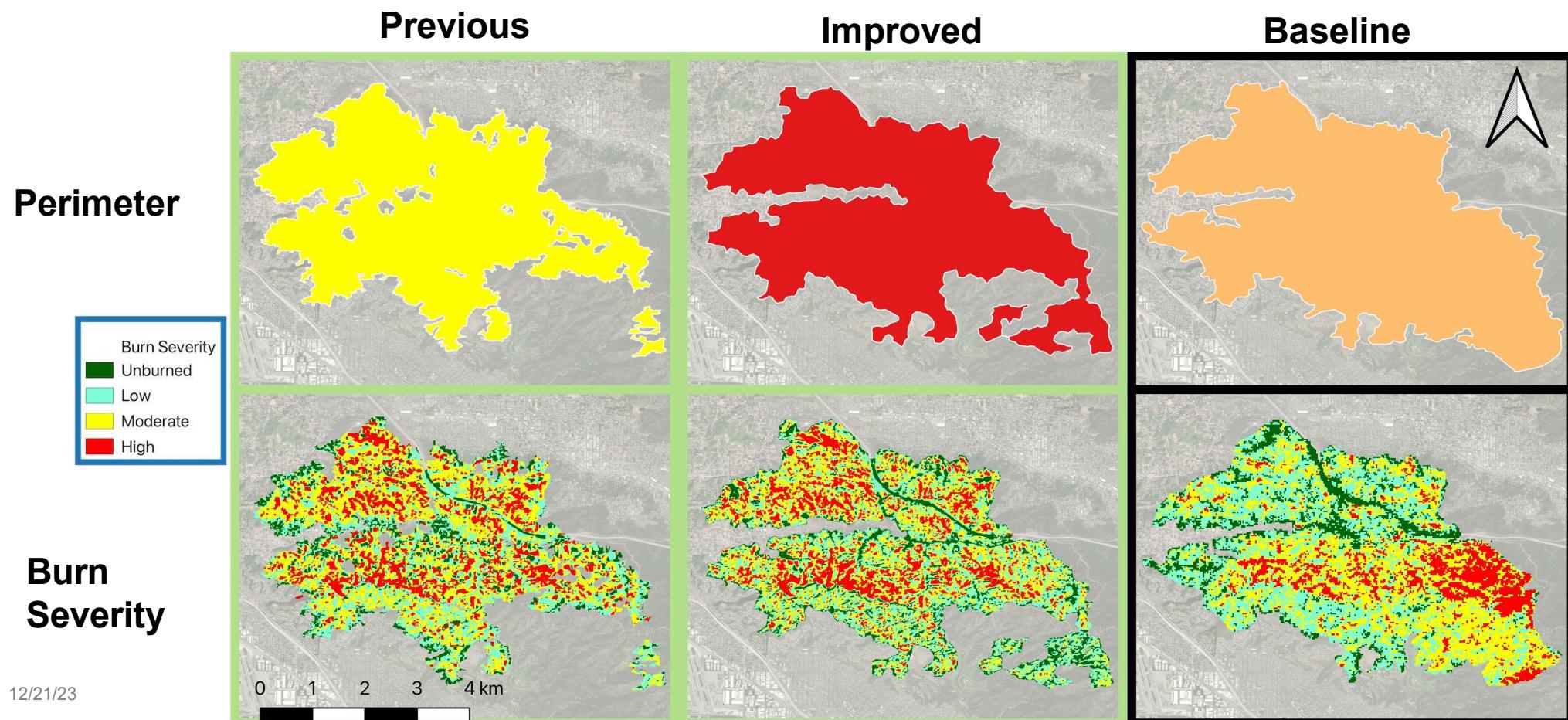
3 inputs require while running:

- Select a flight as the base-image for reprojection
- Select polygons to be considered for the final perimeter
- Select the perimeter to be used for burn severity

Comparison With Previous Work - Bobcat

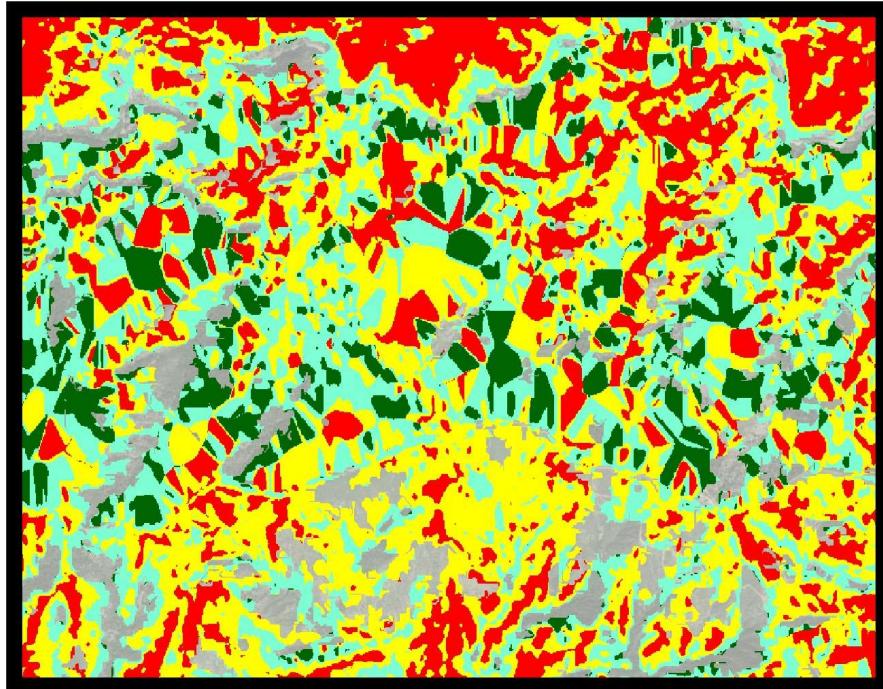


Comparison With Previous Work – La Tuna

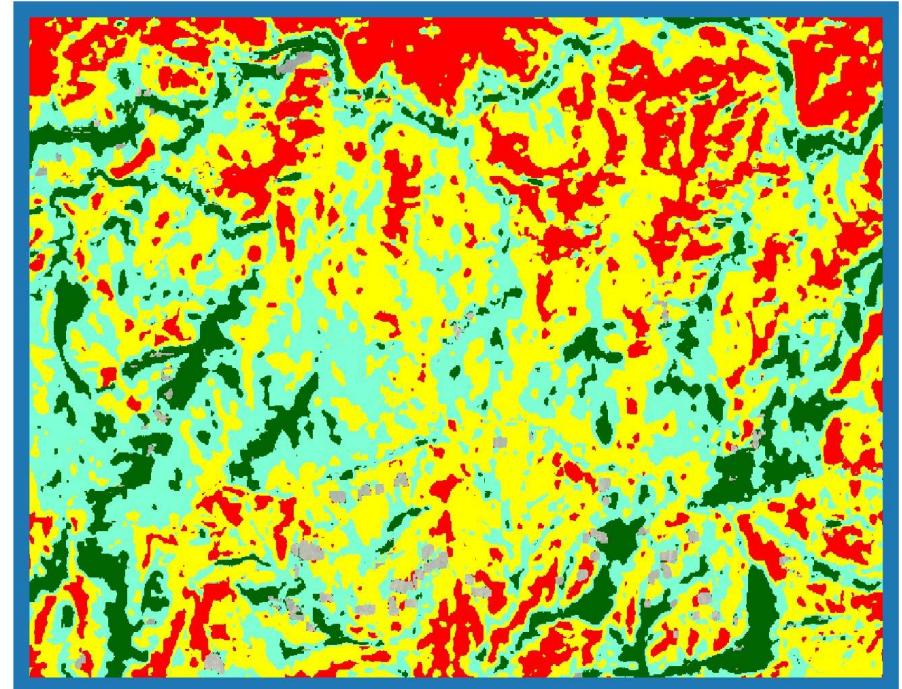


Improvements in Burn Severity

Previous



Improved

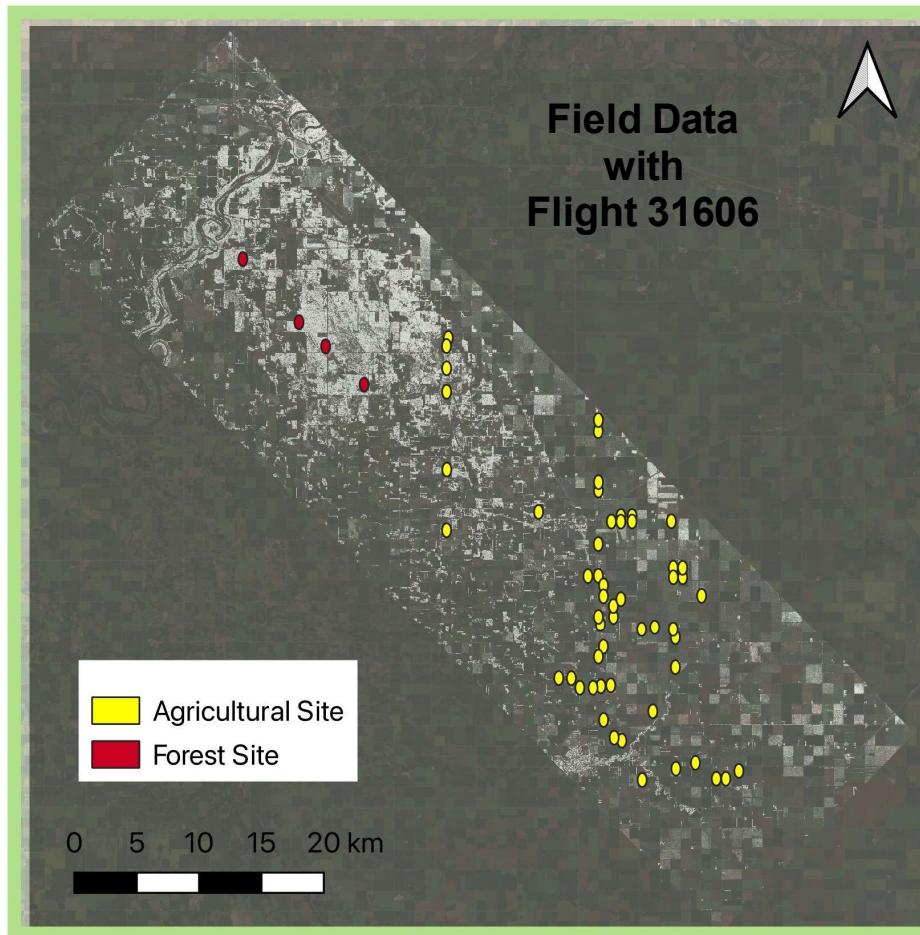


Limitations

- Requires data!!
 - **both** flight directions
 - inc data (older flights tend to lack)
 - reasonable flight dates w.r.t fire dates
- Sensitive to missing data
- Sensitive to segmentation parameter (default value is okay)

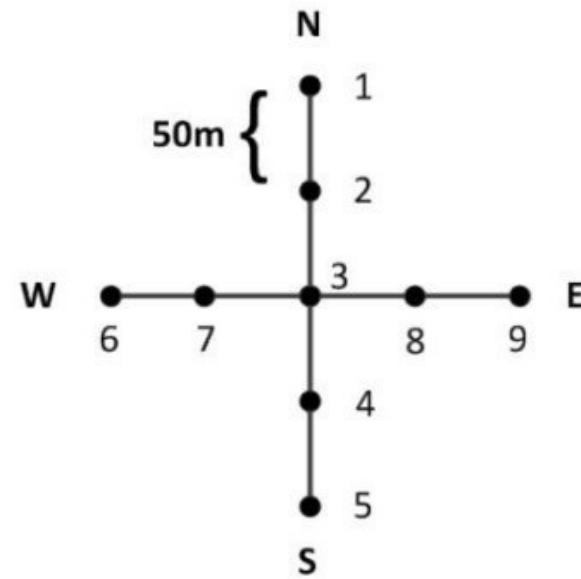
Smapvex12

Field of Study – Winnipeg, Canada



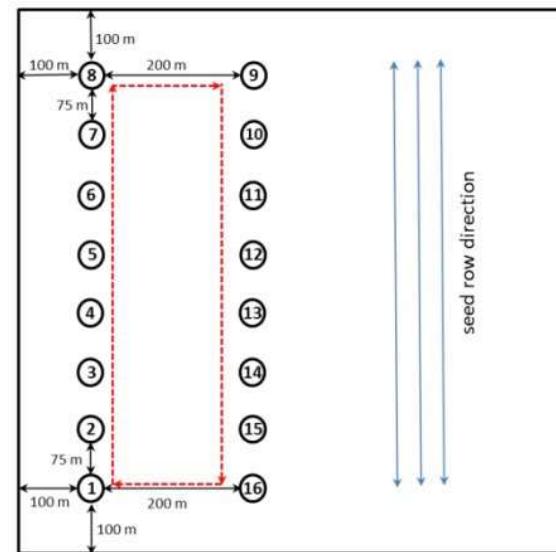
Field Locations

Forested Sites



Schematic representation of the
forestry soil moisture transects.
*Sourced from smapve12 final
report*

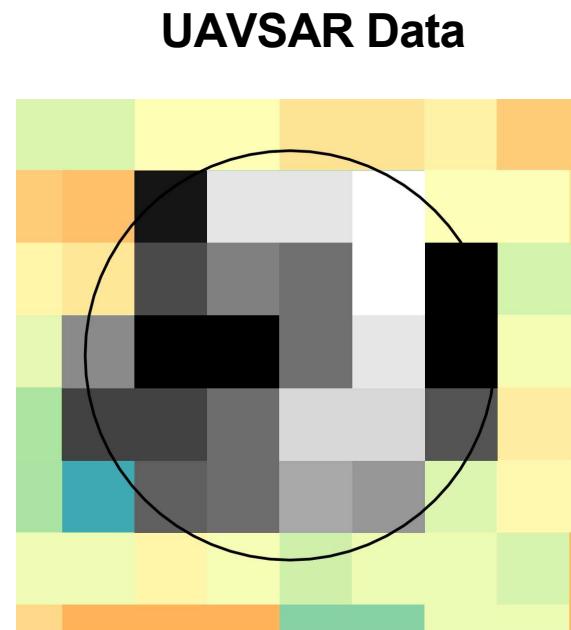
Agricultural Sites



Spacing between soil
moisture sampling points.
*Sourced from smapve12
final report*

Data Extraction

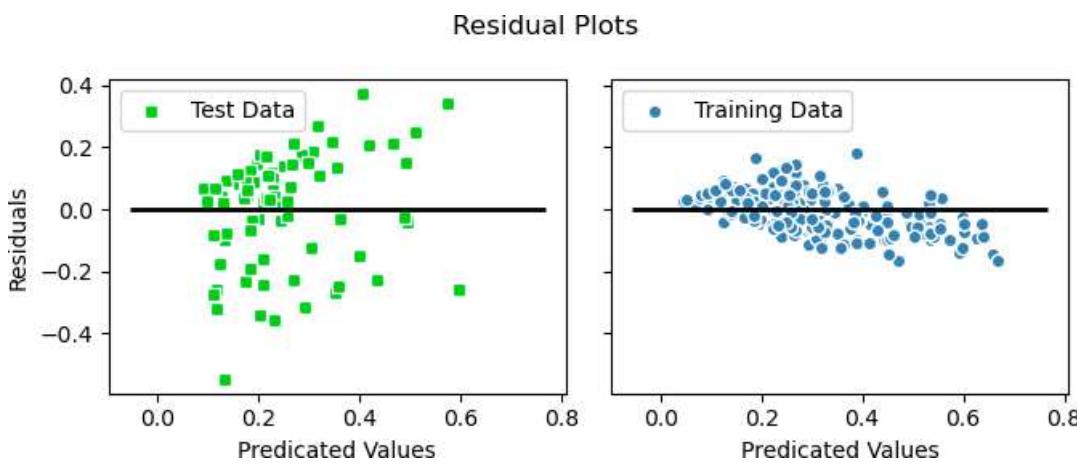
- Using the given field data coordinate to crop a buffer circle of the respective UAVSAR area



