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# Retrieval of leaf chlorophyll content using narrow-band indices for field crops

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# Outline

- Leaf chlorophyll content estimation from narrow-band spectral indices
- Materials & Methods
  - Study area and field measurements
  - AISA imaging spectroscopy data
  - PROSPECT+SAIL radiative transfer model
  - Narrow-band indices
- Results
  - Vegetation indices V.S. Cab, LAI and MTA
  - Four best performing indices
- Conclusions

# Leaf chlorophyll content estimation from narrow-band spectral indices

- Leaf chlorophyll is an extremely important pigment for photosynthesis
- Imaging spectroscopy data allows the spatial mapping of Cab in crops.
- Narrow-band spectral vegetation indices had been widely used for Cab retrieval
- Narrow-band performance was affected by canopy structure (e.g. leaf area index (LAI) and leaf mean tilt angle (MTA)
- We investigated the sensitivity of these indices to structural effects produced by LAI and MTA variations.

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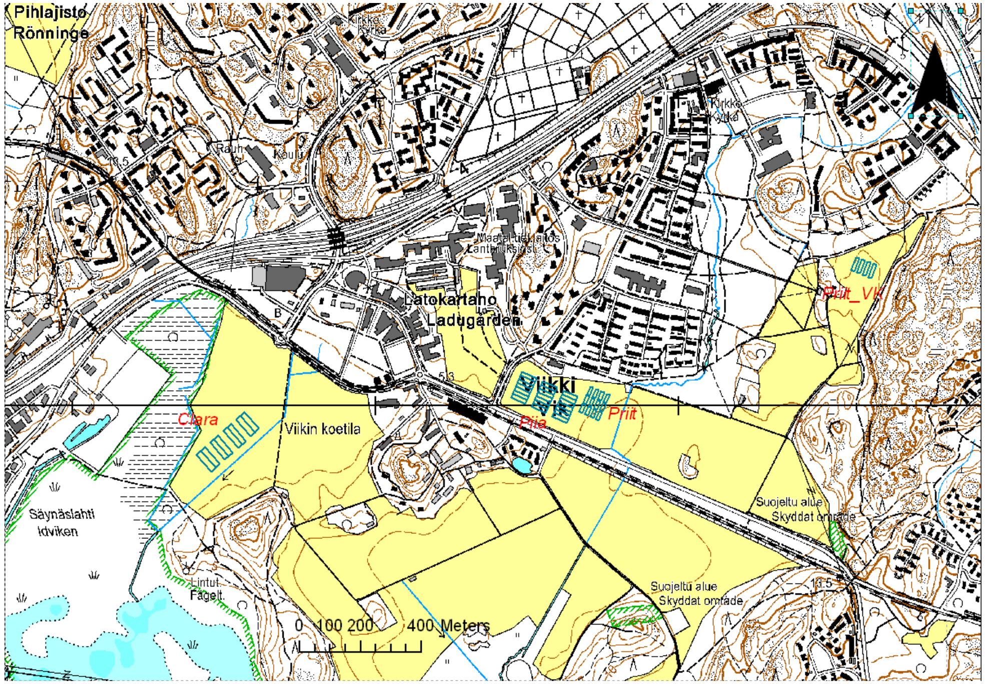
# Study area & crop photographs




