Performance of the METRIC model in estimating evapotranspiration fluxes over an irrigated field in Saudi Arabia using Landsat-8 images

### Rangaswamy Madugundu

### Khalid A. Al-Gaadi

### ElKamil Tola

### Abdalhaleem A. Hassaballa

### Virupakshagouda C. Patil

Study period: June to October 2013

Precision Agriculture Research Chair,

King Saud University,

Riyadh – 11451

Saudi Arabia,

<http://parc.ksu.edu.sa/en>

# Extract of eddy covariance system measurements

#### **Supplementary Table 1**. Instrumentation of eddy covariance system

|  |  |  |  |
| --- | --- | --- | --- |
| # | Measured Parameter | Sensor Description | No. of sensors |
| 1 | Wind speed | 3-axis Ultrasonic anemometer (GILL) | 1 |
| 2 | Air temperature | 3-axis Ultrasonic anemometer (GILL) |
| 3 | Water vapor | Open path analyzer (LI-COR LI7500) | 1 |
| 4 | CO2 | Open path analyzer (LI-COR LI7500) |
| 5 | Soil Heat Flux | Soil heat flux plates (HFP01) | 5 |
| 6 | Net Radiation | Pyranometer (CNR-4 of Kipp & Zonen) and Quantum Sensor (Li-COR) | 1+1 |
| 7 | Soil moisture | ThetaProbe ML2x (4 Nos.) | 5 |
| 8 | Data logger | Sutron (2910 XLite) | 1 |
| 9 | Data storage | 16 GB Data card | 1 |

#### **Supplementary Table 2**. Weather parameters used in the study [measured by eddy covariance system]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Date | Air Temperature (°C) | es(kPa) | e (kPa) | VPD (kPa) | RH(%) | Tdew(°C) |
| 6/3/2013 | 36.42 | 5.88 | 1.37 | 4.51 | 23.99 | 11.49 |
| 6/19/2013 | 39.59 | 7.60 | 3.11 | 4.51 | 44.81 | 24.69 |
| 7/5/2013 | 34.70 | 5.39 | 2.53 | 2.86 | 48.03 | 21.30 |
| 7/21/2013 | 40.96 | 7.03 | 3.06 | 3.97 | 44.89 | 24.36 |
| 8/22/2013 | 42.98 | 7.05 | 2.94 | 4.11 | 44.00 | 23.77 |
| 9/7/2013 | 35.45 | 5.47 | 3.69 | 1.80 | 68.31 | 27.59 |
| 9/23/2013 | 34.52 | 5.97 | 1.84 | 4.13 | 31.66 | 16.18 |
| 10/9/2013 | 26.78 | 3.49 | 2.04 | 1.46 | 59.56 | 17.79 |

#### **Supplementary Table 3**. energy balance components by eddy covariance system

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Date | Net Radiation-Rn (Wm-2) | Soil heat flux-G(W m-2) | Sensible Heat Flux-H(W m-2) | Latent Heat Flux-LE(W m-2) | ET(mm h-1) | ET(mm d-1) |
| 6/3/2013 | 468.00 | 21.60 | -65.80 | 335.70 | 0.64 | 9.46 |
| 6/19/2013 | 500.60 | 44.10 | 112.30 | 160.20 | 0.24 | 2.36 |
| 7/5/2013 | 506.22 | 155.18 | 274.59 | 72.12 | 0.11 | 19.17 |
| 7/21/2013 | 463.27 | 70.33 | 127.34 | 260.79 | 0.38 | 7.92 |
| 8/22/2013 | 513.17 | 37.54 | 14.26 | 637.84 | 0.96 | 14.61 |
| 9/7/2013 | 476.86 | 54.98 | 230.79 | 505.40 | 0.71 | 5.11 |
| 9/23/2013 | 469.60 | 16.50 | 19.03 | 560.80 | 0.89 | 6.20 |
| 10/9/2013 | 456.49 | 110.30 | 68.39 | 148.80 | 0.22 | 12.78 |