Forested Site Soil Moisture

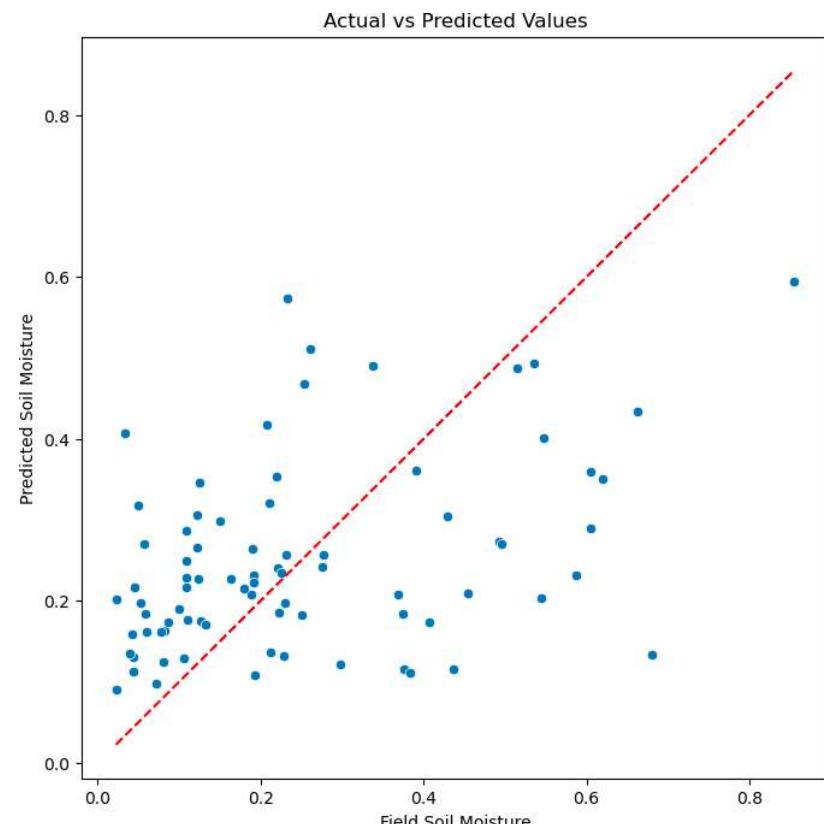
Initial Exploration

- 80/20 train/test split
- X: mean and std of VV, HH, HV, VV/HH
- Y: field soil moisture



```
R^2 Train: 0.9082863322972645  
Adjusted R^2 Train: 0.9058728147261399  
  
R^2 Test: 0.12869900931092393  
Adjusted R^2 Test: 0.029121753232172365
```

12/21/23



```
Cross Validation Scores:  
[0.275654 0.45354411 0.42480273 0.37732452 0.24698304]
```

Feature Selection

RFE Ranking

- MEAN_VV
- STD_HH
- MEAN_VV/HH
- STD_VV/HH

```
cross-val:  
[0.24195768 0.45256078 0.3399675 0.37793098 0.22445894]  
  
R^2 Train: 0.9034069465675635  
Adjusted R^2 Train: 0.9021524913281812  
  
R^2 Test: 0.07831917382619313  
Adjusted R^2 Test: 0.02849858862760901
```

Bad!

Forward Selection

- MEAN_HH
- STD_HH
- STD_HV
- MEAN_VV/HH

```
cross-val:  
[0.24195768 0.45256078 0.3399675 0.37793098 0.22445894]  
  
R^2 Train: 0.9034069465675635  
Adjusted R^2 Train: 0.9021524913281812  
  
R^2 Test: 0.07831917382619313  
Adjusted R^2 Test: 0.02849858862760901
```

Bad!

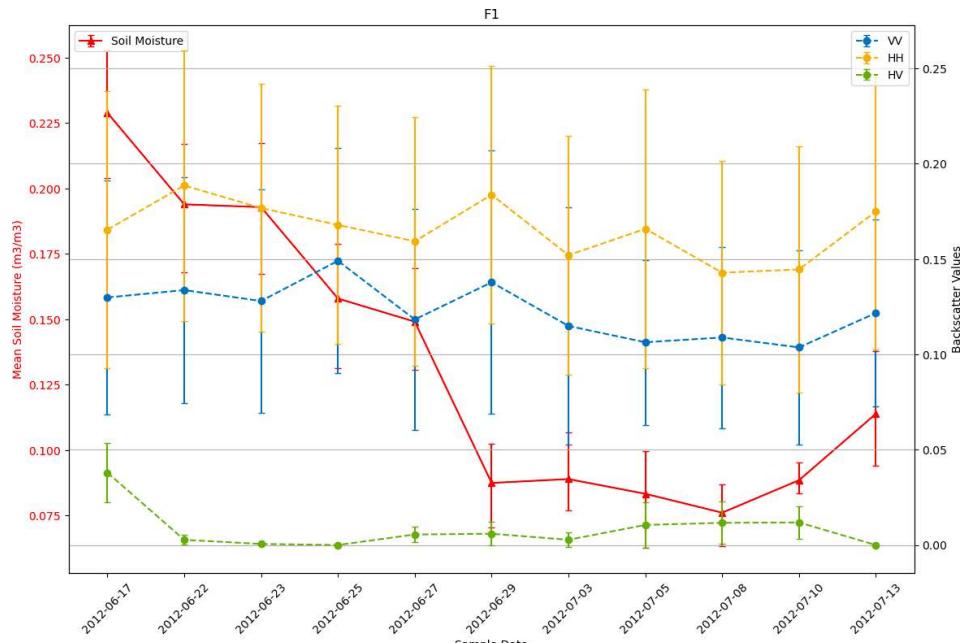
Backward Selection

- MEAN_VV
- STD_VV
- STD_HH
- MEAN_VV/HH

```
cross-val:  
[0.21321173 0.42570427 0.28934128 0.39256172 0.30616166]  
  
R^2 Train: 0.9074637570919957  
Adjusted R^2 Train: 0.90626198770358  
  
R^2 Test: 0.1706483889703101  
Adjusted R^2 Test: 0.1258185721578945
```

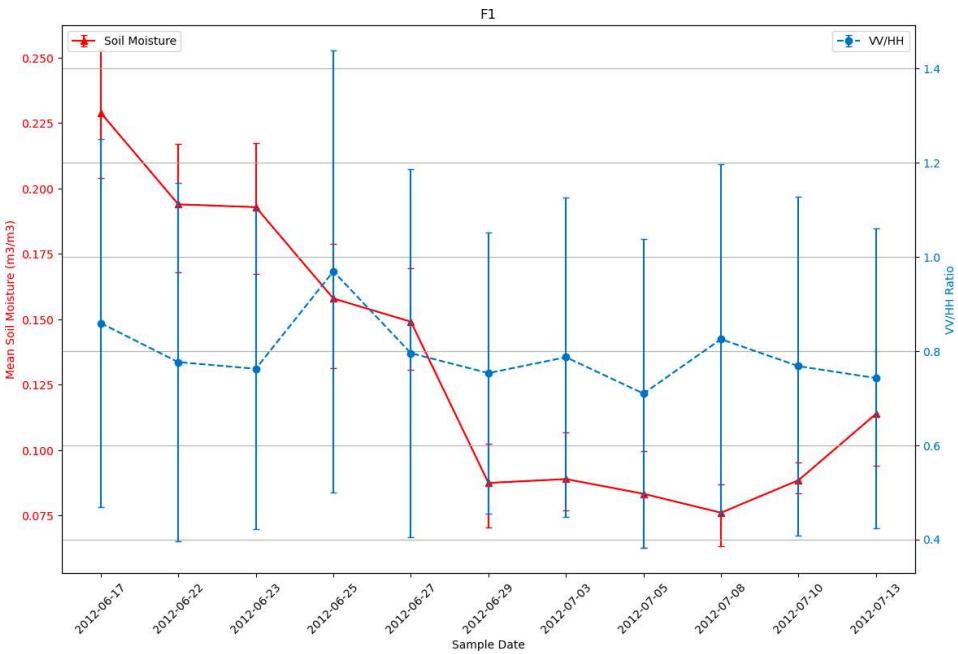
Bad!

F1



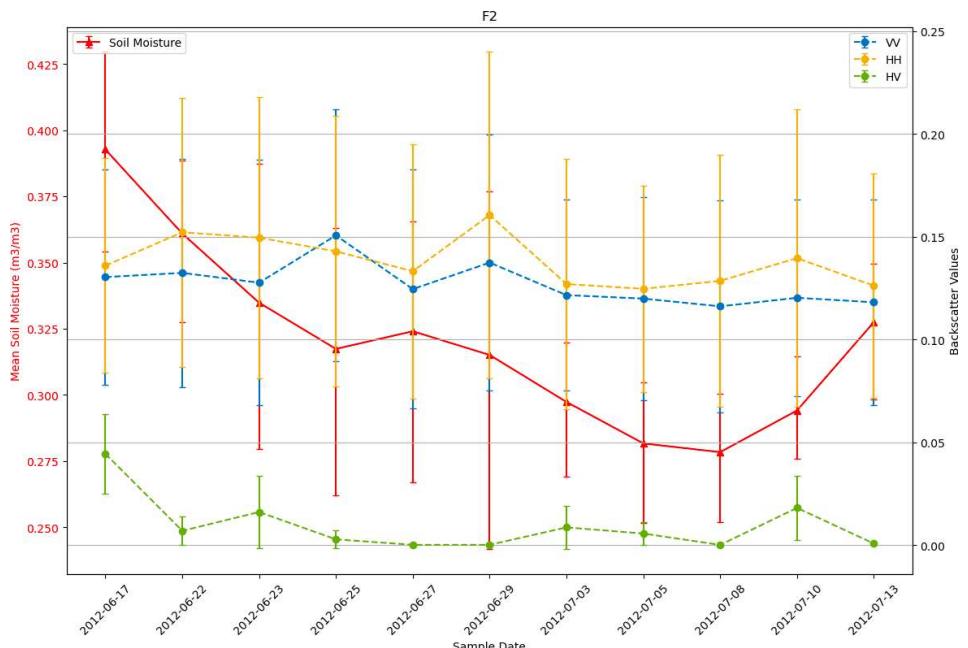
Correlation Coefficient - VV: 0.5675117335553406
 Correlation Coefficient - HH: 0.46880485414147494
 Correlation Coefficient - HV: 0.31235352450316034

12/21/23



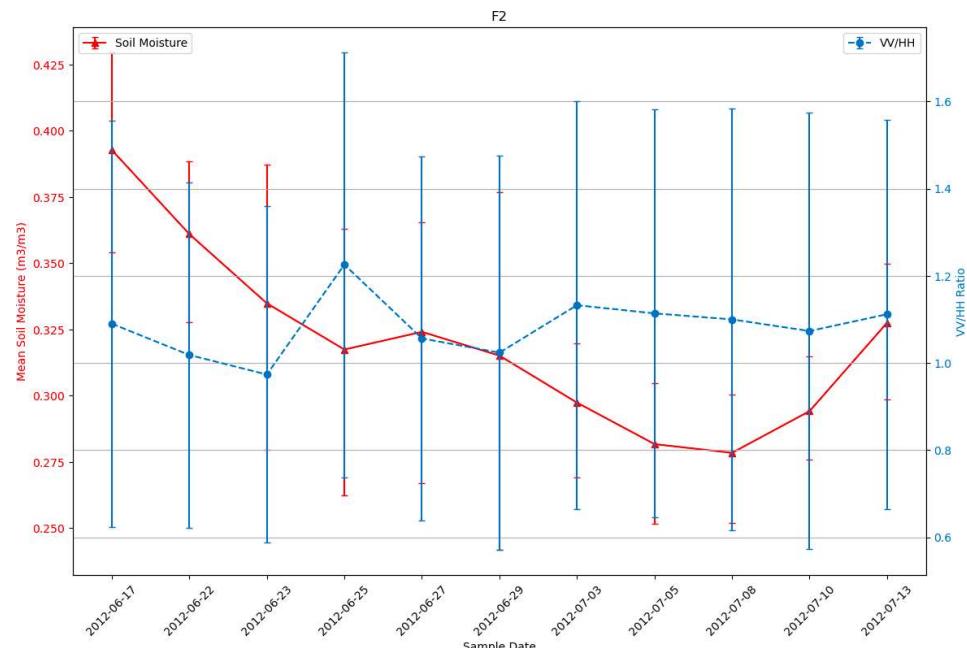
Correlation Coefficient - VV/HH: 0.3781055625350527

F2



Correlation Coefficient - VV: 0.37545379915603017
 Correlation Coefficient - HH: 0.36406039093945736
 Correlation Coefficient - HV: 0.6270338454041595

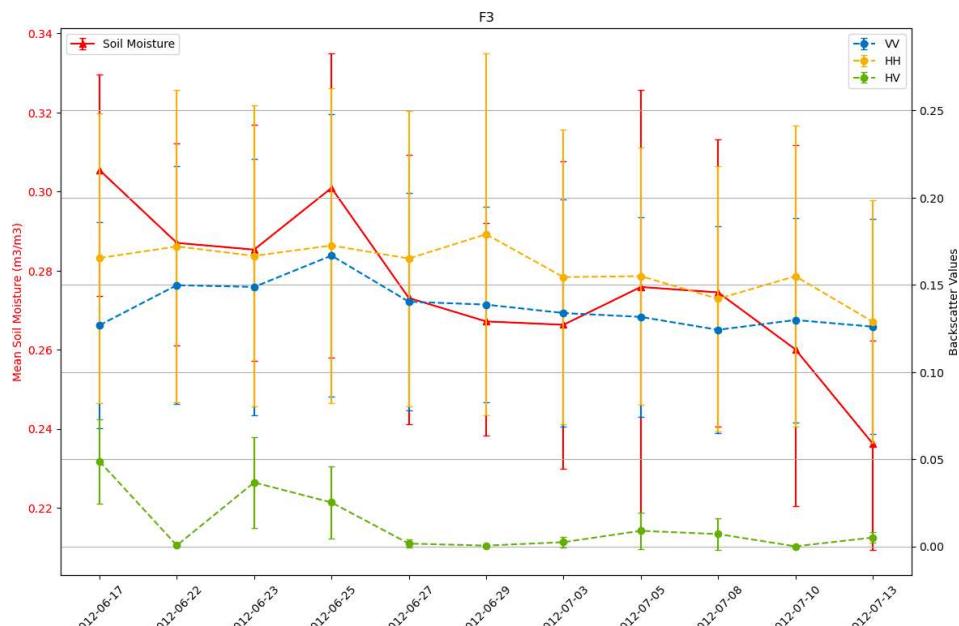
12/21/23



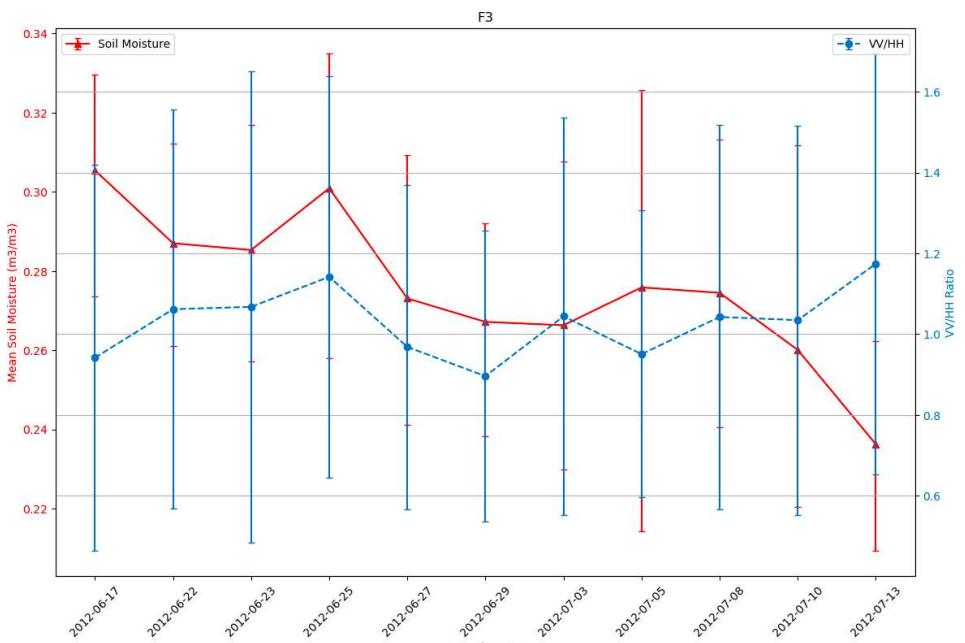
Correlation Coefficient - VV/HH: -0.28175910969290113

