**SUPPLEMENTARY TABLES**

Supplementary Table 1. List of the 29 vegetation indices used in this study

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Description | MODIS | Landsat-8 | Sentinel-2 | Source |
| Vegetation indices by normalized difference |
| *Normalized Difference Vegetation Index* | $$NDVI=\frac{(B2-B1)}{(B2+B1)}$$ | $$NDVI=\frac{(B5-B4)}{(B5+B4)}$$ | $$NDVI=\frac{(B8-B4)}{(B8+B4)}$$ | (Rouse et al. 1974) |
| *Normalized Difference Index5* | $$NDI5=\frac{(B2-B6)}{(B2+B6)}$$ | $$NDI5=\frac{(B5-B6)}{(B5+B6)}$$ | $$NDI5=\frac{(B8-B11)}{(B8+B11)}$$ | (Mcnairn and Protz 1993) |
| *Normalized Difference Index7* | $$NDI7=\frac{(B2-B7)}{(B2+B7)}$$ | $$NDI7=\frac{(B5-B7)}{(B5+B7)}$$ | $$NDI7=\frac{(B8-B12)}{(B8+B12)}$$ | (Mcnairn and Protz 1993) |
| *Normalized Difference Tillage Index* | $$NDTI=\frac{B6-B7}{B6+B7}$$ | $$NDTI=\frac{B6-B7}{B6+B7}$$ | $$NDTI=\frac{B11-B12}{B11+B12}$$ | (Van Deventer et al. 1997) |
| *Normalized Difference Senescent Vegetation Index* | $$NDSVI=\frac{B6-B1}{B6+B1}$$ | $$NDSVI=\frac{B6-B4}{B6+B4}$$ | $$NDSVI=\frac{B11-B4}{B11+B4}$$ | (Qi et al. 2002) |
| *Blue normalized difference vegetation index* | $$BNDVI=\frac{(B2-B3)}{(B2+B3)}$$ | $$BNDVI=\frac{(B5-B2)}{(B5+B2)}$$ | $$BNDVI=\frac{(B8-B2)}{(B8+B2)}$$ | (Yang et al. 2004) |
| *Green Normalized Difference Vegetation Index* | $$GNDVI=\frac{(B2-B4)}{(B2+B4)}$$ | $$GNDVI=\frac{(B5-B3)}{(B5+B3)}$$ | $$GNDVI=\frac{(B8-B3)}{(B8+B3)}$$ | (Gitelson, Kaufman, and Merzlyak 1996) |
| *Standardized Normalized Difference Vegetation Index* | $$SNDVI=\frac{(B2-B1)}{(B1+B2+0,16)}$$ | $$SNDVI=\frac{(B5-B4)}{(B4+B5+0,16)}$$ | $$SNDVI=\frac{(B8-B4)}{(B4+B8+0,16)}$$ | (Gowda et al. 2001) |
| *Infrared Percentage Vegetation Index* | $$IPVI=\frac{B2}{(B2+B1)}$$ | $$IPVI=\frac{B5}{(B5+B4)}$$ | $$IPVI=\frac{B8}{(B8+B4)}$$ | (Crippen 1990) |
| *Green Vegetation Index* | $$VIgreen=\frac{(B4-B1)}{(B4+B1)}$$ | $$VIgreen=\frac{(B3-B4)}{(B3+B4)}$$ | $$VIgreen=\frac{(B3-B4)}{(B3+B4)}$$ | (Gitelson et al. 2002) |
| *Green Residue Cover Index* | $$GRCI=\frac{(B4-B3)}{(B4+B3)}$$ | $$GRCI=\frac{(B3-B2)}{(B3+B2)}$$ | $$GRCI=\frac{(B3-B2)}{(B3+B2)}$$ | (Kavoosi et al. 2020) |
| *Blue Residue Cover Index* | $$BRCI=\frac{(B1-B3)}{(B1+B3)}$$ | $$BRCI=\frac{(B4-B2)}{(B4+B2)}$$ | $$BRCI=\frac{(B4-B2)}{(B4+B2)}$$ | (Kavoosi et al. 2020) |
| *Renormalized Difference Vegetation Index* | $$RDVI=\frac{(B2-B1)}{\sqrt{(B2+B1)}}$$ | $$RDVI=\frac{(B5-B4)}{\sqrt{(B5+B4)}}$$ | $$RDVI=\frac{(B8-B4)}{\sqrt{(B8+B4)}}$$ | [Reujean et Breon, 1995] |
| *Modified Simple Ratio* | $$MSR=\frac{\left(\frac{B2}{B1}\right)-1}{\sqrt{\frac{(B2}{B1})}+1}$$ | $$MSR=\frac{\left(\frac{B5}{B4}\right)-1}{\sqrt{\frac{(B5}{B4})}+1}$$ | $$MSR=\frac{\left(\frac{B8}{B4}\right)-1}{\sqrt{\frac{(B8}{B4})}+1}$$ | (Chen 1996) |
| *Chlorophyll detection indices* |