# METRIC ALGORITHM employed on landsat-8 images

* Centre pivot irrigated alfalfa field
* Sampled locations – 19

##### **Supplementary Table 4.** Land Surface Temperature (°C) from Landsat-8 TIRS bands: SPLIT WINDOW ALGORITHM

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 34.61 | 31.88 | 30.78 | 31.27 | 40.13 | 31.10 | 33.40 | 23.58 |
| 2 | 34.51 | 31.88 | 30.79 | 31.25 | 40.08 | 31.14 | 33.44 | 23.59 |
| 3 | 34.40 | 31.88 | 30.85 | 31.21 | 40.03 | 31.21 | 33.46 | 23.66 |
| 4 | 34.52 | 31.82 | 30.77 | 31.28 | 40.01 | 31.18 | 33.38 | 23.62 |
| 5 | 34.44 | 31.83 | 30.76 | 31.27 | 40.07 | 31.20 | 33.43 | 23.65 |
| 6 | 34.35 | 31.83 | 30.84 | 31.24 | 40.10 | 31.24 | 33.47 | 23.73 |
| 7 | 34.56 | 31.90 | 30.86 | 31.41 | 39.96 | 31.30 | 33.45 | 23.66 |
| 8 | 34.53 | 31.93 | 30.81 | 31.44 | 40.11 | 31.35 | 33.48 | 23.70 |
| 9 | 34.35 | 31.86 | 31.24 | 31.47 | 39.77 | 31.29 | 33.29 | 23.82 |
| 10 | 34.44 | 31.99 | 31.24 | 31.53 | 39.96 | 31.36 | 33.49 | 23.77 |
| 11 | 34.50 | 32.14 | 31.22 | 31.62 | 40.18 | 31.52 | 33.62 | 23.80 |
| 12 | 34.12 | 31.98 | 31.59 | 31.78 | 40.06 | 31.41 | 33.33 | 24.10 |
| 13 | 34.08 | 32.16 | 31.72 | 31.85 | 40.28 | 31.44 | 33.59 | 24.03 |
| 14 | 34.22 | 32.52 | 32.24 | 32.60 | 40.90 | 31.97 | 33.78 | 24.47 |
| 15 | 34.12 | 32.70 | 32.57 | 32.68 | 41.14 | 31.98 | 34.08 | 24.48 |
| 16 | 34.87 | 34.24 | 33.60 | 34.19 | 42.35 | 33.18 | 34.95 | 25.08 |
| 17 | 35.79 | 36.63 | 36.17 | 36.33 | 43.79 | 34.64 | 36.51 | 25.98 |
| 18 | 35.85 | 36.81 | 36.36 | 36.53 | 44.26 | 34.87 | 36.82 | 26.20 |
| 19 | 36.50 | 39.11 | 39.64 | 38.43 | 45.71 | 36.28 | 38.40 | 27.86 |
|  | 34.67 | 33.01 | 32.32 | 32.60 | 40.99 | 32.09 | 34.18 | 24.36 |

##### **Supplementary Table 5.** SAVI from Landsat-8 OLI bands

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 0.3220 | 0.5980 | 0.7335 | 0.8013 | 0.2467 | 0.5215 | 0.2630 | 0.4414 |
| 2 | 0.2861 | 0.5894 | 0.7335 | 0.8013 | 0.2461 | 0.5219 | 0.2635 | 0.4414 |
| 3 | 0.2998 | 0.5893 | 0.7338 | 0.8012 | 0.2455 | 0.5226 | 0.2914 | 0.4426 |
| 4 | 0.2863 | 0.6001 | 0.7335 | 0.8014 | 0.2798 | 0.5222 | 0.2627 | 0.4420 |
| 5 | 0.3006 | 0.6002 | 0.7334 | 0.8013 | 0.2460 | 0.5339 | 0.2634 | 0.4424 |
| 6 | 0.3036 | 0.6001 | 0.7337 | 0.8013 | 0.2464 | 0.5343 | 0.2641 | 0.4673 |
| 7 | 0.3069 | 0.6007 | 0.7338 | 0.8015 | 0.2176 | 0.5348 | 0.2637 | 0.4427 |
| 8 | 0.3213 | 0.6009 | 0.7336 | 0.8016 | 0.2198 | 0.5239 | 0.2642 | 0.4434 |
| 9 | 0.3174 | 0.6004 | 0.7353 | 0.8016 | 0.2150 | 0.5347 | 0.2612 | 0.4452 |
| 10 | 0.3187 | 0.6096 | 0.7352 | 0.8017 | 0.1851 | 0.5240 | 0.2385 | 0.4444 |
| 11 | 0.3053 | 0.6106 | 0.7352 | 0.8018 | 0.1883 | 0.5254 | 0.2663 | 0.4449 |
| 12 | 0.3284 | 0.6094 | 0.7365 | 0.8020 | 0.2190 | 0.5244 | 0.2359 | 0.4497 |
| 13 | 0.3275 | 0.6107 | 0.7370 | 0.8021 | 0.1896 | 0.5247 | 0.2145 | 0.4485 |
| 14 | 0.3144 | 0.5727 | 0.7389 | 0.8031 | 0.2305 | 0.5296 | 0.2176 | 0.3555 |
| 15 | 0.3123 | 0.5741 | 0.6700 | 0.8032 | 0.2337 | 0.5297 | 0.2227 | 0.3556 |
| 16 | 0.3086 | 0.5744 | 0.6609 | 0.7982 | 0.2182 | 0.5402 | 0.2615 | 0.3402 |
| 17 | 0.3320 | 0.5908 | 0.6738 | 0.8009 | 0.2365 | 0.5521 | 0.2841 | 0.3567 |
| 18 | 0.3327 | 0.5920 | 0.6747 | 0.8011 | 0.2422 | 0.5538 | 0.2630 | 0.3606 |
| 19 | 0.3509 | 0.5705 | 0.5622 | 0.7894 | 0.2290 | 0.5462 | 0.2874 | 0.2625 |
|  | 0.31 | 0.59 | 0.71 | 0.80 | 0.23 | 0.53 | 0.26 | 0.41 |