26

F3

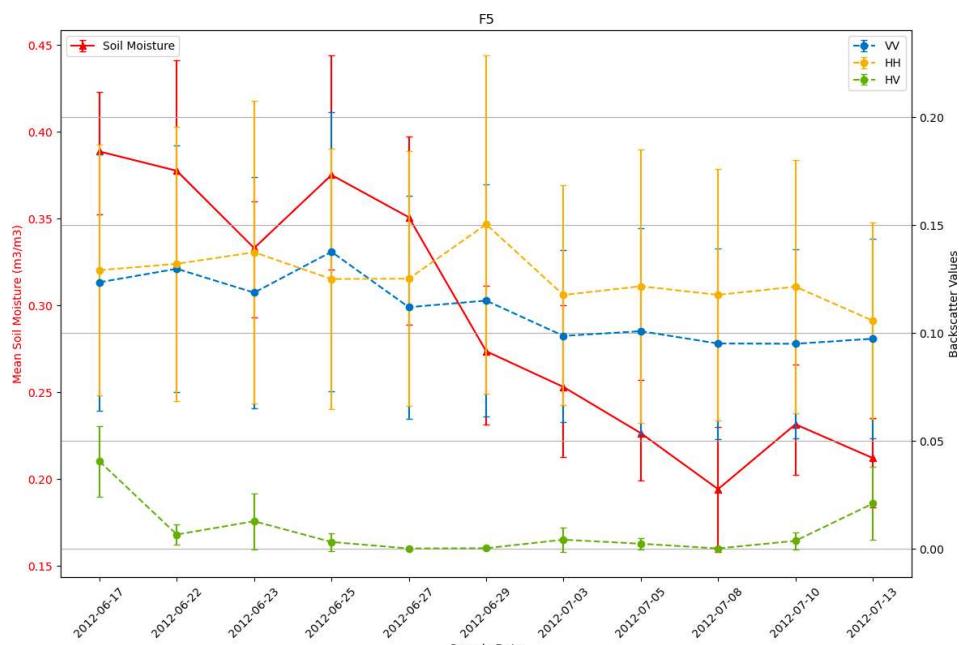


Correlation Coefficient - VV: 0.5118459224591589
 Correlation Coefficient - HH: 0.6680372369346311
 Correlation Coefficient - HV: 0.6848864395056324

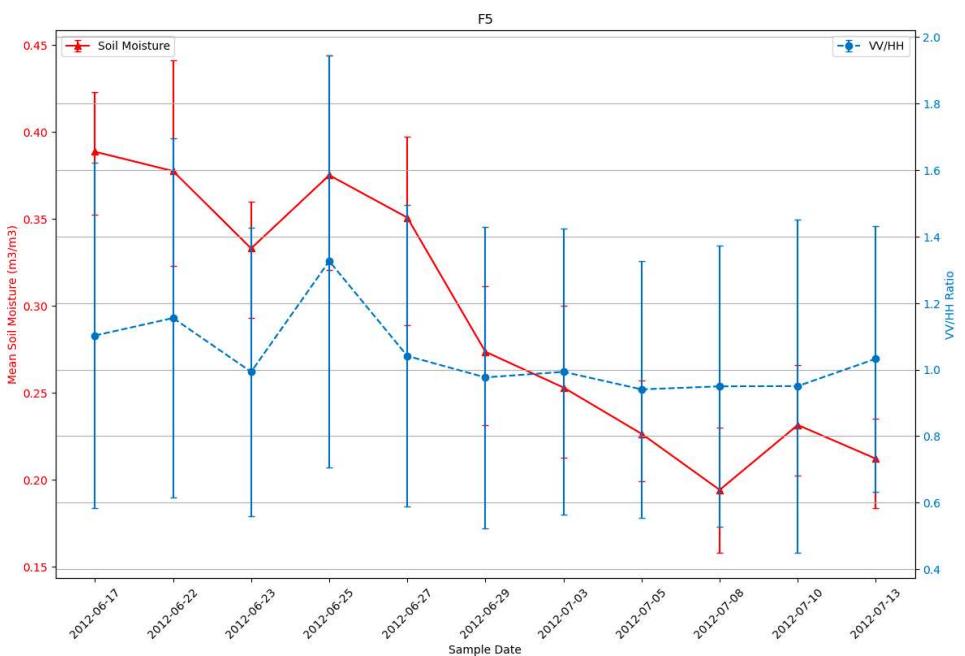


Correlation Coefficient - VV/HH: -0.2264978860214398

F5



Correlation Coefficient - VV: 0.9122764762203305
 Correlation Coefficient - HH: 0.46771769496434656
 Correlation Coefficient - HV: 0.3310715094507148



Correlation Coefficient - VV/HH: 0.7288107879216161

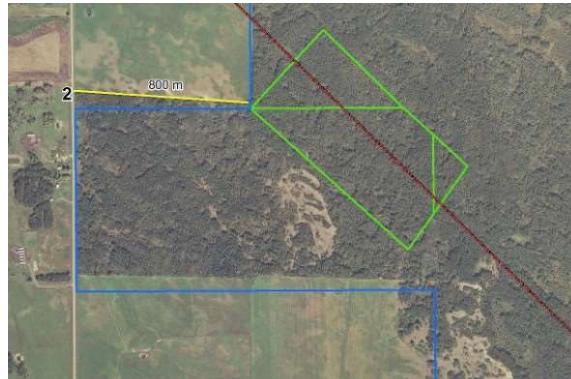
Site Breakdowns

F1



Mainly Aspen
averaging 30 ft

F2



Mainly young
Aspen 20 ft

12/21/23

F3



Aspen

- West of road: 20-40 ft
- East of road: 20-30 ft

F5



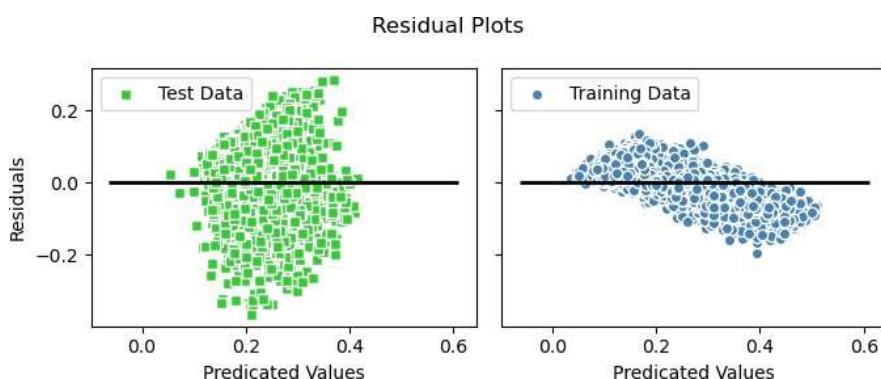
- Aspen(20-40 ft)
- Oak (25 ft)

29

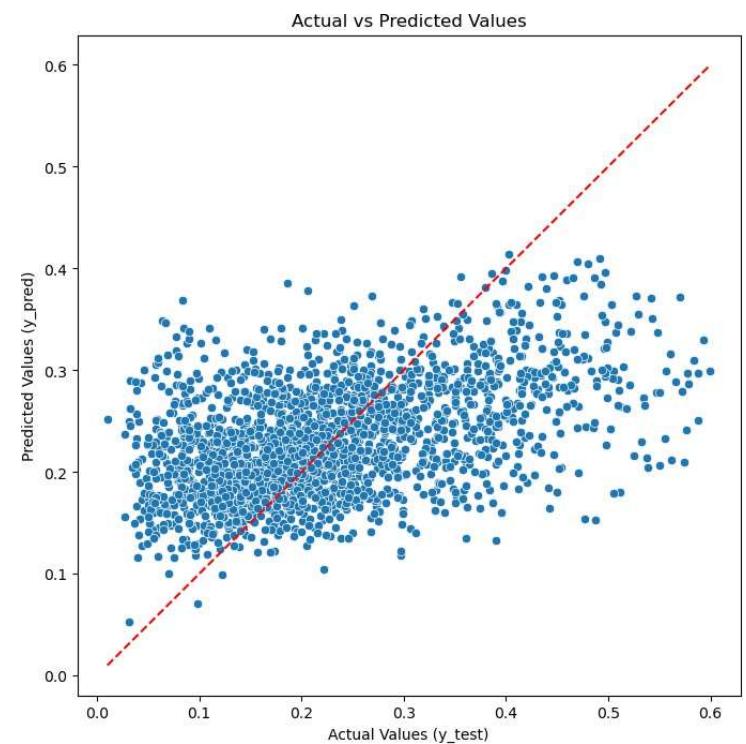
Soil Moisture By Crop

Overall Agricultural Sites

- 80/20 train/test split
- X: mean and std of VV, HH, HV, VV/HH
- Y: field soil moisture

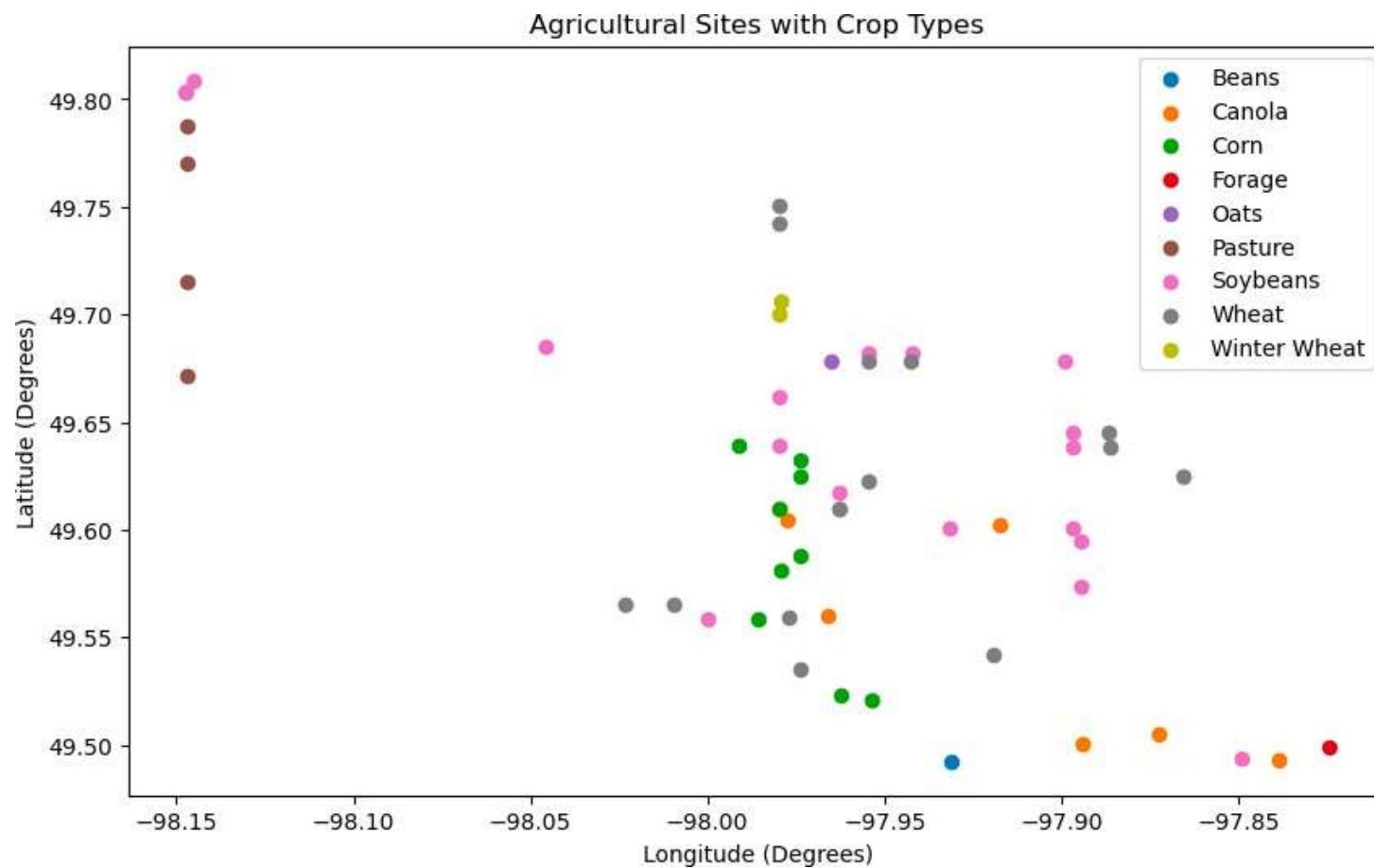


```
R^2 Train: 0.8880574139838779  
Adjusted R^2 Train: 0.8879480683565117  
  
R^2 Test: 0.22268458346469167  
Adjusted R^2 Test: 0.21963778124407318
```

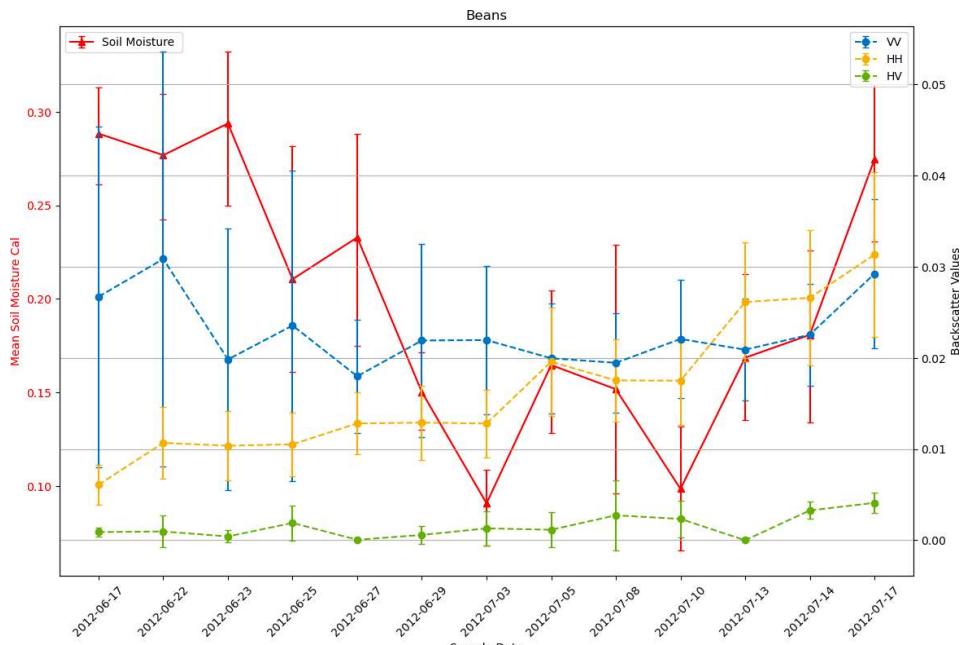


```
cross-val:  
[0.16728019 0.17998177 0.22164384 0.20605362 0.21334789]
```