Study area

Barley

Oat

Turnip rape

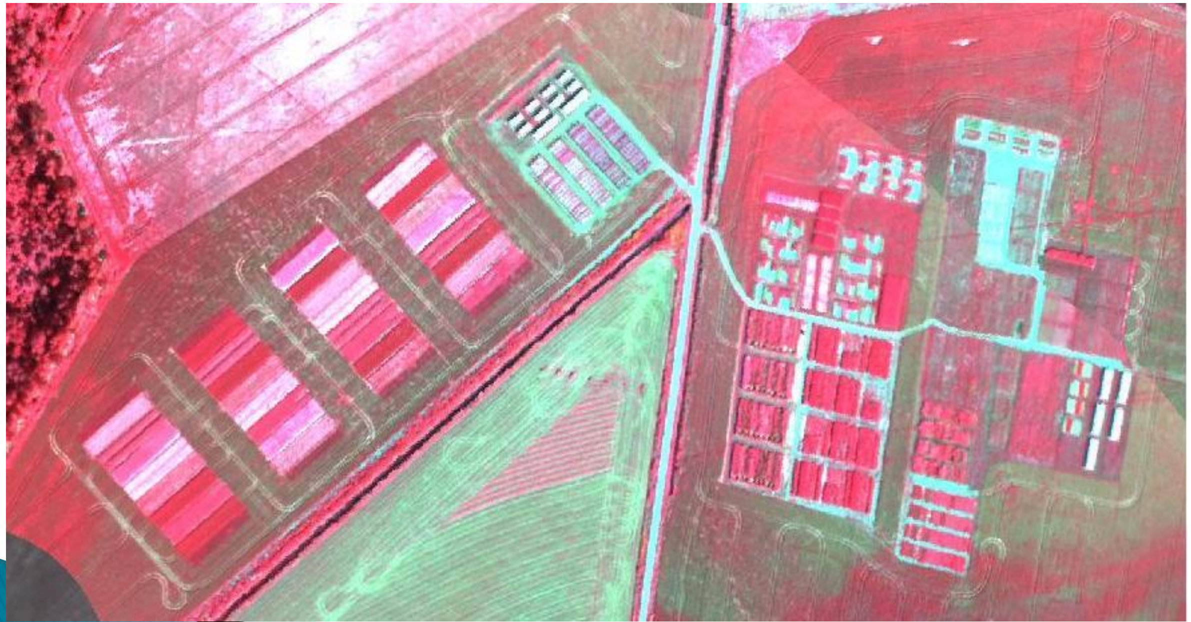
Wheat

Faba bean

Narrow-leafed lupine

# Field measurements and imaging spectroscopy data

- Leaf chlorophyll content a+b (Cab) measured by SPAD-502
- Leaf area index (LAI) measured by SunScan
- Species-specific Leaf Mean tilt Angle (MTA) measured by photographic method
- AISA imaging spectroscopy data



AISA Eagle sensor
Ground spatial resolution: 0.4m
Spectral resolution: 10nm
Spectral range : 400-1000nm

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# PROSPECT+SAIL radiative transfer model

| Model | Variable | Symbol | Unit | Range or value |
|---|---|---|---|---|
| PROSPECT | Leaf structure parameter | *N* | – | 1.55 |
| | Chlorophyll a+b content | Cab | $\mu g\ cm^{-2}$ | 25–100 |
| | Equivalent water thickness | Cw | cm | 0.001–0.02 |
| | Dry matter content | Cm | $g\ cm^{-2}$ | 0.005 |
| | Brown pigment content | Cbp | – | 0 |
| | Carotenoid content | Car | $\mu g\ cm^{-2}$ | Linked to Cab as 0.2×Cab |
| SAIL | Leaf area index | LAI | $m^2\ m^{-2}$ | 1–5 |
| | Leaf mean tilt angle | MTA | ° | 15–70 |
| | Hot spot size | hspot | – | 0.01 |
| | Solar zenith angle | tts | ° | 49.4 |
| | Observer zenith angle | tto | ° | 9 |
| | Azimuth angle | psi | ° | 90 |
| | Direct and diffuse irradiance | Dir/Dif | $W\ m^{-2}\ nm^{-1}$ | Calculated from 6S atmosphere radiative transfer model |
| | Soil reflectance | rsoil0 | – | ASD measurement, corrected by soil reflectance model |