##### **Supplementary Table 6.** field measured Leaf area index (LAI) using lai-2200 (Li-cor) plant canopy analyser

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 1.19 | 3.22 | 3.71 | 5.99 | 1.08 | 3.21 | 1.10 | 2.24 |
| 2 | 1.22 | 3.22 | 3.71 | 5.44 | 1.08 | 3.20 | 1.10 | 2.24 |
| 3 | 1.19 | 3.23 | 3.70 | 5.45 | 1.08 | 3.19 | 1.04 | 2.23 |
| 4 | 1.22 | 3.09 | 3.71 | 5.44 | 1.02 | 3.20 | 1.10 | 2.24 |
| 5 | 1.19 | 3.09 | 3.71 | 5.66 | 1.08 | 3.08 | 1.10 | 2.24 |
| 6 | 1.23 | 3.09 | 3.70 | 5.45 | 1.08 | 3.08 | 1.10 | 2.10 |
| 7 | 1.22 | 3.08 | 3.70 | 5.96 | 1.13 | 3.07 | 1.10 | 2.23 |
| 8 | 1.19 | 3.08 | 3.70 | 5.95 | 1.13 | 3.18 | 1.10 | 2.23 |
| 9 | 1.20 | 3.09 | 3.76 | 5.95 | 1.14 | 3.08 | 1.10 | 2.22 |
| 10 | 1.26 | 3.18 | 3.76 | 5.94 | 1.19 | 3.18 | 1.14 | 2.22 |
| 11 | 1.29 | 3.17 | 3.76 | 5.92 | 1.18 | 3.17 | 1.09 | 2.00 |
| 12 | 1.23 | 3.19 | 3.72 | 5.90 | 1.13 | 3.18 | 1.15 | 1.98 |
| 13 | 1.24 | 3.17 | 3.70 | 5.88 | 1.18 | 3.17 | 1.19 | 1.98 |
| 14 | 1.27 | 3.68 | 3.64 | 5.76 | 1.11 | 3.13 | 1.24 | 2.44 |
| 15 | 1.27 | 3.66 | 5.95 | 5.75 | 1.10 | 3.55 | 1.23 | 2.44 |
| 16 | 1.28 | 3.66 | 6.26 | 6.39 | 1.13 | 3.43 | 1.16 | 2.52 |
| 17 | 1.23 | 3.44 | 5.82 | 6.04 | 1.10 | 3.16 | 1.11 | 2.44 |
| 18 | 1.22 | 3.30 | 5.79 | 6.02 | 1.09 | 3.14 | 1.15 | 2.42 |
| 19 | 1.12 | 3.71 | 5.63 | 7.54 | 1.11 | 3.22 | 1.10 | 2.91 |
|  | 1.22 | 3.28 | 4.29 | 5.92 | 1.11 | 3.19 | 1.13 | 2.28 |