Crop Distribution

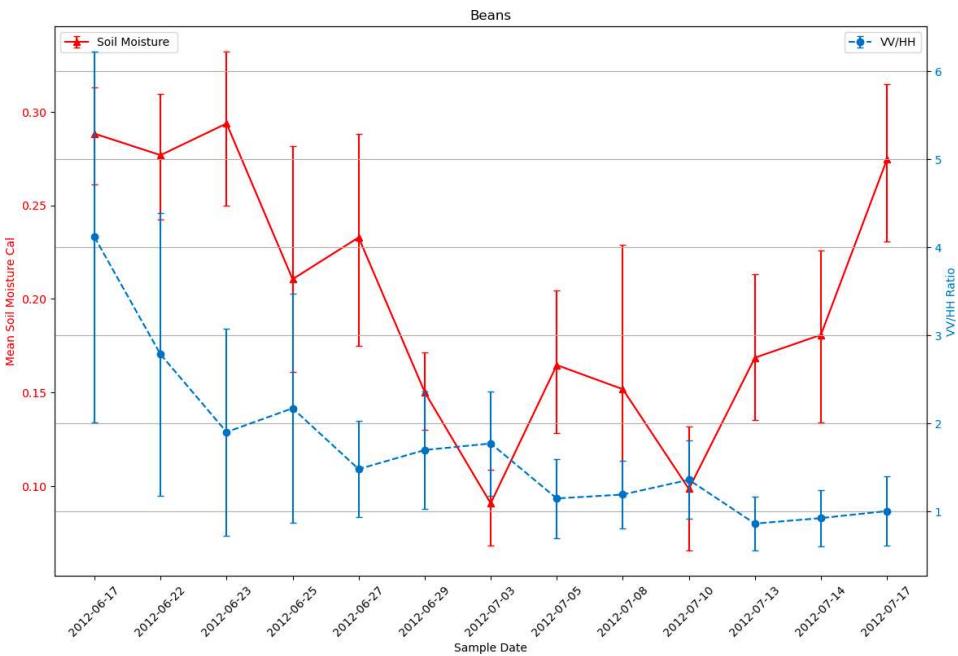


Beans



Correlation Coefficient - VV: 0.478038260710532
 Correlation Coefficient - HH: -0.18840069469423448
 Correlation Coefficient - HV: -0.0907952583938913

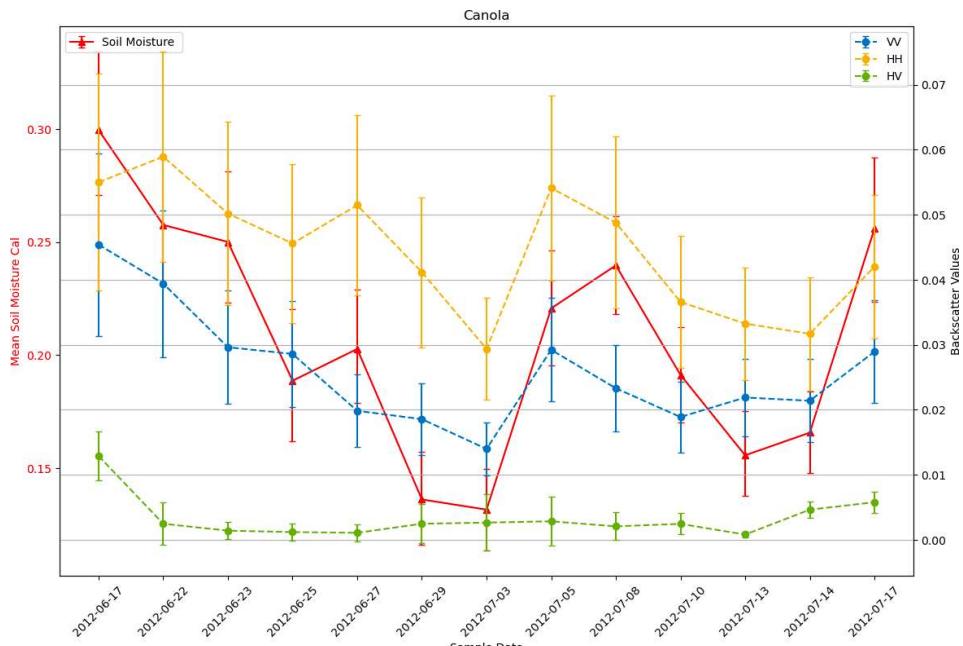
12/21/23



Correlation Coefficient - VV/HH: 0.4927642924453957

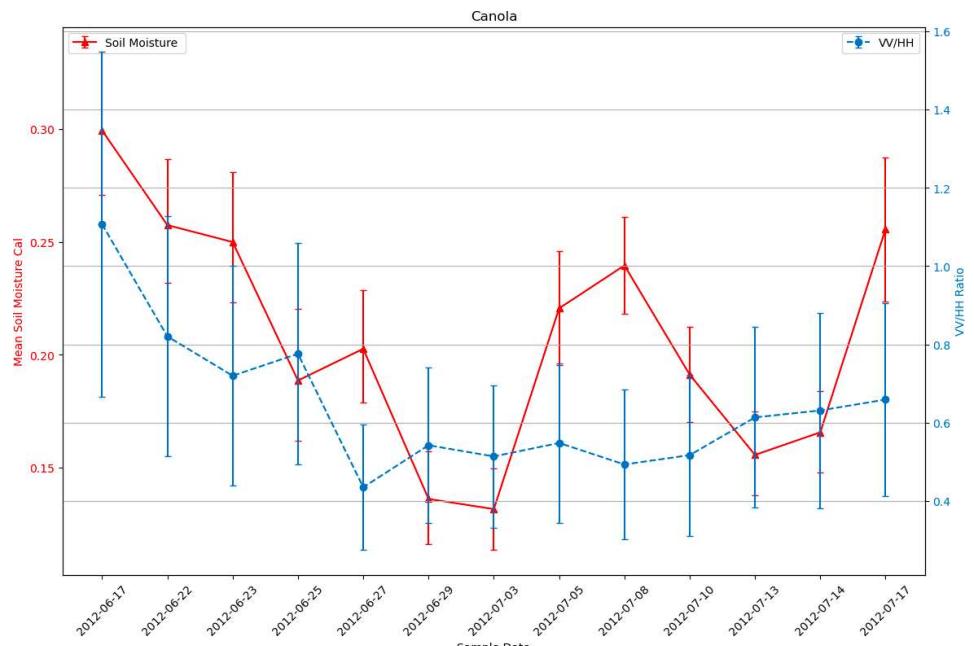
33

Canola



Correlation Coefficient - VV: 0.8502735853172997
 Correlation Coefficient - HH: 0.7772660690802519
 Correlation Coefficient - HV: 0.541883111768216

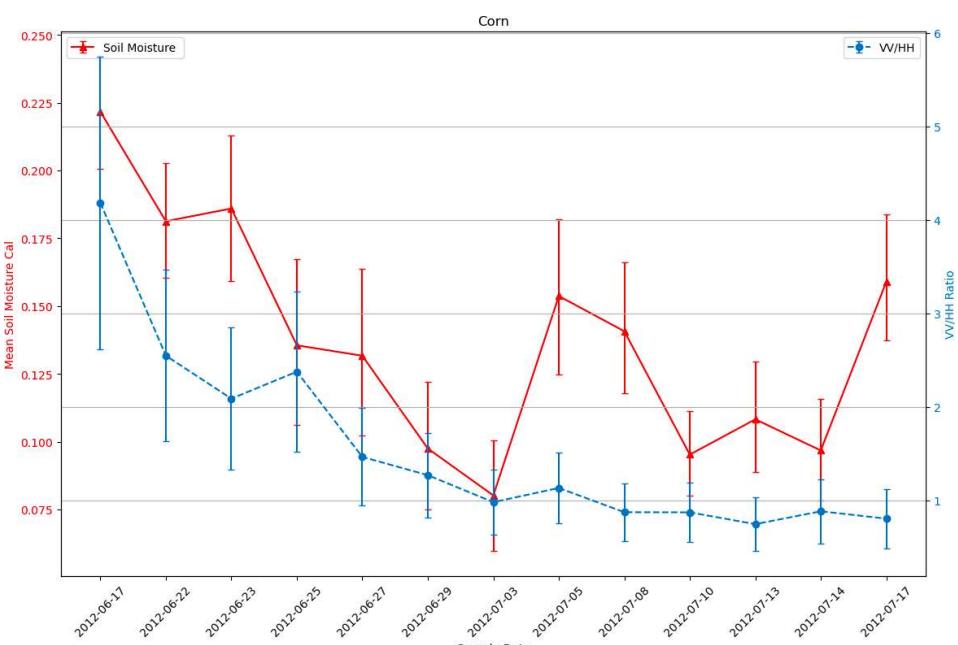
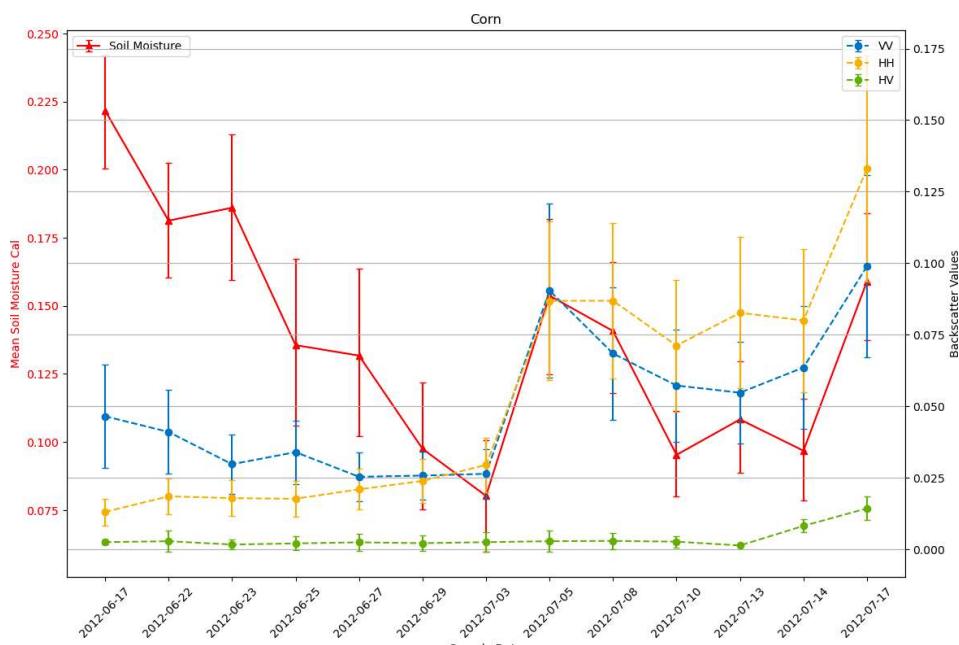
12/21/23



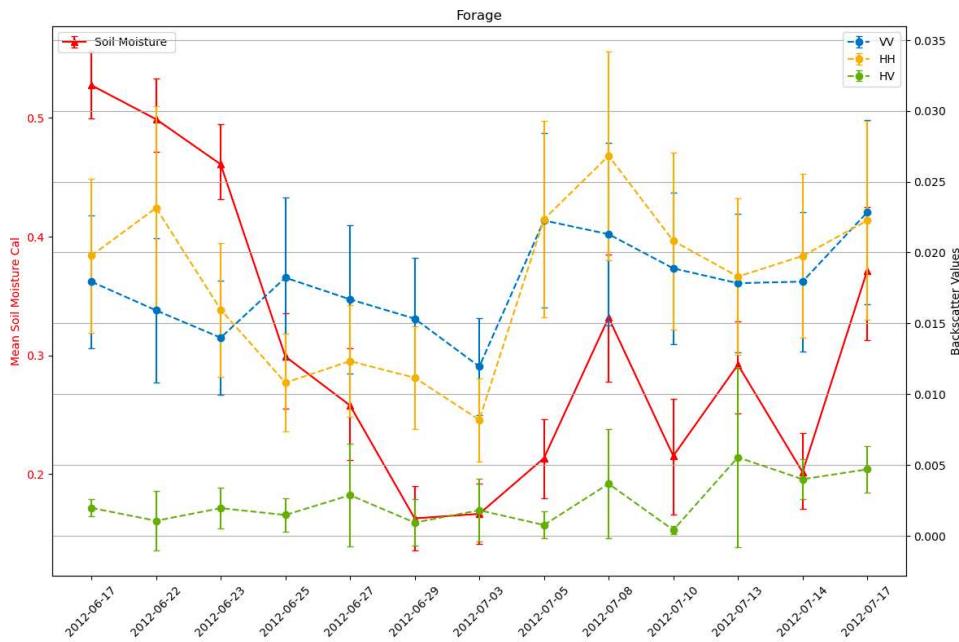
Correlation Coefficient - VV/HH: 0.6169237670960545

34

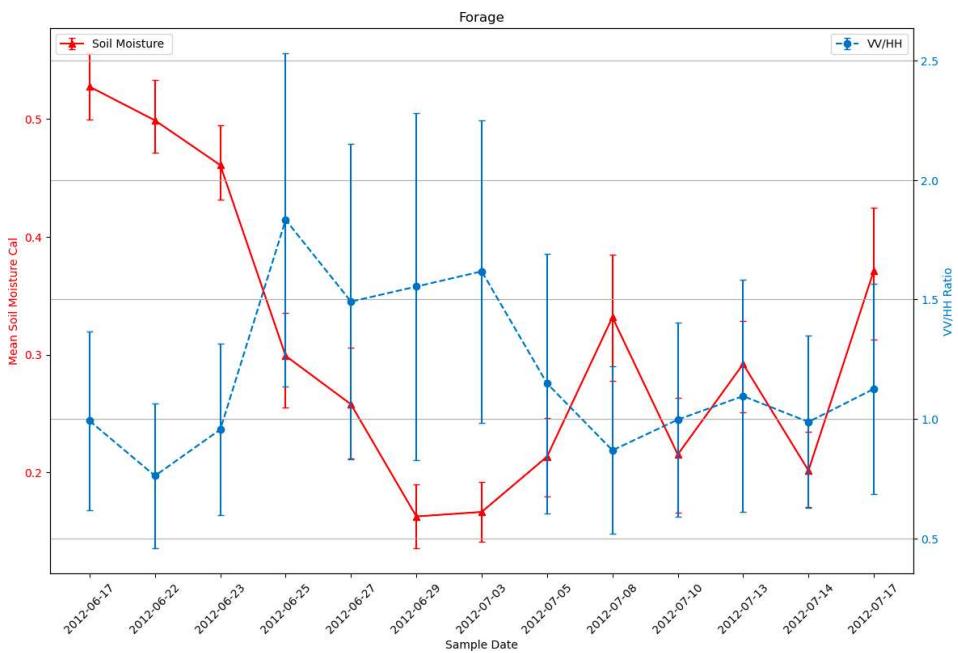
Corn



Forage

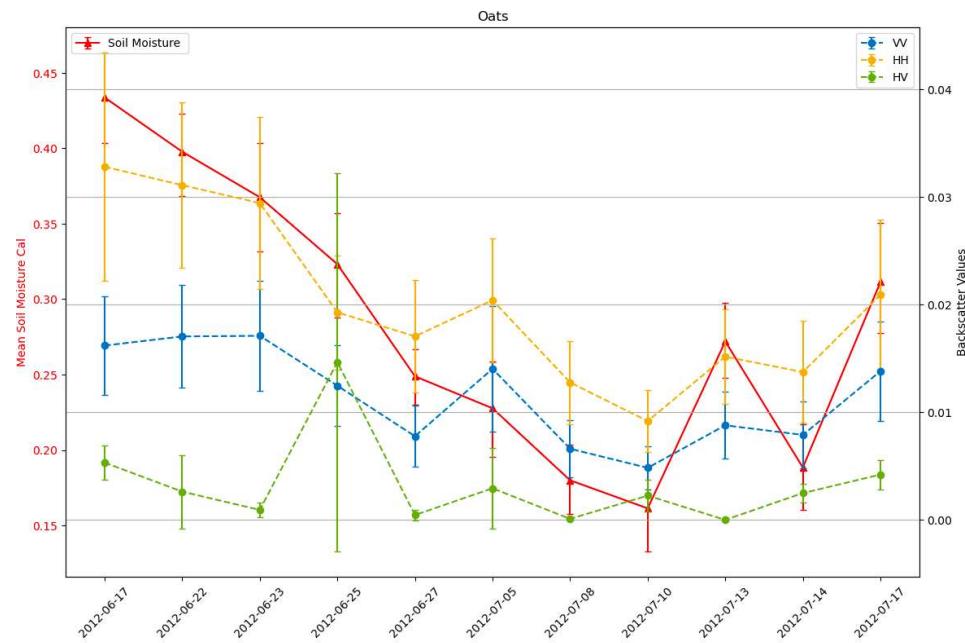


Correlation Coefficient – VV: 0.040728983319283374
 Correlation Coefficient – HH: 0.40285163710350724
 Correlation Coefficient – HV: 0.06587254468579698