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# Narrow-band indices

| Index | Name | Formulation | Scale | species | Reference |
|---|---|---|---|---|---|
| BGI | Blue Green Pigment Index | $R_{450}/R_{550}$ | leaf | Vine (*Vitis vinifera L.*) | Zarco-Tejada et al. (2005) |
| CTR | Carter vegetation index | $R_{695}/R_{420}$ | leaf | Persimmon (*Diospyros virginiana*), Pine (*Pinus taeda* | |
| CTR2 | | | | | |
| CTR3 | | | | | |
| CTR4 | | | | | |
| CTR5 | | | | | |
| CTR6 | | | | | |
| CUR | | | | | |
| Datt | | | | | |
| Datt2 | | | | | |
| Datt3 | | | | | |
| Datt4 | | | | | |
| Datt5 | | | | | |
| DD | | | | | |
| Gitelson1999 | | | | | |
| Gitelson2003 | | | | | |
| Gitelson-Chl1 | | | | | |
| Gitelson-Chl2 | | | | | |
| GR | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| MCARI | Modifed Chlorophyll Absobtion Ratio Index | $[(R_{700}-R_{670})-0.2*(R_{700}-R_{550})]*(R_{700}/R_{670})$ | canopy | Corn (*Zea mays L.*) | Daughtry et al.(2000) |
| MCARI/ OSAVI | Ratio of MCARI/ OSAVI | MCARI/ OSAVI | canopy | | Daughtry et al.(2000) |
| MCARI2 | | | | | |
| MCARI2/ OSAVI2 | | | | | |
| mNDVI | | | | | |
| mND705 | | | | | |
| mSR | | | | | |
| mSR705 | | | | | |
| mSR2 | | | | | |
| MSAVI | | | | | |
| MTCI | | | | | |
| ND | | | | | |
| ND | | | | | |
| ND | | | | | |
| ND | | | | | |
| NDI | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| OSAVI | optimization of soil-adjusted vegetation | $[(R_{800}-R_{670})/(R_{800}+R_{670}+0.16)]*(1+0.16)$ | canopy | SAIL model | Rondeaux et al.(1996) |
| OSAVI2 | optimization of soil-adjusted vegetation | $[(R_{750}-R_{705})/(R_{750}+R_{705}+0.16)]*(1+0.16)$ | canopy | Winter wheat (*Triticum aestivum L.*) | Wu et al. (2008) |
| PSRI | Plant Senescence reflectance index | $(R_{678}-R_{500})/R_{700}$ | leaf | Maple (*Acer platanoides L.*), Chestnut (*Aesculus hippocastanum L.*), Potato (*Solanum tuberosum L.*), Coleus (*Coleus blumei Benth.*), Lemon (*Citrus limon L.*), Apple (*Malus domestica Borkh.*) | Merzlyak et al. (1999) |
| RDVI | Renormalized Difference Vegetation Index | $(R_{800}-R_{670})/\sqrt{(R_{800}+R_{670}}$ | canopy | SAIL model | Roujean and Breon (1995) |
| RARS | Ratio analysis of reflectance spectra | $R_{746}/R_{513}$ | leaf | Soybean (*Glycine max Merr.*) | Chappelle et al. (1992) |
| RARSb | | $R_{675}/(R_{650}*R_{700})$ | leaf | Beech (*Fagus sylvatica*), Oak (*Quercus robur*), Maple (*Acer negundo*) and Chestnut (*Castanea sativa*). | Blackburn (1998) |
| SIPI | Structure Insensitive Pigment Index | $(R_{800}-R_{455})/(R_{800}-R_{680})$ | leaf | Maize (*Zea mays L.*), wheat (*Triticum aestivum L*), tomato | Peñuelas et al. (1995) |

| | | | | | |
|---|---|---|---|---|---|
| | Absorption Ratio Index | $(R_{700}/R_{670})]$ | | | (2002) |
| TCARI2 | | $3*[(R_{750}-R_{705})-0.2*(R_{750}-R_{550})*(R_{750}/R_{705})]$ | canopy | Winter wheat (*Triticum aestivum L.*) | Wu et al. (2008) |
| TCARI/OSAVI | Ratio of TCARI/OSAVI | TCARI/OSAVI | canopy | Corn | Haboudane et al. (2002) |
| TCARI2/OSAVI2 | Ratio of TCARI2/OSAVI2 | TCARI2/OSAVI2 | canopy | Winter wheat (*Triticum aestivum L.*) | Wu et al. (2008) |
| TVI | Triangular Vegetation Index | $0.5*[120*(R_{750}-R_{550})-200*(R_{670}-R_{550})]$ | canopy | Simulations with PROSAIL model | Broge and Leblanc (2001) |
| Vogelmann | Vogelmann derivative index | $D_{715}/D_{705}$ | leaf | Maple (*Acer saccharum Marsh*) | Vogelmann et al. (1993) |
| Vogelmann2 | Vogelmann index | $R_{740}/R_{720}$ | leaf | | Vogelmann et al. (1993) |
| ZM | Zarco and Miller | $R_{750}/R_{710}$ | canopy | Maple (*Acer saccharum Marsh*) | Zarco-Tejada et al. (2001) |