##### **Supplementary Table 7.** landsat-8 estimated Leaf area index (LAI)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 1.11 | 3.64 | 4.84 | 3.90 | 1.09 | 3.73 | 1.20 | 2.43 |
| 2 | 1.08 | 3.63 | 4.84 | 6.87 | 1.10 | 3.73 | 1.19 | 2.43 |
| 3 | 1.09 | 3.63 | 4.84 | 5.08 | 1.10 | 3.73 | 0.99 | 2.01 |
| 4 | 1.08 | 3.64 | 4.84 | 6.88 | 0.90 | 4.36 | 1.20 | 2.44 |
| 5 | 1.09 | 3.64 | 4.84 | 6.88 | 1.10 | 3.66 | 1.19 | 2.43 |
| 6 | 1.09 | 3.64 | 4.84 | 6.87 | 1.09 | 3.66 | 1.19 | 2.42 |
| 7 | 1.10 | 3.64 | 4.84 | 7.16 | 1.29 | 3.66 | 1.19 | 2.42 |
| 8 | 1.11 | 3.64 | 4.84 | 6.88 | 1.27 | 3.72 | 1.19 | 2.41 |
| 9 | 1.11 | 3.64 | 4.84 | 6.88 | 1.31 | 3.66 | 1.21 | 2.47 |
| 10 | 1.11 | 3.64 | 4.84 | 4.44 | 1.56 | 3.72 | 1.44 | 2.92 |
| 11 | 1.10 | 3.64 | 4.84 | 6.88 | 1.53 | 3.71 | 1.17 | 2.38 |
| 12 | 1.12 | 3.64 | 4.84 | 6.88 | 1.28 | 4.35 | 1.47 | 2.98 |
| 13 | 1.12 | 3.64 | 4.84 | 6.88 | 1.52 | 3.71 | 1.76 | 3.59 |
| 14 | 1.11 | 3.62 | 4.84 | 5.86 | 1.20 | 3.69 | 1.71 | 3.48 |
| 15 | 1.10 | 3.62 | 4.82 | 6.89 | 1.18 | 3.69 | 1.64 | 3.33 |
| 16 | 1.10 | 3.62 | 4.81 | 6.85 | 1.28 | 4.25 | 1.21 | 2.46 |
| 17 | 1.12 | 3.63 | 4.82 | 5.94 | 1.16 | 3.57 | 1.04 | 2.11 |
| 18 | 1.12 | 3.63 | 4.82 | 6.87 | 1.12 | 3.56 | 1.20 | 2.43 |
| 19 | 1.14 | 3.62 | 4.78 | 6.78 | 1.21 | 3.60 | 1.01 | 2.06 |
|  | 1.11 | 3.63 | 4.83 | 6.40 | 1.23 | 3.78 | 1.27 | 2.59 |

# Landsat-8 derieved energy balance components over alfalfa field extract of METRIC ALGORITHM

##### **Supplementary Table 8.** landsat-8 estimated net radiation [w m-2]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 486.2 | 489.7 | 488.7 | 488.6 | 501.7 | 487.8 | 490.6 | 476.6 |
| 2 | 486.2 | 489.7 | 488.7 | 488.5 | 501.6 | 487.8 | 490.6 | 476.6 |
| 3 | 486.3 | 489.7 | 488.8 | 488.5 | 501.5 | 488.0 | 490.8 | 476.7 |
| 4 | 486.1 | 489.6 | 488.7 | 488.6 | 501.6 | 487.9 | 490.6 | 476.7 |
| 5 | 486.2 | 489.6 | 488.6 | 488.6 | 501.6 | 488.0 | 490.6 | 476.7 |
| 6 | 486.2 | 489.6 | 488.8 | 488.5 | 501.6 | 488.1 | 490.7 | 476.9 |
| 7 | 486.3 | 489.8 | 488.8 | 488.8 | 501.3 | 488.2 | 490.7 | 476.7 |
| 8 | 486.3 | 489.8 | 488.7 | 488.9 | 501.6 | 488.2 | 490.7 | 476.8 |
| 9 | 487.0 | 489.7 | 489.4 | 488.9 | 501.0 | 488.1 | 490.4 | 477.0 |
| 10 | 486.9 | 489.9 | 489.4 | 489.0 | 501.2 | 488.2 | 490.6 | 476.9 |
| 11 | 486.8 | 490.2 | 489.4 | 489.1 | 501.5 | 488.4 | 490.9 | 476.9 |
| 12 | 487.6 | 489.9 | 490.0 | 489.4 | 501.5 | 488.3 | 490.4 | 477.4 |
| 13 | 487.8 | 490.2 | 490.2 | 489.5 | 501.7 | 488.3 | 490.7 | 477.3 |
| 14 | 488.5 | 490.6 | 491.0 | 490.7 | 502.8 | 489.2 | 491.0 | 477.8 |
| 15 | 489.1 | 490.9 | 491.4 | 490.8 | 503.2 | 489.2 | 491.5 | 477.8 |
| 16 | 490.7 | 493.3 | 493.0 | 493.1 | 505.0 | 491.1 | 493.0 | 478.7 |
| 17 | 494.8 | 497.1 | 497.1 | 496.5 | 507.3 | 493.5 | 495.5 | 480.2 |
| 18 | 495.1 | 497.4 | 497.4 | 496.8 | 508.1 | 493.8 | 495.8 | 480.5 |
| 19 | 500.5 | 500.9 | 502.4 | 499.5 | 510.3 | 496.0 | 498.4 | 482.9 |
|  | 488.66 | 491.46 | 491.07 | 490.64 | 502.95 | 489.37 | 491.76 | 477.75 |