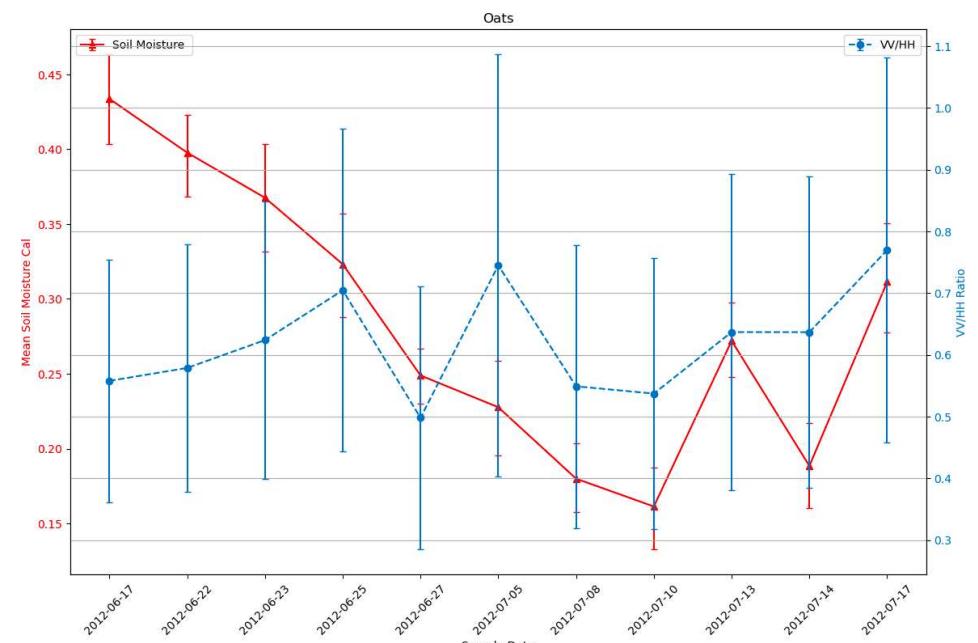


Correlation Coefficient – VV/HH: -0.5353455574467415

Oats

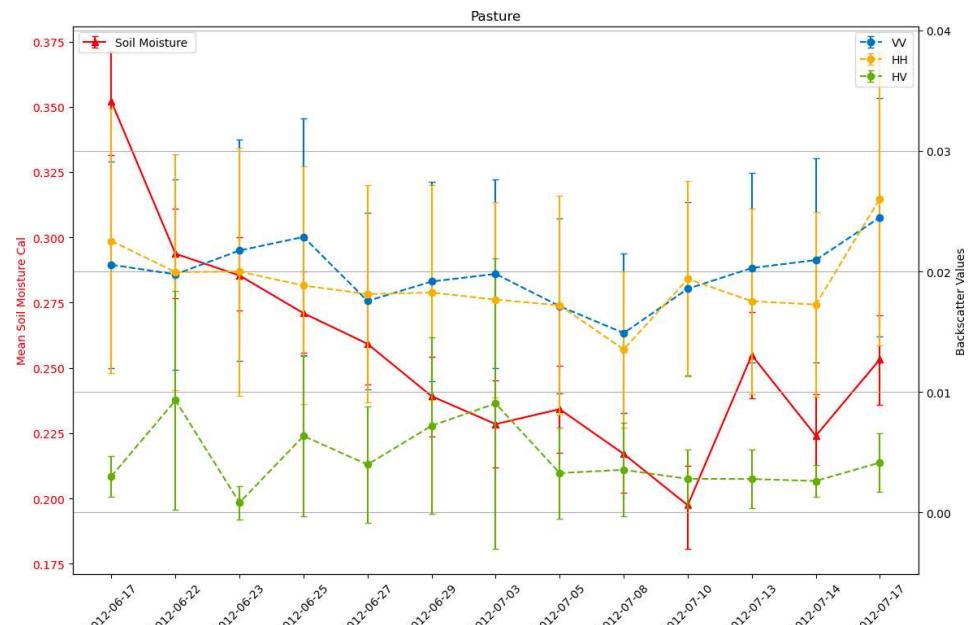


Correlation Coefficient - VV: 0.8773611342898586
 Correlation Coefficient - HH: 0.940609109046539
 Correlation Coefficient - HV: 0.3153845799984768



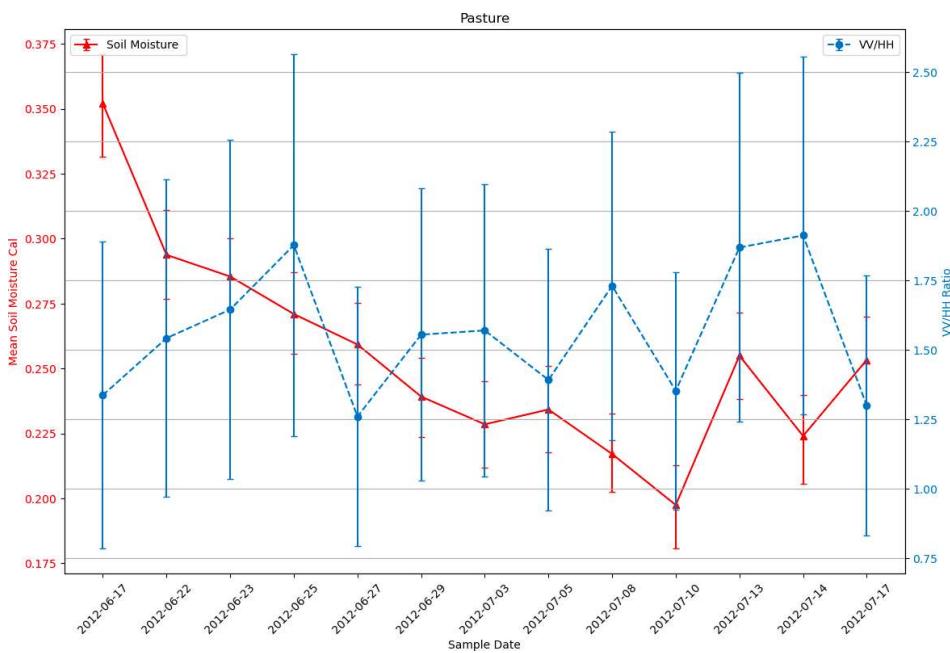
Correlation Coefficient - VV/HH: 0.08328827446770473

Pasture



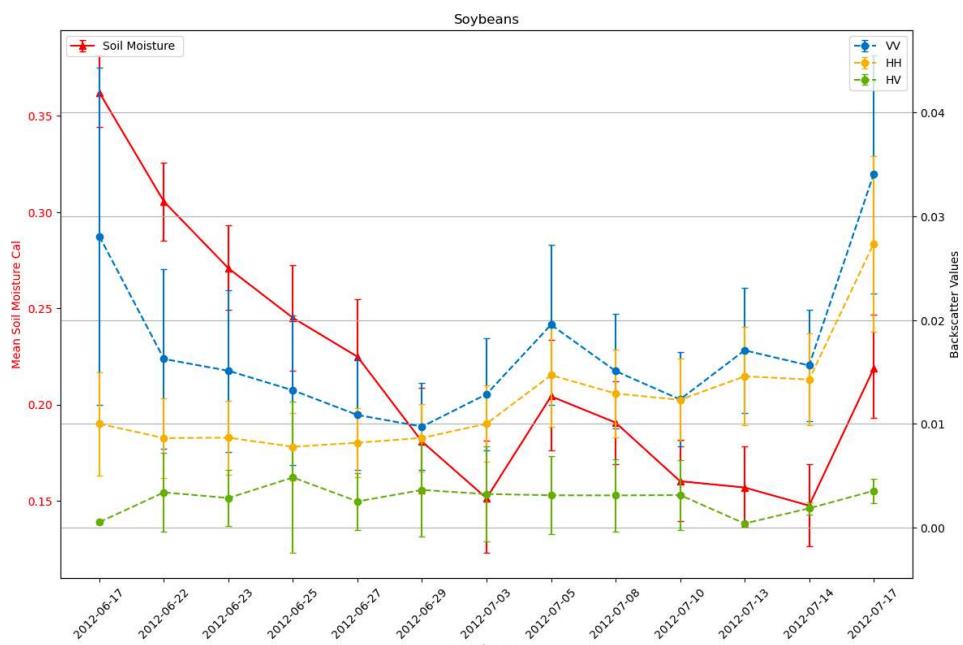
Correlation Coefficient – VV: 0.37360228263540096
 Correlation Coefficient – HH: 0.50202763095736
 Correlation Coefficient – HV: 0.009891160569141397

12/21/23

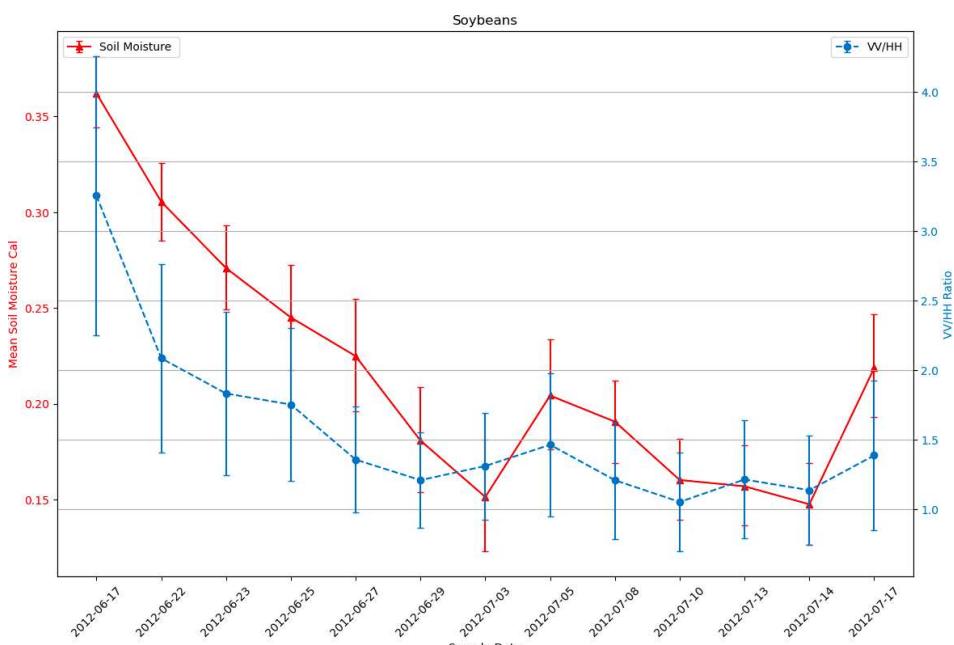


Correlation Coefficient – VV/HH: -0.15947985802065356

Soybeans

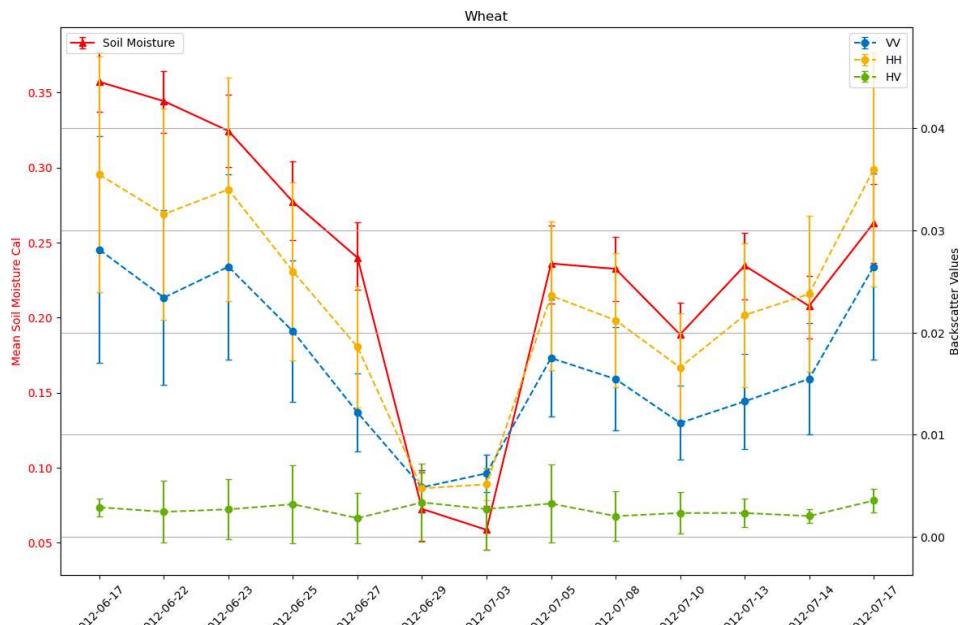


Correlation Coefficient - VV: 0.41153650479650167
 Correlation Coefficient - HH: -0.25091692963879786
 Correlation Coefficient - HV: -0.10081351539366983



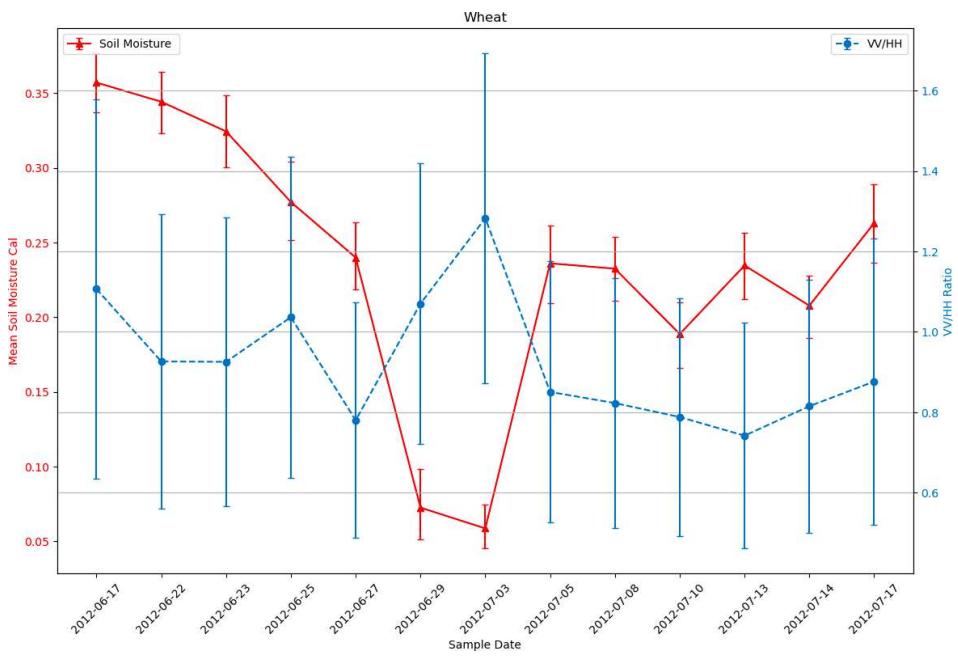
Correlation Coefficient - VV/HH: 0.9286840467678052