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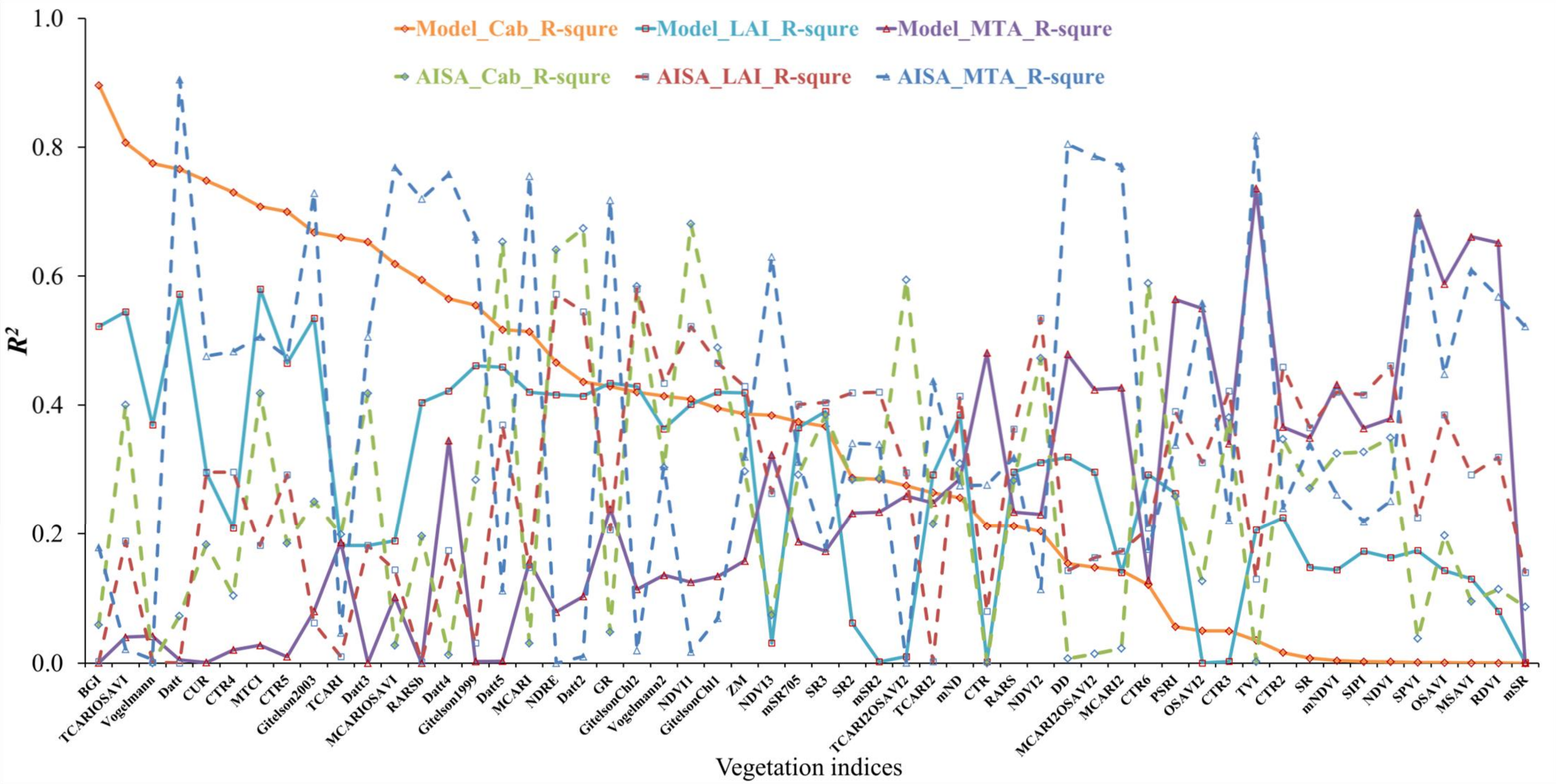