##### **Supplementary Table 9.** landsat-8 estimated soil heat flux - g [w m-2]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 27.9 | 94.6 | 147.4 | 84.4 | 89.8 | 47.5 | 14.6 | 104.2 |
| 2 | 33.1 | 94.6 | 147.4 | 84.4 | 97.5 | 47.5 | 14.6 | 104.2 |
| 3 | 27.7 | 94.6 | 147.4 | 84.4 | 89.7 | 47.5 | 6.1 | 104.2 |
| 4 | 33.1 | 97.6 | 147.3 | 84.4 | 181.1 | 47.5 | 14.6 | 104.2 |
| 5 | 27.7 | 97.6 | 147.3 | 84.4 | 89.7 | 51.6 | 14.6 | 104.2 |
| 6 | 33.1 | 97.6 | 147.4 | 84.4 | 89.8 | 51.6 | 14.6 | 107.5 |
| 7 | 33.1 | 97.6 | 147.4 | 84.5 | 85.3 | 51.6 | 14.6 | 104.2 |
| 8 | 27.7 | 97.6 | 147.4 | 84.5 | 86.6 | 47.5 | 14.6 | 104.2 |
| 9 | 27.9 | 97.6 | 147.6 | 84.5 | 83.9 | 51.6 | 14.6 | 104.3 |
| 10 | 27.9 | 97.6 | 147.6 | 84.5 | 77.5 | 47.5 | 22.5 | 104.3 |
| 11 | 33.1 | 97.7 | 147.6 | 84.5 | 67.6 | 47.6 | 14.5 | 104.3 |
| 12 | 22.5 | 97.6 | 147.8 | 84.6 | 86.1 | 47.5 | 22.5 | 104.4 |
| 13 | 22.5 | 97.7 | 147.9 | 84.6 | 67.6 | 47.5 | 30.4 | 104.4 |
| 14 | 27.7 | 86.3 | 148.2 | 84.9 | 92.6 | 47.7 | 30.5 | 90.4 |
| 15 | 27.7 | 86.4 | 137.9 | 84.9 | 96.5 | 47.7 | 30.5 | 90.4 |
| 16 | 32.8 | 83.6 | 136.2 | 72.7 | 79.6 | 47.9 | 22.5 | 86.8 |
| 17 | 27.8 | 84.5 | 137.5 | 73.4 | 118.4 | 48.3 | 22.5 | 87.1 |
| 18 | 27.8 | 84.5 | 137.6 | 73.4 | 105.6 | 48.3 | 31.1 | 87.2 |
| 19 | 22.5 | 73.3 | 116.2 | 44.8 | 175.5 | 41.2 | 30.1 | 67.6 |
|  | 28.62 | 92.54 | 143.73 | 80.65 | 97.94 | 48.16 | 19.98 | 98.31 |

