**Table S1*.*** Details of satellite covariates from sentinel-1 and 2A used in the study*.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Covariates** | **Abbreviation** | | **Formula** | **Reference** |
| Coastal aerosol | B1 | - | | (Li et al., 2016) |
| Blue band | B2 | - | | (Wulder et al., 2016) |
| Green band | B3 | - | | (Wulder et al., 2016) |
| Red band | B4 | - | | (Wulder et al., 2016) |
| Vegetation red edge | B5 | - | | (Horler et al., 1983) |
| Vegetation red edge | B6 | - | | (Horler et al., 1983) |
| Vegetation red edge | B7 | - | | (Horler et al., 1983) |
| NIR | B8 | - | | (Wulder et al., 2016) |
| Narrow NIR | B8A | - | | (Wulder et al., 2016) |
| Water vapour | B9 | - | |  |
| SWIR-1 | B11 | - | | (Wulder et al., 2016) |
| SWIR-2 | B12 | - | | (Wulder et al., 2016) |
| Backscattering coefficients of VH band | Sigma0\_VH | - | | (Attema et al., 2010) |
| Backscattering coefficients of VV band | Sigma0\_VV | **-** | | (Attema et al., 2010) |
| Corrected Transformed Vegetation Index | CTVI |  | | (Perry and Lautenschlager, 1984) |
| Difference Vegetation Index | DVI | s × NIR - R | | (Richardson and Wiegand, 1977) |
| Green Normalized Difference Vegetation Index | GNDVI |  | | (Gitelson et al., 1996) |
| Global Environmental Monitoring Index | GEMI |  | | (Pinty and Verstraete, 1992) |
| Modified Normalized Difference Water Index | MNDWI |  | | (Xu, 2006) |
| Modified Soil Adjusted Vegetation Index | MSAVI |  | | (Qi et al., 1994) |
| Modified Soil Adjusted Vegetation Index 2 | MSAVI2 |  | | (Qi et al., 1994) |
| Normalized Burn Ratio Index | NBRI |  | | (García and Caselles, 1991) |
| Normalized Difference Vegetation Index | NDVI |  | | (Purevdorj et al., 1988) |
| Normalized Difference Water Index | NDWI |  | | (McFEETERS, 1996) |
| Normalized Difference Water Index 2 | NDWI2 |  | | (Gao, 1996) |
| Ratio Vegetation Index | RVI |  | | (Richardson and Wiegand, 1977) |
| Normalized Ratio Vegetation Index | NRVI |  | | (Baret and Guyot, 1991) |
| Soil Adjusted Vegetation Index | SAVI |  | | (Huete, 1988) |
| Soil Adjusted Total Vegetation Index | SATVI |  | | (Marsett et al., 2006) |
| Specific Leaf Area Vegetation Index | SLAVI |  | | (Lymburner et al., 2000) |
| Simple Ratio Vegetation Index | SR |  | | (Birth and McVey, 1968) |
| Transformed Vegetation Index | TVI |  | | (Deering, 1975) |
| Thiam’s Transformed Vegetation Index | TTVI |  | | (Thiam, 1998) |
| Weighted Difference Vegetation Index | WDVI | NIR – a × R | | (Richardson and Wiegand, 1977) |