Wheat



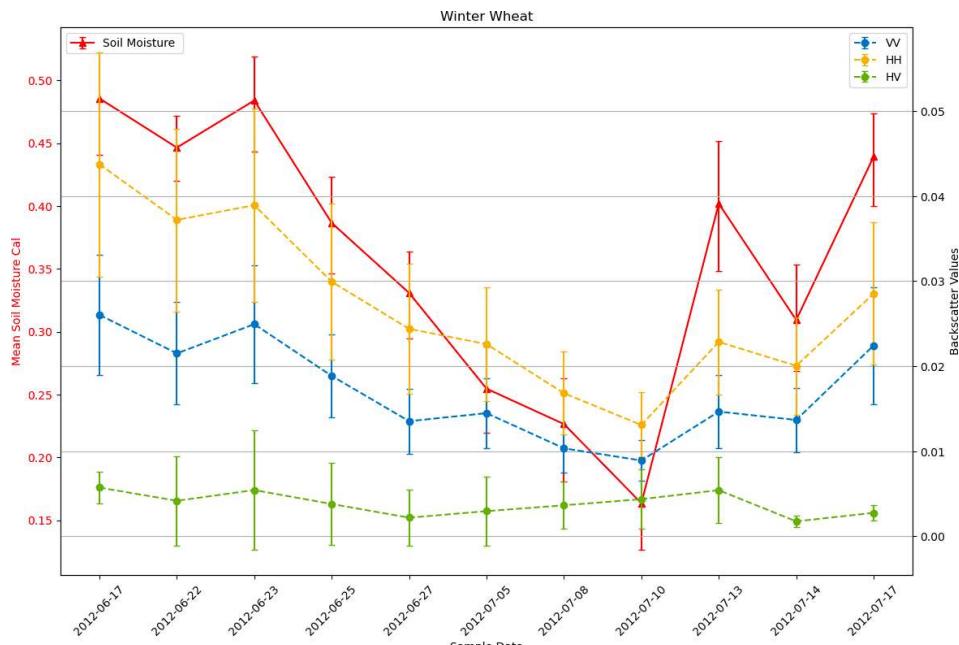
Correlation Coefficient - VV: 0.9069857254944927
 Correlation Coefficient - HH: 0.9337322846160099
 Correlation Coefficient - HV: -0.06445842374945009

12/21/23



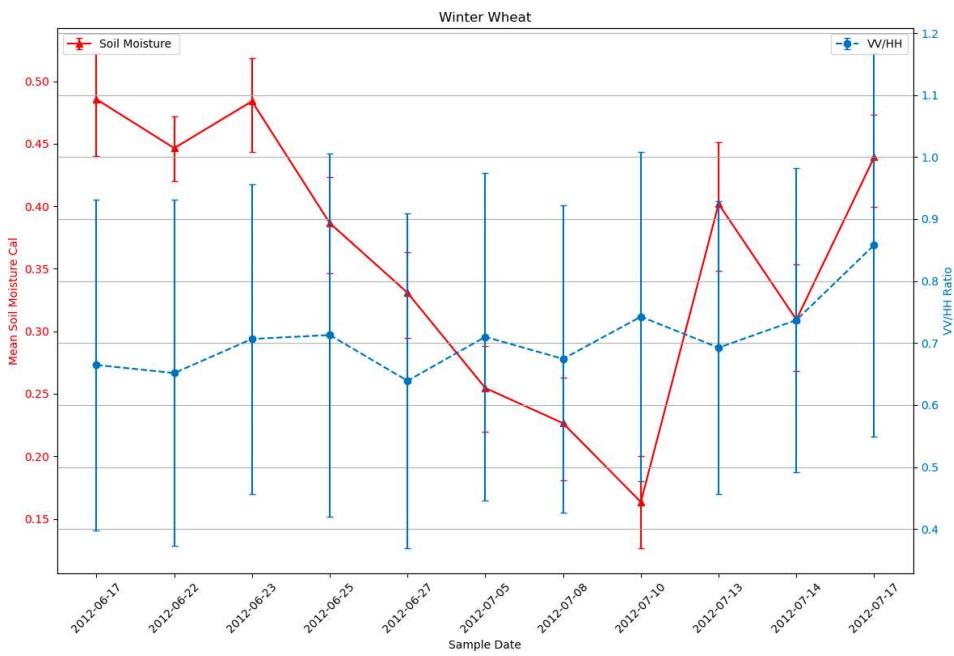
Correlation Coefficient - VV/HH: -0.3053794431716168

Winter Wheat



Correlation Coefficient - VV: 0.9294763055652095
 Correlation Coefficient - HH: 0.9055928216785305
 Correlation Coefficient - HV: 0.41970685207151903

12/21/23



Correlation Coefficient - VV/HH: -0.016729398750164104

Summary – Correlation Coefficient

PolSAR:

- 1) Oats: HH(0.94), VV(0.88)
- 2/3) Wheat: HH(0.93), VV(0.91)
- 2/3) Winter Wheat: VV(0.93), HH(0.91)
- 4) Canola: VV(0.85), HH(0.78)
- 5) Pasture: HH(0.50), VV(0.37)
- 6) Beans: VV(0.48), HH(-0.19)
- 7) Soybeans: VV(0.41), HH(-0.25)
- 8) Forage: HH(0.40), VV(0.04)
- 9) Corn: VV(0.13), HH(-0.21)

VV/HH:

- 1) Soybeans (0.93)
- 2) Corn (0.77)
- 3) Canola (0.62)
- 4) Forage (-0.54)
- 5) Beans (0.49)
- 6) Wheat (-0.31)
- 7) Pasture (-0.16)
- 8) Oats (0.08)
- 9) Winter Wheat (-0.02)

Strength of VV,HH seems to be inverse with VV/HH

Biomass & Plant Water Content by Crop

Field Data and UAVSAR data mapping

Field Data UAVSAR Data

6/16/2012 → 6/17/2012

6/21/2012 → 6/22/2012

6/24/2012 → 6/25/2012

6/28/2012 → 6/29/2012

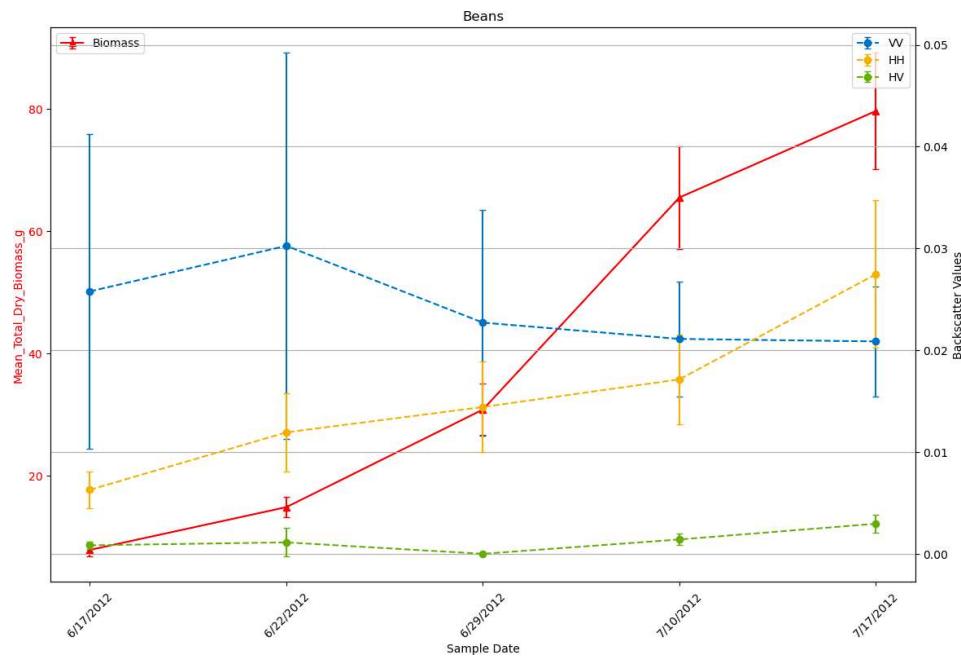
7/7/2012 → 7/8/2012

7/9/2012 → 7/10/2012

7/16/2012 → 7/17/2012

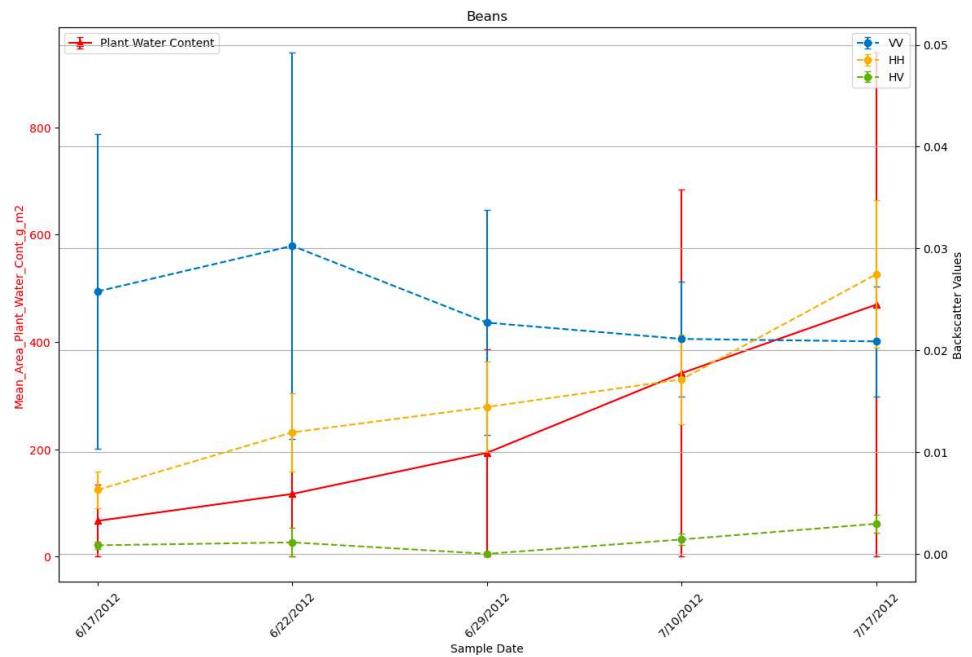
Beans

Dry Biomass



Correlation Coefficient - VV: -0.8067960532153169
 Correlation Coefficient - HH: 0.925114099148892
 Correlation Coefficient - HV: 0.7307540799625463

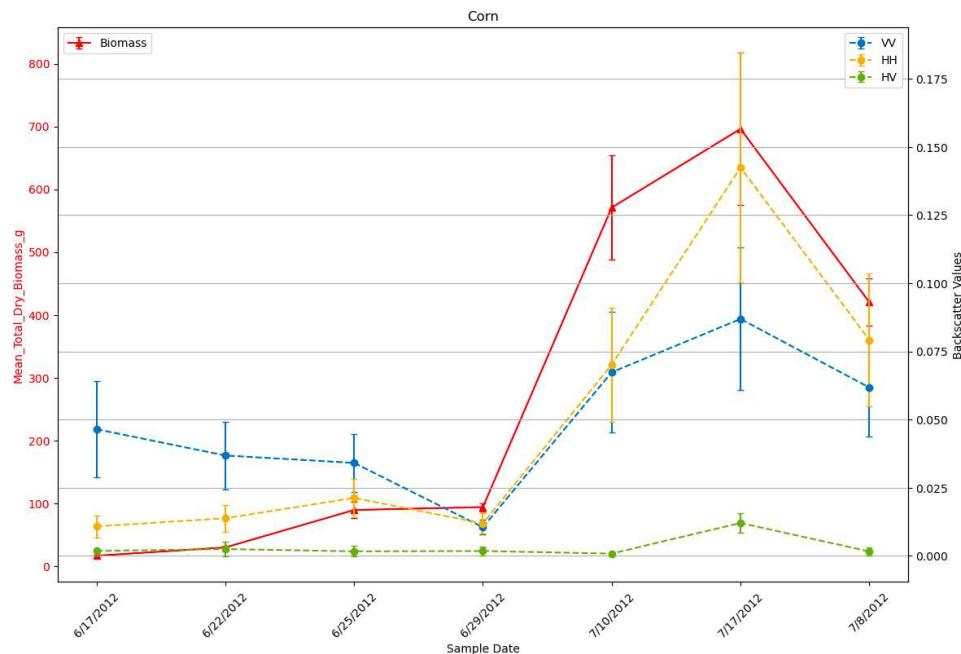
Plant Water Content



Correlation Coefficient - VV: -0.7761769739567524
 Correlation Coefficient - HH: 0.9619266209857985
 Correlation Coefficient - HV: 0.7694535659948993

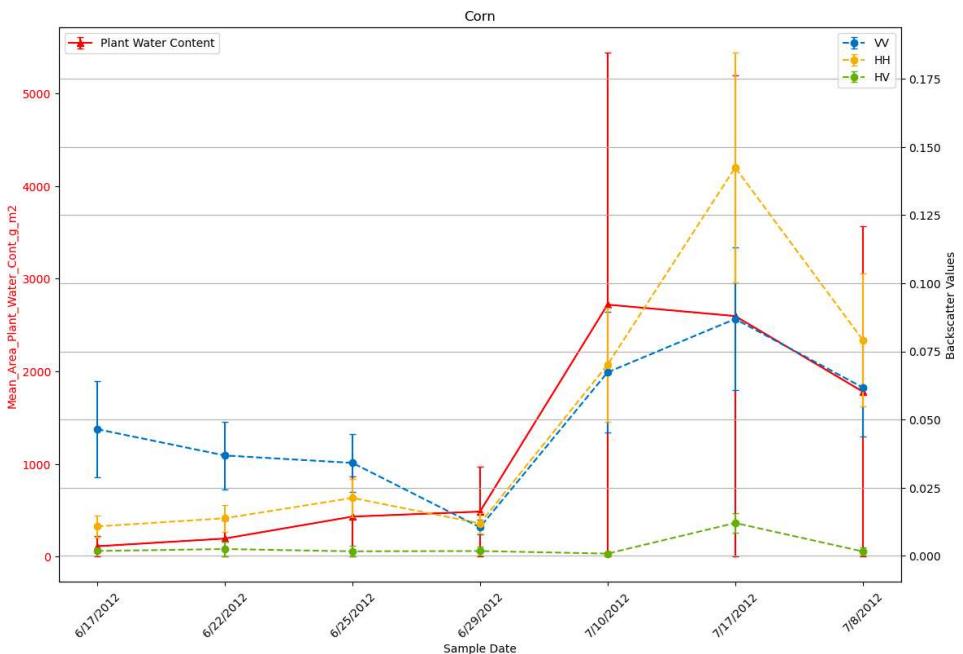
Corn

Dry Biomass



Correlation Coefficient - VV: 0.8578457366597068
 Correlation Coefficient - HH: 0.9492425395155937
 Correlation Coefficient - HV: 0.5786796263279141