##### **Supplementary Table 10.** landsat-8 estimated sensible heat flux - H [w m-2]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | -55.8 | 188.2 | 293.3 | 168.0 | 17.7 | 94.4 | 29.2 | 207.3 |
| 2 | -66.1 | 188.2 | 293.3 | 168.0 | 17.7 | 94.4 | 29.2 | 207.3 |
| 3 | -55.3 | 188.2 | 293.4 | 167.9 | 17.7 | 94.4 | 12.3 | 207.4 |
| 4 | -66.1 | 194.1 | 293.3 | 168.0 | 35.9 | 94.4 | 29.2 | 207.3 |
| 5 | -55.3 | 194.1 | 293.3 | 168.0 | 17.7 | 102.5 | 29.2 | 207.4 |
| 6 | -66.1 | 194.1 | 293.4 | 168.0 | 17.7 | 102.6 | 29.2 | 213.9 |
| 7 | -66.1 | 194.2 | 293.4 | 168.1 | 3.5 | 102.6 | 29.2 | 207.4 |
| 8 | -55.3 | 194.2 | 293.3 | 168.1 | 3.5 | 94.5 | 29.2 | 207.4 |
| 9 | -55.8 | 194.2 | 293.8 | 168.1 | 3.5 | 102.6 | 29.2 | 207.5 |
| 10 | -55.8 | 194.3 | 293.8 | 168.1 | -13.7 | 94.5 | 45.0 | 207.5 |
| 11 | -66.2 | 194.4 | 293.8 | 168.2 | -13.7 | 94.6 | 29.2 | 207.5 |
| 12 | -45.0 | 194.2 | 294.2 | 168.3 | 3.5 | 94.5 | 45.0 | 207.8 |
| 13 | -45.0 | 194.4 | 294.4 | 168.4 | -13.6 | 94.5 | 60.8 | 207.7 |
| 14 | -55.4 | 171.8 | 294.9 | 168.9 | 3.7 | 94.8 | 60.8 | 179.9 |
| 15 | -55.4 | 171.9 | 274.4 | 169.0 | 3.7 | 94.8 | 60.9 | 179.9 |
| 16 | -65.4 | 166.4 | 271.0 | 144.6 | -13.4 | 95.3 | 45.0 | 172.6 |
| 17 | -55.5 | 168.1 | 273.7 | 146.0 | -13.3 | 96.0 | 45.0 | 173.3 |
| 18 | -55.5 | 168.2 | 273.9 | 146.1 | -13.2 | 96.1 | 62.1 | 173.4 |
| 19 | -45.0 | 145.8 | 231.3 | 89.0 | -31.2 | 81.9 | 60.1 | 134.4 |
|  | -57.19 | 184.15 | 286.10 | 160.45 | 1.77 | 95.75 | 39.98 | 195.62 |

##### **Supplementary Table 11.** landsat-8 estimated latent heat flux - LE [w m-2]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 569.9 | 206.9 | 48.0 | 236.2 | 475.0 | 345.9 | 534.3 | 165.1 |
| 2 | 585.4 | 206.9 | 48.0 | 236.2 | 474.9 | 346.0 | 534.4 | 165.1 |
| 3 | 569.4 | 206.9 | 48.0 | 236.2 | 474.9 | 346.1 | 509.2 | 165.1 |
| 4 | 585.4 | 198.0 | 48.0 | 236.2 | 447.6 | 346.0 | 534.3 | 165.1 |
| 5 | 569.2 | 198.0 | 48.0 | 236.2 | 474.9 | 333.9 | 534.4 | 165.1 |
| 6 | 585.5 | 198.0 | 48.0 | 236.2 | 474.9 | 333.9 | 534.4 | 155.5 |
| 7 | 585.5 | 198.0 | 48.0 | 236.3 | 495.9 | 334.0 | 534.4 | 165.1 |
| 8 | 569.3 | 198.0 | 48.0 | 236.3 | 496.2 | 346.2 | 534.4 | 165.1 |
| 9 | 570.7 | 198.0 | 48.0 | 236.3 | 495.7 | 334.0 | 534.2 | 165.2 |
| 10 | 570.7 | 198.0 | 48.0 | 236.3 | 521.6 | 346.2 | 558.1 | 165.2 |
| 11 | 586.1 | 198.1 | 48.0 | 236.4 | 522.0 | 346.3 | 534.7 | 165.2 |
| 12 | 555.1 | 198.0 | 48.0 | 236.5 | 496.1 | 346.2 | 557.9 | 165.3 |
| 13 | 555.3 | 198.1 | 48.0 | 236.5 | 522.1 | 346.3 | 582.0 | 165.2 |
| 14 | 571.7 | 232.5 | 47.9 | 236.9 | 497.2 | 346.7 | 582.3 | 207.6 |
| 15 | 572.2 | 232.6 | 79.1 | 237.0 | 497.6 | 346.8 | 582.8 | 207.6 |
| 16 | 588.9 | 243.3 | 85.8 | 275.7 | 525.1 | 347.8 | 560.5 | 219.4 |
| 17 | 578.8 | 244.6 | 86.0 | 277.2 | 527.2 | 349.2 | 563.0 | 219.8 |
| 18 | 578.5 | 244.7 | 86.0 | 277.3 | 527.9 | 349.4 | 589.0 | 219.9 |
| 19 | 568.0 | 281.8 | 154.9 | 365.7 | 557.0 | 372.9 | 588.6 | 281.0 |
|  | 574.5 | 214.8 | 61.25 | 249.55 | 500.20 | 345.46 | 551.72 | 183.82 |