**Table S2.** Calibration between downscaled aggregated LST using RF, TsHARP and TPS with observed LST (Landsat-8/9).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **RF** | | | **TsHARP** | | | **TPS** | | |
| **Date** | **R2** | **RMSE** | **nRMSE** | **R2** | **RMSE** | **nRMSE** | **R2** | **RMSE** | **nRMSE** |
|  |  |  |  | **IARI** | | |  |  |  |
| 30.Oct.2020 | 0.985 | 0.228 | 0.075 | 0.976 | 0.367 | 0.12 | 0.991 | 0.176 | 0.058 |
| 24.Nov.2020 | 0.997 | 0.196 | 0.067 | 0.963 | 0.276 | 0.094 | 0.97 | 0.227 | 0.077 |
| 17.Dec.2022 | 0.979 | 0.192 | 0.067 | 0.957 | 0.256 | 0.089 | 0.983 | 0.173 | 0.06 |
| 27.Jan.2021 | 0.976 | 0.163 | 0.056 | 0.965 | 0.166 | 0.071 | 0.982 | 0.143 | 0.049 |
| 20.Feb.2021 | 0.979 | 0.173 | 0.058 | 0.969 | 0.233 | 0.078 | 0.989 | 0.129 | 0.043 |
| 23.Mar.2021 | 0.983 | 0.192 | 0.064 | 0.964 | 0.309 | 0.078 | 0.995 | 0.106 | 0.035 |
| 18.Nov.2021 | 0.982 | 0.167 | 0.056 | 0.985 | 0.165 | 0.055 | 0.981 | 0.174 | 0.058 |
| 13.Dec.2021 | 0.984 | 0.186 | 0.063 | 0.987 | 0.173 | 0.059 | 0.981 | 0.204 | 0.07 |
| 29.Dec.2021 | 0.961 | 0.153 | 0.052 | 0.962 | 0.161 | 0.052 | 0.981 | 0.204 | 0.07 |
| 15.Feb.2022 | 0.983 | 0.142 | 0.048 | 0.961 | 0.233 | 0.079 | 0.996 | 0.069 | 0.023 |
| 19.Mar.2022 | 0.985 | 0.187 | 0.061 | 0.967 | 0.312 | 0.101 | 0.999 | 0.045 | 0.015 |
| 04.Apr.2022 | 0.985 | 0.187 | 0.06 | 0.968 | 0.292 | 0.093 | 0.995 | 0.11 | 0.035 |
| **Mean** | 0.982 | 0.181 | 0.061 | 0.969 | 0.245 | 0.081 | 0.987 | 0.147 | 0.049 |
| **SD** | 0.008 | 0.023 | 0.007 | 0.009 | 0.069 | 0.020 | 0.009 | 0.056 | 0.020 |
| **SE** | 0.0023 | 0.0065 | 0.0021 | 0.0027 | 0.019 | 0.0057 | 0.0024 | 0.016 | 0.0056 |
|  |  |  |  | **CAZRI** | | |  |  |  |
| 5.Mar.2021 | 0.976 | 0.385 | 0.123 | 0.977 | 0.359 | 0.114 | 0.992 | 0.214 | 0.068 |
| 21.Mar.2021 | 0.983 | 0.305 | 0.097 | 0.994 | 0.17 | 0.054 | 0.991 | 0.213 | 0.068 |
| 18.Dec.2021 | 0.979 | 0.323 | 0.108 | 0.993 | 0.178 | 0.06 | 0.991 | 0.205 | 0.069 |
| 21.Feb.2022 | 0.981 | 0.439 | 0.143 | 0.982 | 0.274 | 0.089 | 0.999 | 0.055 | 0.018 |
| **Mean** | 0.980 | 0.363 | 0.118 | 0.987 | 0.245 | 0.079 | 0.993 | 0.172 | 0.056 |
| **SD** | 0.003 | 0.061 | 0.020 | 0.008 | 0.089 | 0.028 | 0.004 | 0.078 | 0.025 |
| **SE** | 0.0014 | 0.030 | 0.0099 | 0.0041 | 0.044 | 0.013 | 0.0019 | 0.038 | 0.012 |
|  |  |  |  | **UBKV** | | |  |  |  |
| 08.Mar.2021 | 0.989 | 0.103 | 0.034 | 0.952 | 0.24 | 0.08 | 0.997 | 0.051 | 0.017 |
| 24.Mar.2021 | 0.979 | 0.148 | 0.049 | 0.966 | 0.202 | 0.067 | 0.994 | 0.079 | 0.026 |
| 05.Dec.2021 | 0.982 | 0.163 | 0.054 | 0.977 | 0.189 | 0.063 | 0.987 | 0.14 | 0.047 |
| 21.Dec.2021 | 0.981 | 0.117 | 0.06 | 0.975 | 0.213 | 0.072 | 0.987 | 0.149 | 0.05 |
| **Mean** | 0.983 | 0.133 | 0.049 | 0.968 | 0.211 | 0.071 | 0.991 | 0.105 | 0.035 |
| **SD** | 0.004 | 0.028 | 0.011 | 0.011 | 0.022 | 0.007 | 0.005 | 0.047 | 0.016 |
| **SE** | 0.0021 | 0.013 | 0.0055 | 0.0056 | 0.010 | 0.0036 | 0.0025 | 0.023 | 0.0080 |

A collage of graphs

Description automatically generated

**Figure S1.** Variable importance in downscaling LST by RF model (a) IARI (b) CAZRI and (c) UBKV.

**Figure S2.** Validation of downscaled-and-aggregated LST from LANDSAT-8 with MODIS Aqua and Terra LST products at 1000 m resolution [1:1 line is shown as dotted line].

A screenshot of a computer generated image

Description automatically generated

**Figure S3.** Spatial extent of observed LST (30 m) over IARI farm scale in pre- and post-monsoon period*,* 2020-2022.A screenshot of a computer generated image

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**Figure S4.** Spatial extent of TPS downscaled LST (10 m) over IARI farm scale pre- and post-monsoon period, 2020-2022.A screenshot of a computer generated image

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**Figure S5.** Spatial extent of TsHARP downscaled LST (10 m) over IARI farm scale in the scale pre and post-monsoon period, 2020-2022.A screenshot of a graph

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**Figure S6.** Spatial extent of observed LST (30 m) over CAZRI site.A screenshot of a graph

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**Figure S7.** Spatial extent of TPS downscaled LST (10 m) over CAZRI site.A screenshot of a graph

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**Figure S8.** Spatial extent of TsHARP downscaled LST (10 m) over CAZRI site.![A screenshot of a map

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**Figure S9.** Spatial extent of observed LST (30 m) over UBKV site.![A group of maps of different colors

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**Figure S10.** Spatial extent of TPS downscaled LST (10 m) over UBKV site.![A screenshot of a map

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**Figure S11.** Spatial extent of TsHARP downscaled LST (10 m) over UBKV site.A screenshot of a computer generated image

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**Figure S12.** NDVI maps at IARI (semi-arid) site, covered the pre-monsoon to post-monsoon period from 2020-2022.![A screenshot of a map

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**Figure S13.** NDVI maps at 10 m over CAZRI (arid) site 2021-2022.

![A screenshot of a map

Description automatically generated]()

**Figure S14.** NDVI maps at 10 m over UBKV (Per-humid) site 2021.