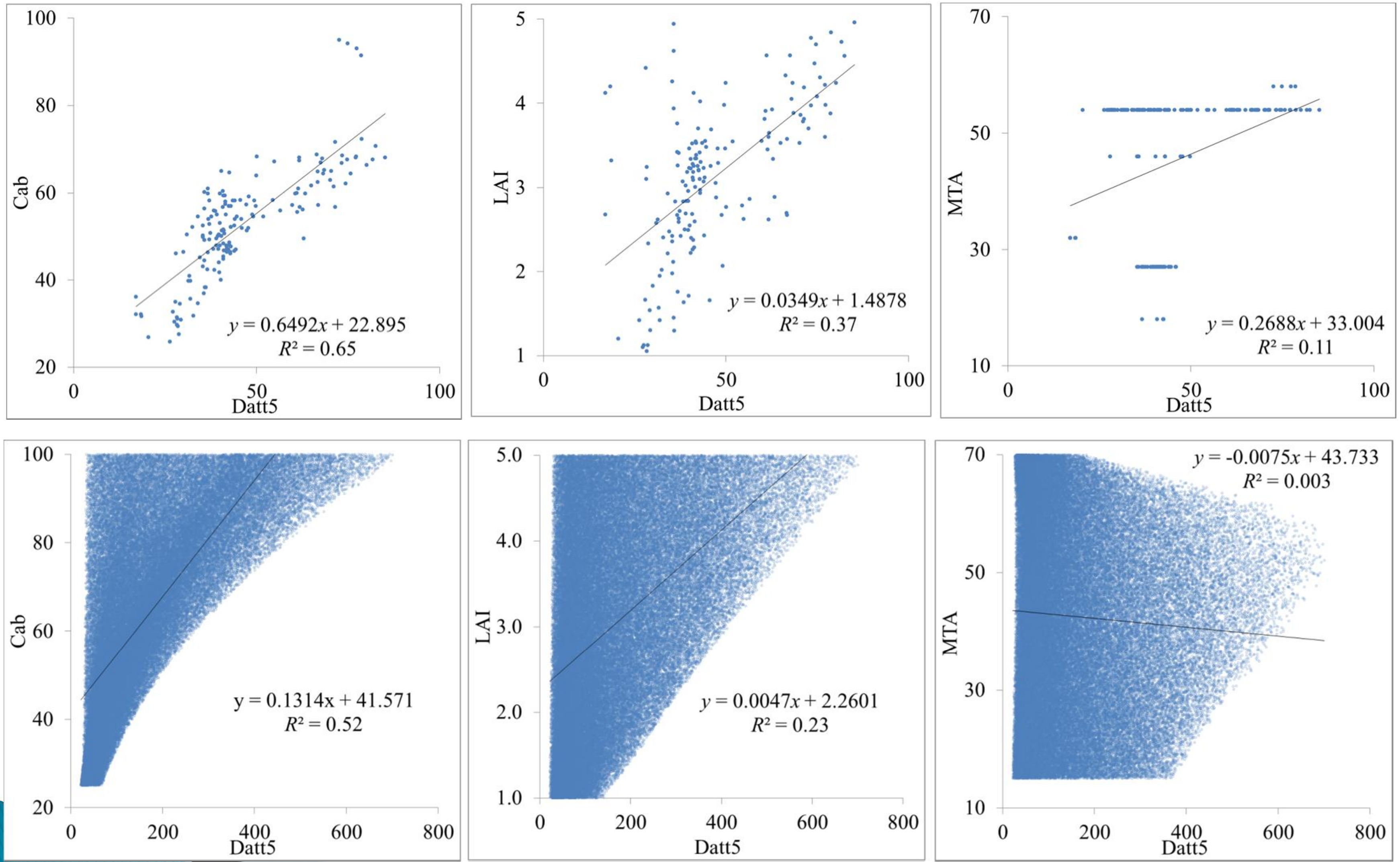
# Vegetation indices V.S. Cab, LAI and MTA