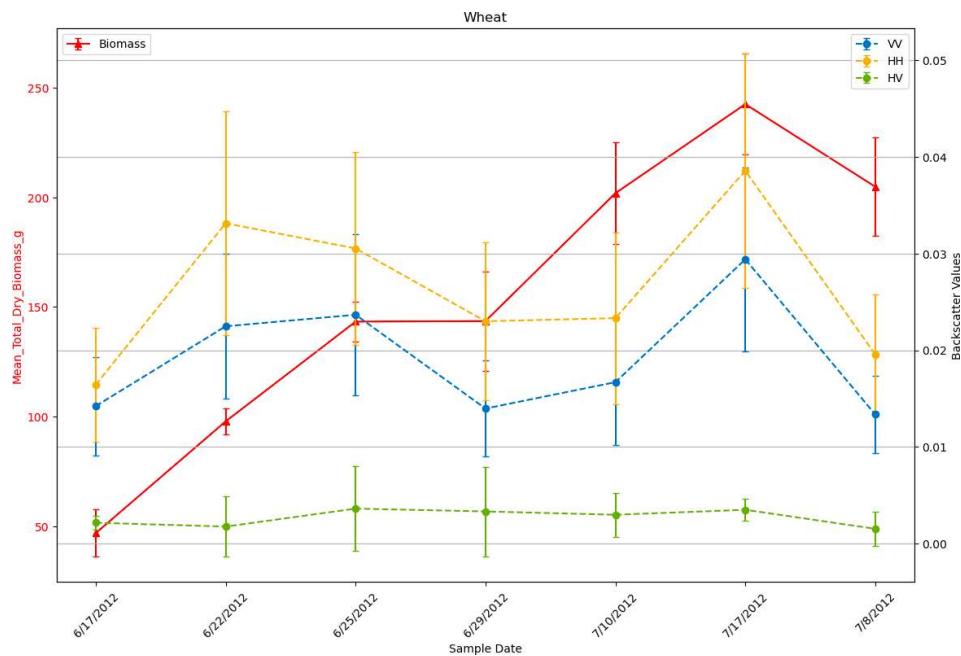
Plant Water Content



Correlation Coefficient - VV: 0.8215055529805064
 Correlation Coefficient - HH: 0.8885274323933744
 Correlation Coefficient - HV: 0.4519125621733771

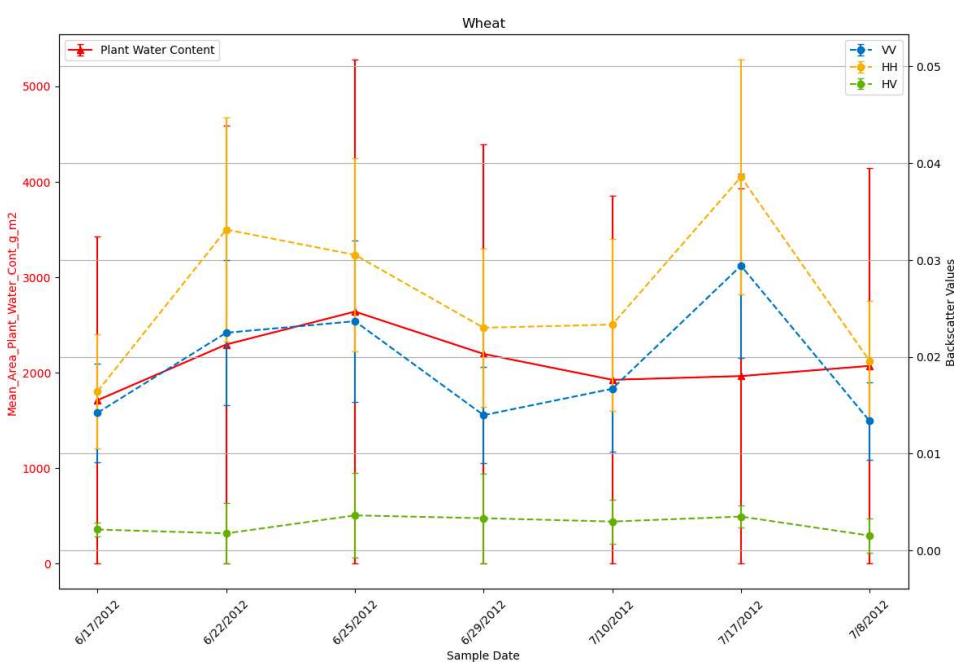
Wheat

Dry Biomass



Correlation Coefficient - VV: 0.3365105672776096
 Correlation Coefficient - HH: 0.3915483761778894
 Correlation Coefficient - HV: 0.3384566911279177

Plant Water Content



Correlation Coefficient - VV: 0.33603190061530924
 Correlation Coefficient - HH: 0.43325688968497483
 Correlation Coefficient - HV: 0.2947488742479333

Observations

- VV & HH have good correlations with most of the crops' dry biomass and plant water content
- HV's correlation is not as weak as observed for soil moisture
- Consistent low HV values (generally < 0.01)

view Appendix for other crops

Future Works

- Fire Monitoring:
 - Improve run time
 - Incorporate missing data treatment from Summer
 - Enhance capability for fire progression
- Fuel Moisture:
 - Individual forested site and crop for modelling
 - Decomposition
 - Utilize more flight lines

Acknowledgement

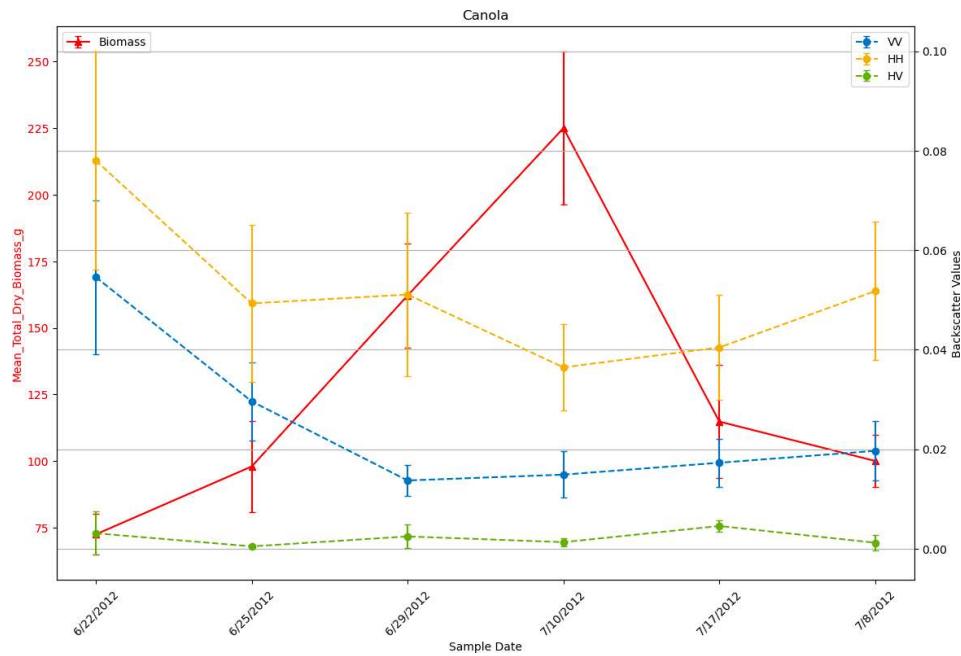
Thank you all!

- Yunling, Karen, Charlie for meeting with me every week and providing guidance!
- Sean Buckley for sponsoring this internship
- JPL for the opportunity to come back this semester
- Education Office & 334 Business team for coordinating my onboarding and offboarding

Appendix – Biomass Visualizations

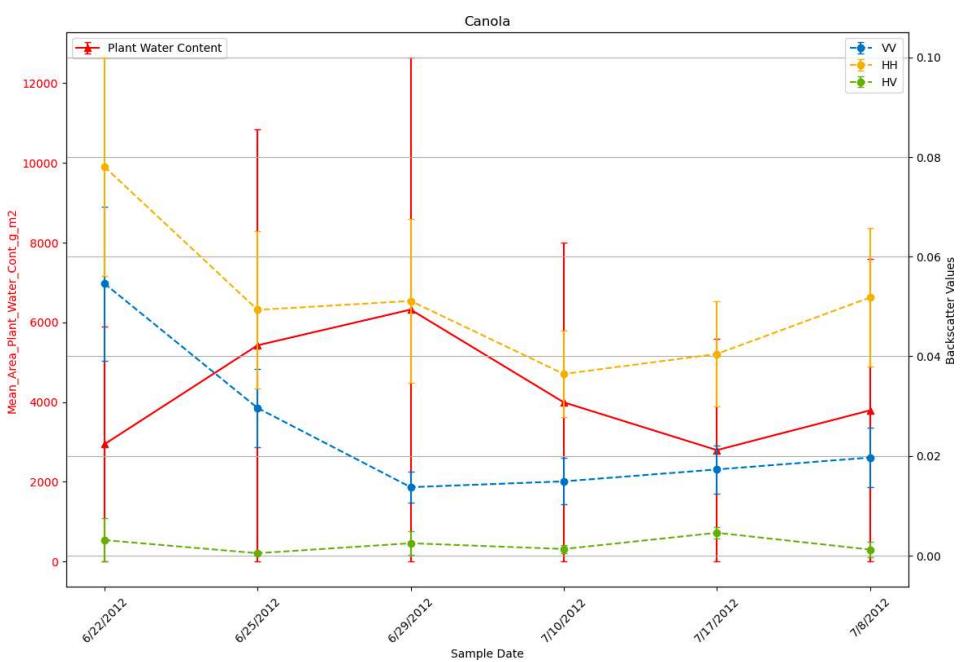
Canola

Dry Biomass



Correlation Coefficient - VV: -0.6672811440124319
 Correlation Coefficient - HH: -0.6774086793187527
 Correlation Coefficient - HV: -0.1866809573331928

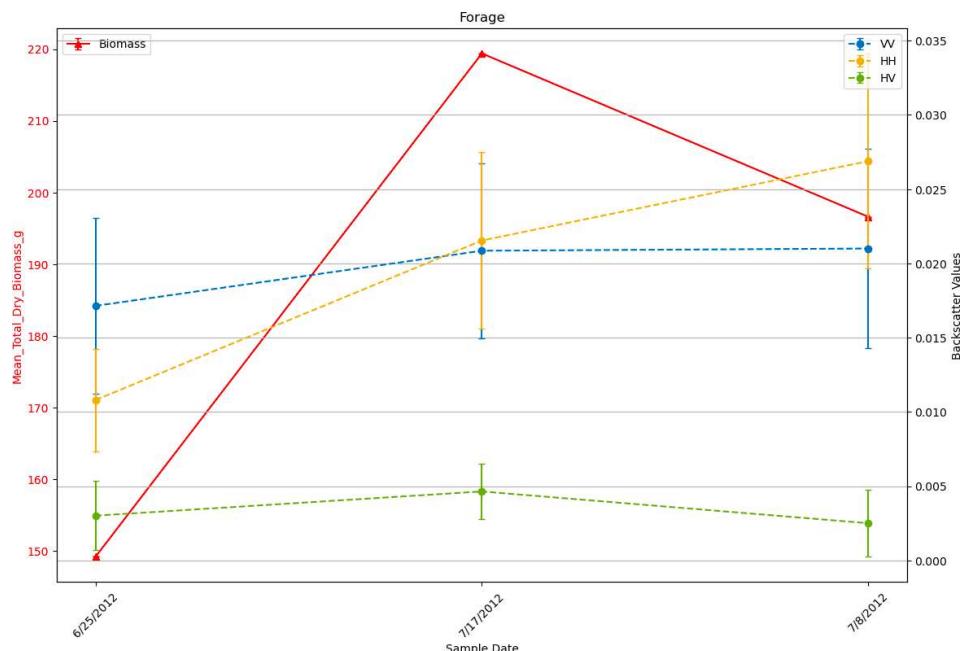
Plant Water Content



Correlation Coefficient - VV: -0.3705479888696389
 Correlation Coefficient - HH: -0.1808600629950915
 Correlation Coefficient - HV: -0.5165235895670481

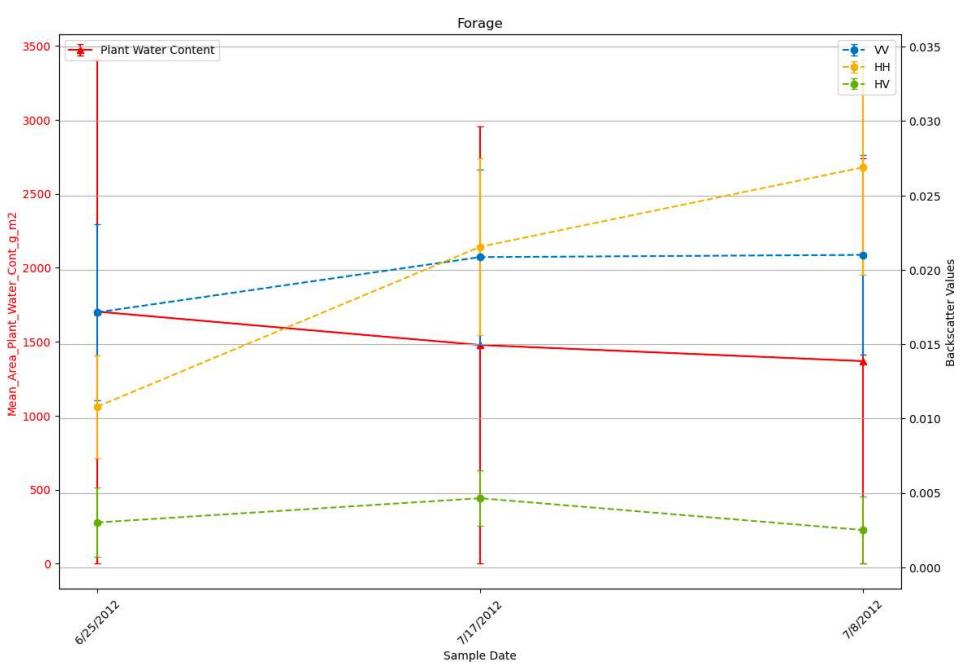
Forage

Dry Biomass



Correlation Coefficient - VV: 0.9365595723772736
 Correlation Coefficient - HH: 0.7924889897915617
 Correlation Coefficient - HV: 0.5797098400937182

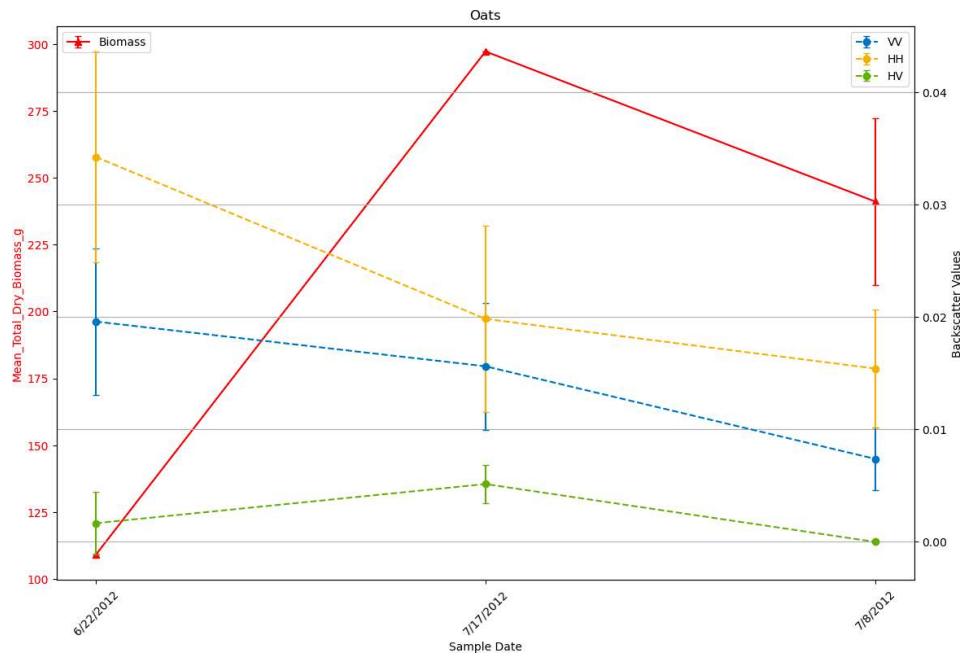
Plant Water Content



Correlation Coefficient - VV: -0.9581451021545959
 Correlation Coefficient - HH: -0.9999721902920418
 Correlation Coefficient - HV: 0.030082067204898644