| *Modified Chlorophyll Absorption in Reflectance Index* | $$MCARI=\left[\left(B2-B1\right)-0,2\left(B2-B4\right)\right]\*(\frac{B2}{B1})$$ | $$MCARI=\left[\left(B5-B4\right)-0,2\left(B5-B3\right)\right]\*(\frac{B5}{B4})$$ | $$MCARI=\left[\left(B8-B4\right)-0,2\left(B8-B3\right)\right]\*(\frac{B8}{B4})$$ | (Daughtry et al. 2000) |
| *Transformed Chlorophyll Absorption in Reflectance Index* | $$TCARI=3[\left(B2-B1\right)-0.2\left(B2-B4\right)\*(\frac{B2}{B1})]$$ | $$TCARI=3[\left(B5-B4\right)-0.2\left(B5-B3\right)\*(\frac{B5}{B4})]$$ | $$TCARI=3[\left(B8-B4\right)-0.2\left(B8-B3\right)\*(\frac{B8}{B4})]$$ | (Haboudane et al. 2002) |
| *Triangular Vegetation Index* | $$TVI=0.5[120\left(B2-B4\right)-200\left(B1-B4\right)]$$ | $$TVI=0.5[120\left(B5-B3\right)-200\left(B4-B3\right)]$$ | $$TVI=0.5[120\left(B8-B3\right)-200\left(B4-B3\right)]$$ | (Broge and Leblanc 2001) |
| *Green Chlorophyll Vegetation Index* | $$GCVI=(\frac{B2}{B4})-1$$ | $$GCVI=(\frac{B5}{B3})-1$$ | $$GCVI=(\frac{B8}{B3})-1$$ | (Gitelson et al. 2003) |
| *Vegetation indices with correction for atmospheric or soil effects* |
| *Visible Atmospherically Resistant Index* | $$VARI=\frac{(B4-B1)}{(B4+B1-B3)}$$ | $$VARI=\frac{(B3-B4)}{(B3+B4-B2)}$$ | $$VARI=\frac{(B3-B4)}{(B3+B4-B2)}$$ | (Gitelson et al. 2002) |
| *Perpendicular Vegetation Index* | $$PVI=\frac{(B2-1.28B1-0.04)}{\sqrt{2.6384}}$$ | $$PVI=\frac{(B5-1.28B4-0.04)}{\sqrt{2.6384}}$$ | $$PVI=\frac{(B8-1.28B4-0.04)}{\sqrt{2.6384}}$$ | (Richardson and Wiegand 1977) |
| *Soil-Adjusted Vegetation Index* | $$SAVI=\left[\frac{\left(B2-B1\right)}{\left(B2+B1+L\right)}\right]×(1+L)$$ | $$SAVI=\left[\frac{\left(B5-B4\right)}{\left(B5+B4+L\right)}\right]×(1+L)$$ | $$SAVI=\left[\frac{\left(B8-B4\right)}{\left(B8+B4+L\right)}\right]×(1+L)$$ | (Huete 1988) |
| *Optimized Soil-Adjusted Vegetation Index* | $$OSAVI=\frac{1.16(B2 - B1)}{(B2+B1+0.16)}$$ | $$OSAVI=\frac{1.16(B5 - B4)}{(B5+B4+0.16)}$$ | $$OSAVI=\frac{1.16(B8 - B4)}{(B8+B4+0.16)}$$ | (Rondeaux, Steven, and Baret 1996) |
| *Crop Residue Cover* | $$CRC=\frac{B6-B4}{B6+B4}$$ | $$CRC=\frac{B6-B3}{B6+B3}$$ | $$CRC=\frac{B11-B3}{B11+B3}$$ | (Sullivan et al. 2006) |
| *Dead Fuel Index* | $$DFI=100 (1- \frac{B7}{B6}) \frac{B1}{B2}$$ | $$DFI=100 (1- \frac{B7}{B6}) \frac{B4}{B5}$$ | $$DFI=100 (1 - \frac{B12}{B11}) \frac{B4}{B8}$$ | (Cao et al. 2010) |
| *Soil Tillage Index* | $$STI=\frac{B6}{B7}$$ | $$STI=\frac{B6}{B7}$$ | $$STI=\frac{B11}{B12}$$ | (Van Deventer et al. 1997) |
| *Vegetation indices by ratio* |
| *Simple Ratio Index* | $$SRI=\frac{B2}{B1}$$ | $$SRI=\frac{B5}{B4}$$ | $$SRI=\frac{B8}{B4}$$ | (Jordan 1969) |
| *Ratio Vegetation Index2* | $$RVI2=\frac{B4}{B1}$$ | $$RVI2=\frac{B3}{B4}$$ | $$RVI2=\frac{B3}{B4}$$ | (Jordan 1969) |
| *Ratio Vegetation Index3* | $$RVI3=\frac{B4}{B3}$$ | $$RVI3=\frac{B3}{B2}$$ | $$RVI3=\frac{B3}{B2}$$ | (Jordan 1969) |
| *Ration B7/B6* | $$\frac{B7}{B6}$$ | $$\frac{B7}{B6}$$ | $$\frac{B12}{B11}$$ | (Guerschman et al. 2009) |