##### **Supplementary Table 12.** landsat-8 estimated evapotranspiration [mm h-1]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | 3-Jun-13 | 19-Jun-13 | 5-Jul-13 | 21-Jul-13 | 22-Aug-13 | 7-Sep-13 | 23-Sep-13 | 9-Oct-13 |
| 1 | 0.85 | 0.31 | 0.07 | 0.42 | 0.74 | 0.53 | 0.82 | 0.25 |
| 2 | 0.91 | 0.32 | 0.07 | 0.42 | 0.74 | 0.53 | 0.82 | 0.25 |
| 3 | 0.88 | 0.32 | 0.07 | 0.42 | 0.74 | 0.53 | 0.78 | 0.25 |
| 4 | 0.90 | 0.31 | 0.07 | 0.42 | 0.70 | 0.53 | 0.82 | 0.25 |
| 5 | 0.88 | 0.31 | 0.07 | 0.42 | 0.74 | 0.51 | 0.82 | 0.25 |
| 6 | 0.88 | 0.31 | 0.07 | 0.42 | 0.74 | 0.51 | 0.82 | 0.24 |
| 7 | 0.87 | 0.31 | 0.07 | 0.42 | 0.78 | 0.51 | 0.82 | 0.25 |
| 8 | 0.85 | 0.31 | 0.07 | 0.42 | 0.77 | 0.53 | 0.82 | 0.25 |
| 9 | 0.85 | 0.31 | 0.07 | 0.42 | 0.78 | 0.51 | 0.83 | 0.25 |
| 10 | 0.85 | 0.30 | 0.07 | 0.42 | 0.82 | 0.53 | 0.86 | 0.25 |
| 11 | 0.87 | 0.30 | 0.07 | 0.41 | 0.81 | 0.53 | 0.82 | 0.25 |
| 12 | 0.84 | 0.30 | 0.07 | 0.41 | 0.78 | 0.53 | 0.86 | 0.25 |
| 13 | 0.84 | 0.30 | 0.07 | 0.41 | 0.81 | 0.53 | 0.89 | 0.25 |
| 14 | 0.86 | 0.34 | 0.07 | 0.40 | 0.76 | 0.52 | 0.89 | 0.31 |
| 15 | 0.86 | 0.34 | 0.12 | 0.40 | 0.76 | 0.52 | 0.88 | 0.31 |
| 16 | 0.87 | 0.34 | 0.12 | 0.45 | 0.78 | 0.50 | 0.83 | 0.32 |
| 17 | 0.83 | 0.32 | 0.11 | 0.42 | 0.75 | 0.48 | 0.79 | 0.30 |
| 18 | 0.83 | 0.32 | 0.11 | 0.42 | 0.75 | 0.48 | 0.82 | 0.30 |
| 19 | 0.80 | 0.35 | 0.19 | 0.53 | 0.76 | 0.49 | 0.79 | 0.36 |
|  | 0.86 | 0.32 | 0.09 | 0.42 | 0.76 | 0.52 | 0.83 | 0.27 |

For additional information, please contact:

Dr. Rangaswamy Madugundu Ph.D.

Assistant Professor,

Precision Agriculture Research Chair

College of Food and Agriculture Sciences,

King Saud University,

Riyadh - 11451

Email: rmadugundu@ksu.edu.sa