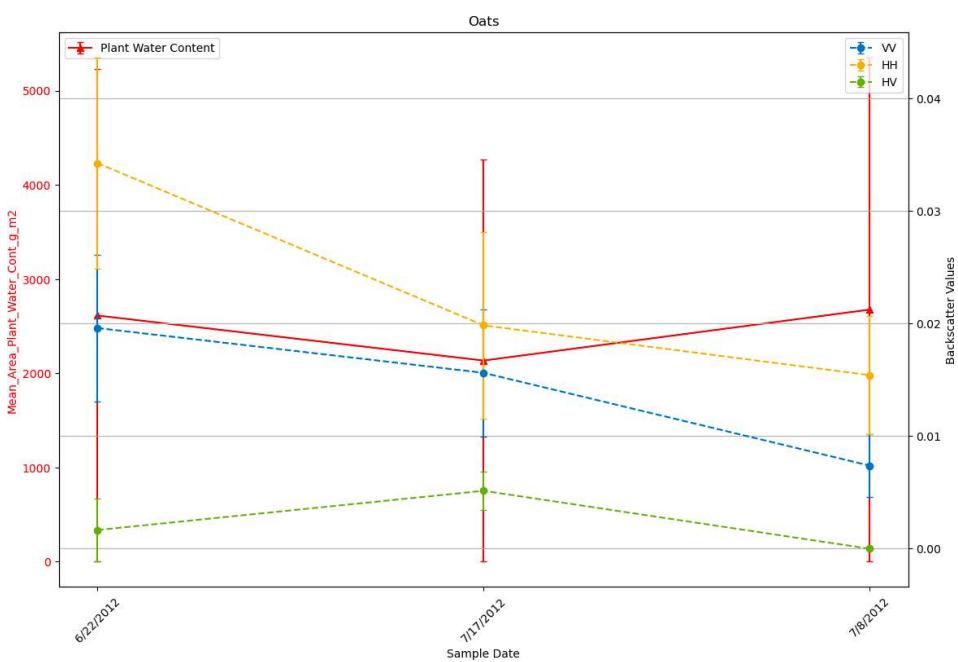
Oats

Dry Biomass



Correlation Coefficient - VV: -0.5260410931390412
 Correlation Coefficient - HH: -0.8672532141948207
 Correlation Coefficient - HV: 0.4758446802643318

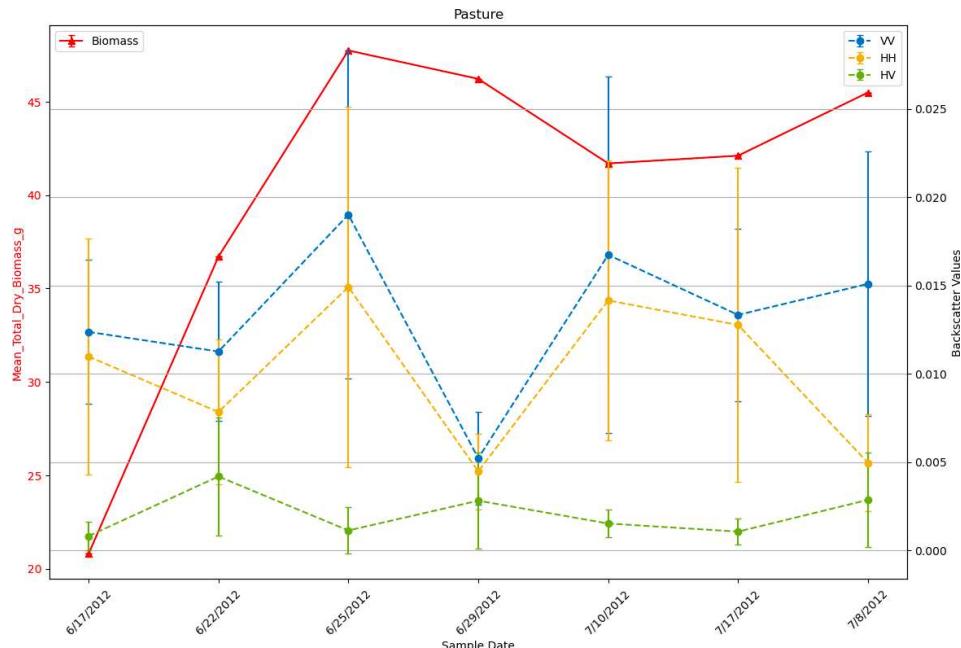
Plant Water Content



Correlation Coefficient - VV: -0.30024855252994237
 Correlation Coefficient - HH: 0.18961144355710674
 Correlation Coefficient - HV: -0.9767668138281304

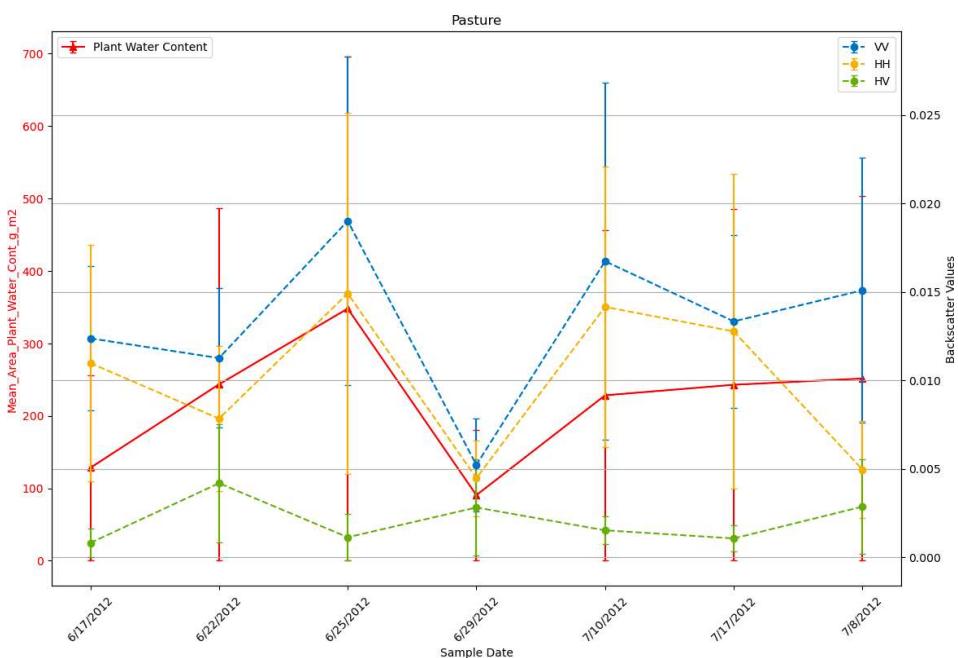
Pasture

Dry Biomass



Correlation Coefficient - VV: 0.13865170502091873
 Correlation Coefficient - HH: -0.09543438321652706
 Correlation Coefficient - HV: 0.2273735466961601

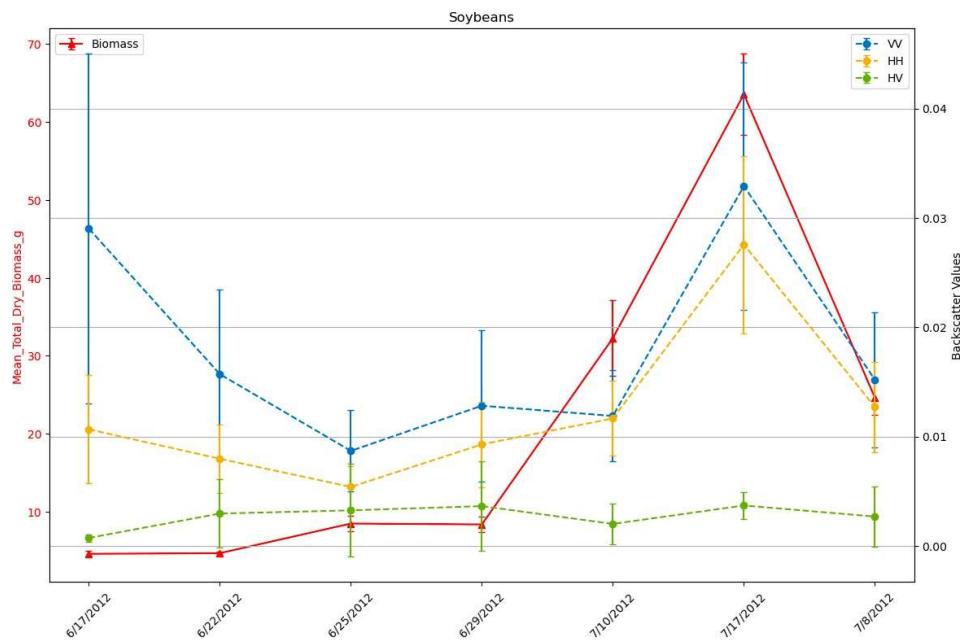
Plant Water Content



Correlation Coefficient - VV: 0.8369344590048847
 Correlation Coefficient - HH: 0.5198198188164935
 Correlation Coefficient - HV: -0.08480489911113759

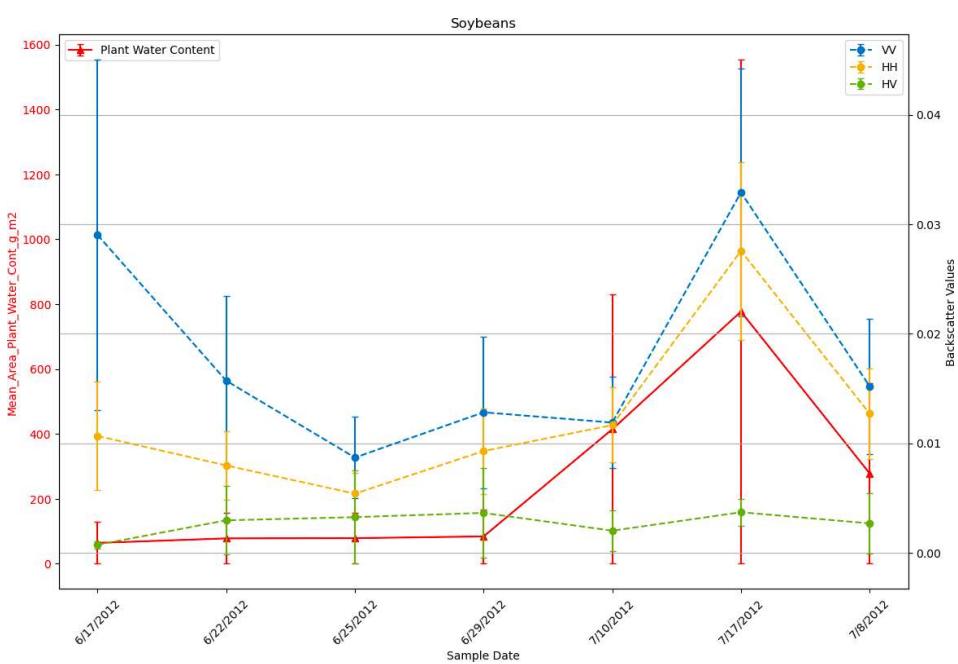
Soybeans

Dry Biomass



Correlation Coefficient - VV: 0.49785358073108055
 Correlation Coefficient - HH: 0.9262984669292073
 Correlation Coefficient - HV: 0.32320328130147635

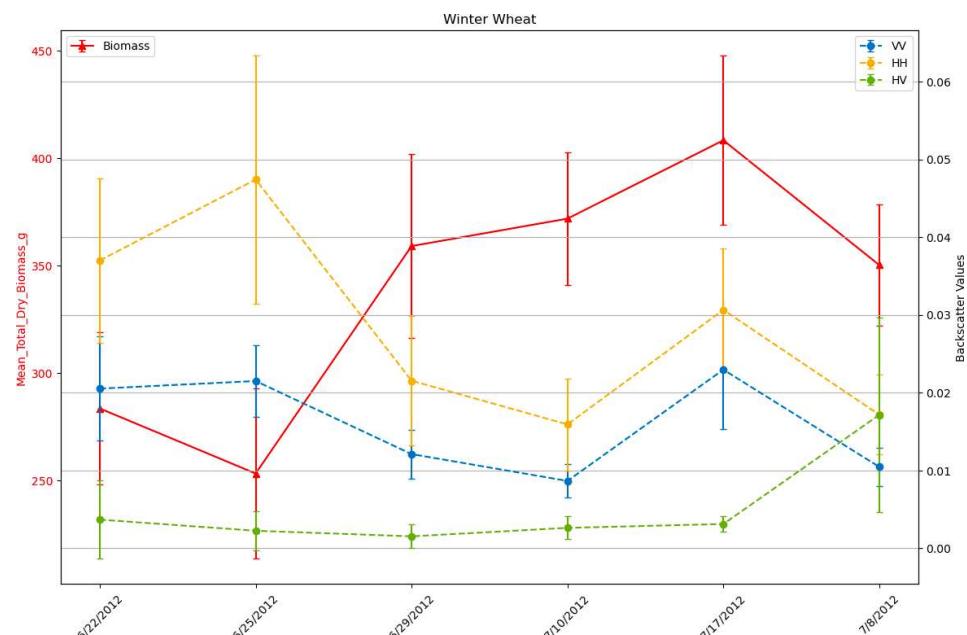
Plant Water Content



Correlation Coefficient - VV: 0.5144336083787829
 Correlation Coefficient - HH: 0.9267372911136538
 Correlation Coefficient - HV: 0.28803587966145183

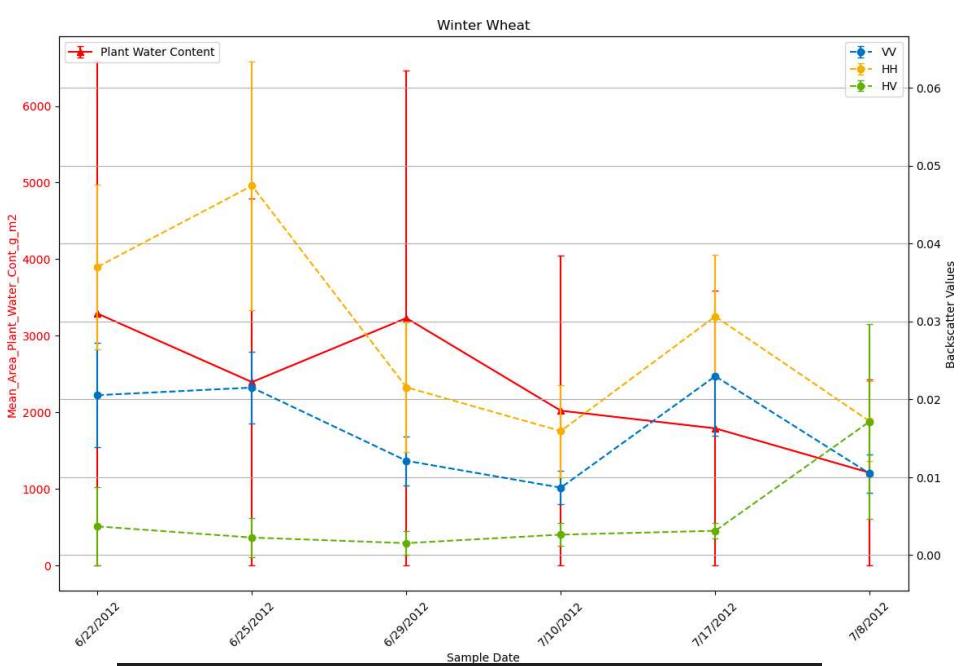
Winter Wheat

Dry Biomass



Correlation Coefficient - VV: -0.3397330446266409
 Correlation Coefficient - HH: -0.7299904110124725
 Correlation Coefficient - HV: 0.09690053033660384

Plant Water Content



Correlation Coefficient - VV: 0.22762410767016486
 Correlation Coefficient - HH: 0.36323082776291477
 Correlation Coefficient - HV: -0.6692232918928409