# Datt5: $R_{860}/(R_{550} * R_{708})$



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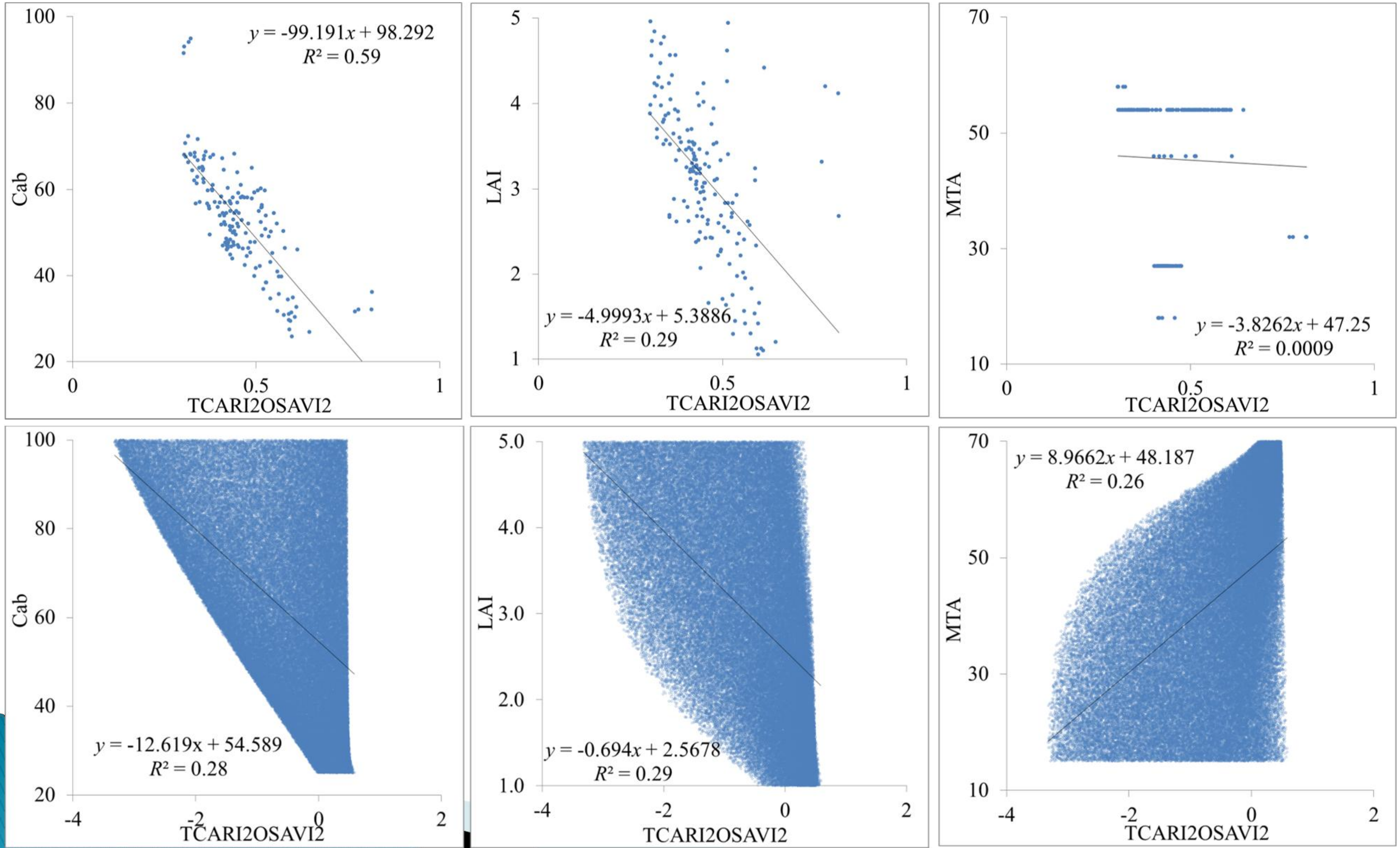
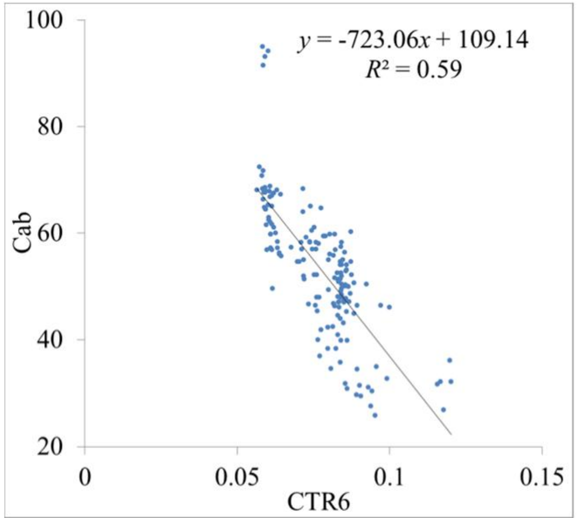
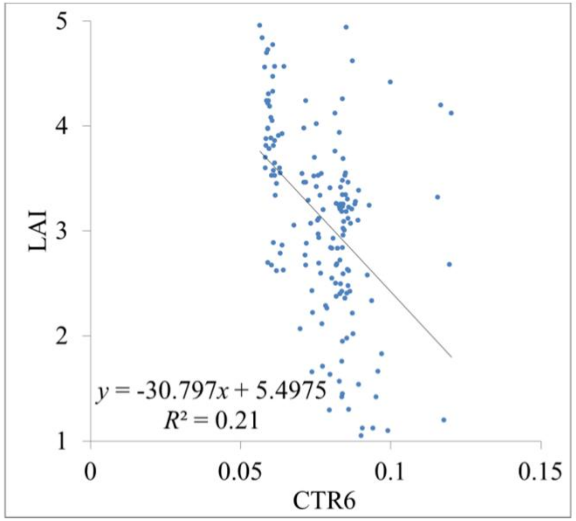
# TCARI2/OSAVI2

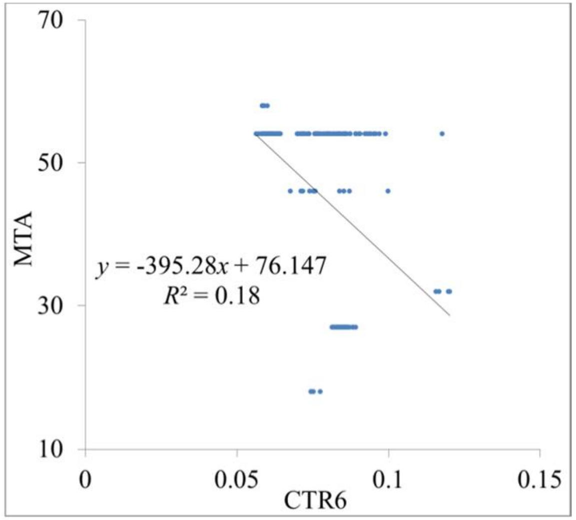
- **TCARI2**= $3*[(R_{750}-R_{705}) - 0.2*(R_{750}-R_{550})*(R_{750}/R_{705})]$
- **OSAVI2**= $[(R_{750}-R_{705})/(R_{750}+R_{705}+0.16)]*(1+0.16)$