**Supplementary Table 2: Number of models tested to estimate BH and BT**

|  |  |  |
| --- | --- | --- |
|   | BH | BT |
|  | MLS | MML | RF | GBM | MLS | MML | RF | GBM |
| Landsat-8 | 6 | 57 | 42 | 42 | 6 | 57 | 42 | 42 |
| MODIS | 6 | 57 | 42 | 42 | 6 | 57 | 42 | 42 |
| Sentinel-2 | 7 | 120 | 99 | 99 | 8 | 247 | 219 | 219 |
| Total | 19 | 234 | 183 | 183 | 20 | 361 | 303 | 303 |
| 619 models tested for BH | 987 models tested for BT |

Supplementary Table 3. Optimization parameters used with random forest

|  |  |  |
| --- | --- | --- |
| Parameters | Definitions | Typical default values |
| mtry | Number of features to use at each split | 1 to 10 |
| ntree | Number of trees to grow | 1 to 25 |
| nodesize | Minimum number of observations in a terminal node | 1 to 5 |

Supplementary Table 4. Optimization parameters used with Gradient Bosting Machines

|  |  |  |
| --- | --- | --- |
| Parameters | Definitions | Value tested |
| ntree | Total number of trees | 50,100,200 |
| Interaction.depth | Maximum depth of variable interactions | 1,3,6 |
| shrinkage | Learning rate | 0.0001, 0.01, 0.1 |
| n.minobsinnode | Minimum number of observations in the trees terminal nodes | 3,5,10 |

Supplementary Table 5. Simple linear models for the assessment of the herbaceous biomass during the dry-season developed by Jacques et *al.* (2014) and in this study, both using the STI index based on MODIS and the best model using Sentinel-2 images.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model equation | Sensor | RMSE (kg‧DM/ha) | R2 | RRMSE (%) | Reference |
| $$-3316+3158\*STI$$ | MODIS | 280 | 0.66 | **44** | Jacques et *al.* (2014) |
| $$-3060+ 3421\*STI$$ | MODIS | 555 | 0.42 | **39** | Model of this study |
| $$3326.60+16221.51\*NDI5-721.34\*GRCI+84.72\*DFI-19074.62\*TCARI+1638.59\*SRI$$ | Sentinel-2 | 378 | 0.74 | **26** | Best model of this study to estimate BH |

Supplementary Table 6. Performance of MLS, MML, RF and GBM models with Landsat-8

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Landsat-8 | R2 | RMSE | RRMSE | INDICES |
| MLS | BH | 0,37 | 569 | 40 | NDI5 |
| BT | 0,39 | 825 | 45 | VIgreen |
| MML | BH | 0,62 | 437 | 30 | NDI5 CRC DFI TCARI |
| BT | 0,77 | 526 | 26 | NDI5 TCARI DFI SRI |
| RF | BH | 0,63 | 476 | 33 | NDI5 BRCI DFI |
| BT | 0,63 | 683 | 34 | NDI5 TCARI VIgreen DFI |
| GBM | BH | 0,68 | 450 | 31 | VARI, BRCI DFI |
| BT | 0,63 | 622 | 31 | NDI5,TCARI DFI SRI |

Supplementary Table 7. Performance of MLS, MML, RF and GBM models with MODIS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| MODIS | R2 | RMSE | RRMSE | INDICES |
| MLS | BH | 0,42 | 575 | 40 | DFI |
| BT | 0,51 | 923 | 46 | NDI5 |
| MML | BH | 0,65 | 414 | 29 | NDI5, DFI, TCARI |
| BT | 0,69 | 551 | 27 | RVI2, NDI5, DFI, TCARI |
| RF | BH | 0,57 | 482 | 34 | NDI5, VIgreen, DFI, TCARI |
| BT | 0,64 | 694 | 35 | NDI5, TCARI, DFI, RVI3 |
| GBM | BH | 0,55 | 469 | 33 | NDI5, VIgreen, DFI, TCARI |
| BT | 0,69 | 605 | 30 | TCARI, DFI, CRC, RVI3 |

**Supplementary Table 8.** Performance of MLS, MML, RF and GBM models with Sentinel-2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sentinel-2 | R2 | RMSE | RRMSE | INDICES |
| MLS | BH | 0,43 | 567 | 39 | NDI5 |
| BT | 0,36 | 901 | 45 | NDI5 |
| MML | BH | 0,74 | 378 | 26 | NDI5, GRCI, SRI, DFI, TCARI |
| BT | 0,78 | 496 | 25 | NDI5, DFI, SRI, TCARI, GRCI, RVI3 |
| RF | BH | 0,45 | 544 | 38 | NDI5, SRI, GRCI, DFI, RVI3 |
| BT | 0,53 | 816 | 41 | NDI5, RVI2, DFI, SRI, TCARI, GRCI |
| GBM | BH | 0,53 | 476 | 33 | NDI5, GRCI, DFI, RVI3, TCARI |
| BT | 0,57 | 712 | 35 | NDI5, SRI, TCARI |

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