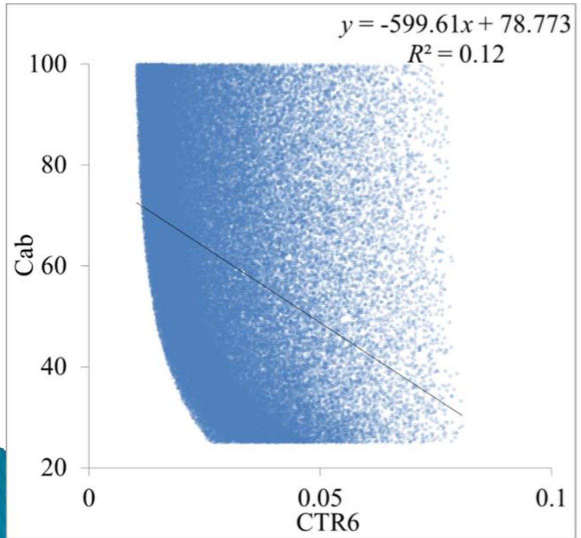


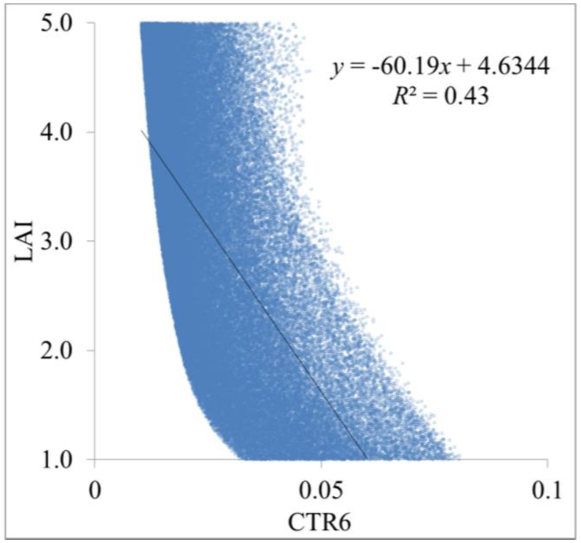
# CTR6 $R_{550}$

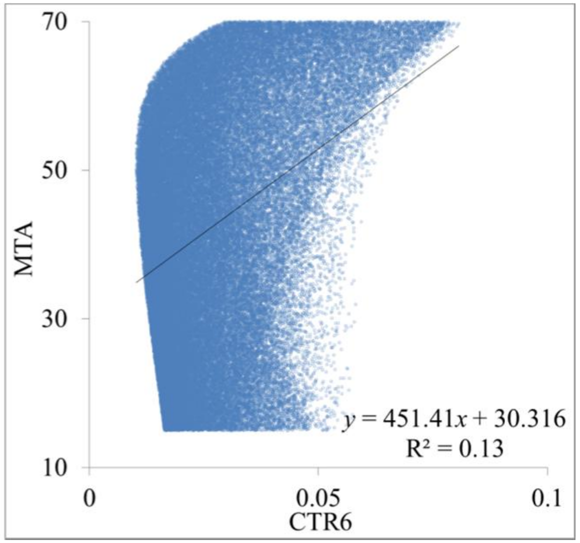

y = -723.06x + 109.14
R² = 0.59
Cab
CTR6
100
80
60
40
20
0
0.05
0.1
0.15


y = -30.797x + 5.4975
R² = 0.21
LAI
CTR6
5
4
3
2
1
0
0.05
0.1
0.15


y = -395.28x + 76.147
R² = 0.18
MTA
CTR6
70
50
30
10
0
0.05
0.1
0.15

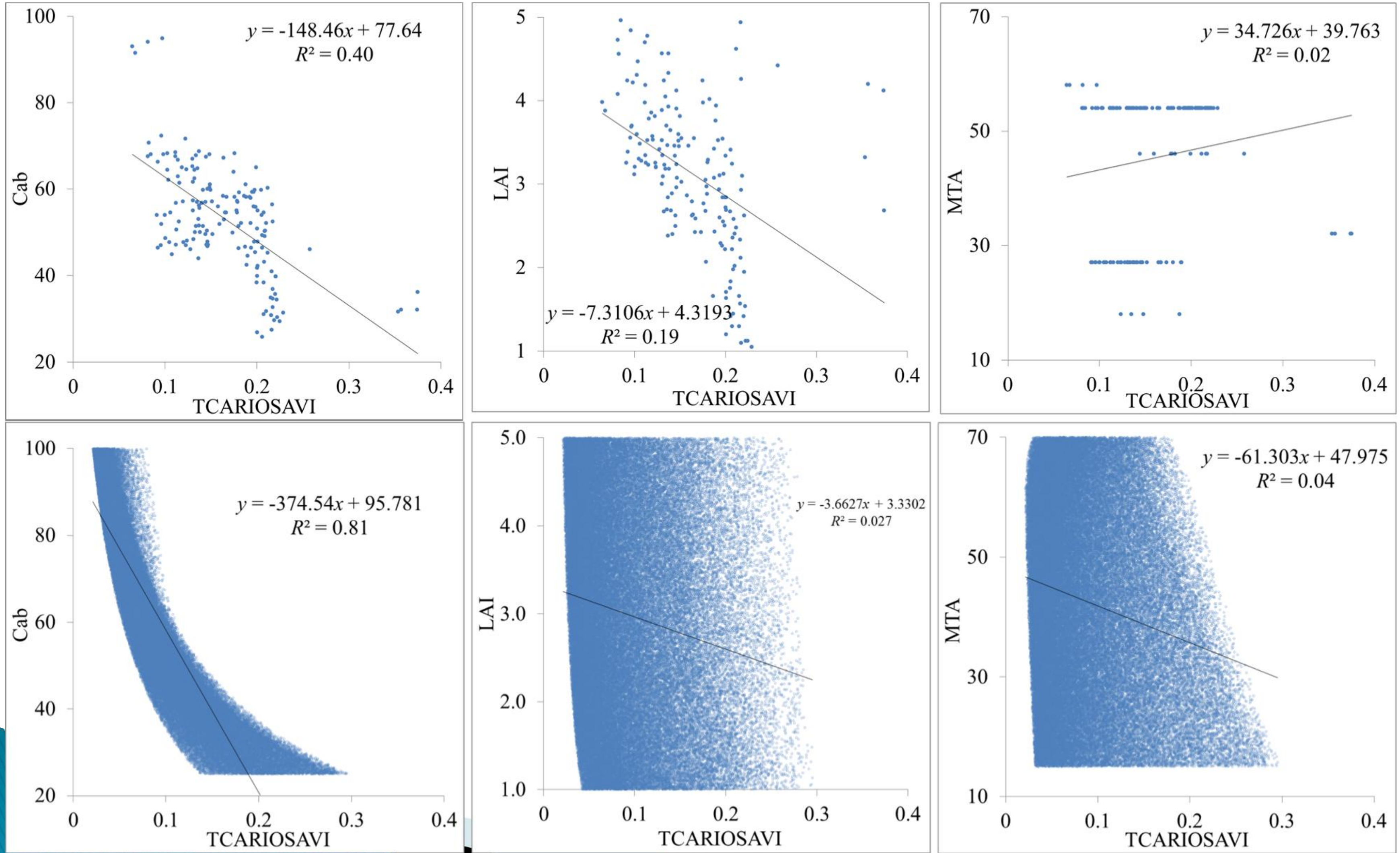

y = -599.61x + 78.773
R² = 0.12
Cab
CTR6
100
80
60
40
20
0
0.05
0.1


y = -60.19x + 4.6344
R² = 0.43
LAI
CTR6
5.0
4.0
3.0
2.0
1.0
0
0.05
0.1


y = 451.41x + 30.316
R² = 0.13
MTA
CTR6
70
50
30
10
0
0.05
0.1

# TCARI/OSAVI

- **TCARI=** $3*[(R_{700}-R_{670})-0.2*(R_{700}-R_{550})*(R_{700}/R_{670})]$
- **OSAVI=** $[(R_{800}-R_{670})/(R_{800}+R_{670}+0.16)]*(1+0.16)$



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# Conclusions

- The best correlation index is Datt5= $R_{860}/(R_{550} * R_{708})$, which is sensitive to Cab ($R^2$ =0.65) but insensitive to MTA ($R^2$ =0.11)
- Both two TCARI/OSAVI indices performed well

TCARI/OSAVI: Cab ($R^2$ =0.40) , MTA ($R^2$ =0.02)

TCARI2/OSAVI2: Cab ($R^2$ =0.59) , MTA ($R^2$ =0.0009)

Thank you

Q&A