# Appendix 1: Information of each agro-climatic zone in Africa

Table 3. Information of agro-climatic zones with cropland in Africa.

| Broad Biome[*] | Global Environmental Zones (Agro-Climatic Zones)[*] | Sub-Zone[*] | CVs[¤] | CVs no Pheno.[†] | $R^2$[‡] | Num. of valid obs. | Percent of total obs. |
|---|---|---|---|---|---|---|---|
| Arctic/Alpine | D. Extremely cold and wet | D1 | N.A. | N.A. | 0.00 | 0 | N.A. |
| | | D2 | N.A. | N.A. | 0.00 | 0 | N.A. |
| Boreal/Alpine | E. Cold and wet | E1 | N.A. | N.A. | 0.00 | 0 | N.A. |
| | | E2 | N.A. | N.A. | 0.00 | 0 | N.A. |
| | | E4 | N.A. | N.A. | 1.00 | 4 | 100.00% |
| | F. Extremely cold and mesic | F12 | N.A. | N.A. | 0.00 | 2 | 100.00% |
| | | F15 | N.A. | N.A. | 0.00 | 0 | N.A. |
| | G. Cold and mesic | G7 | 21.73% | 20.47% | 0.94 | 31 | 33.33% |
| | | G8 | N.A. | N.A. | 0.01 | 0 | 0.00% |
| | | G11 | 8.94% | 7.19% | 0.75 | 1096 | 99.82% |
| | | G13 | 9.93% | 8.90% | 0.75 | 516 | 99.42% |
| Cool temperate | H. Cool temperate and dry | H2 | 21.21% | 27.63% | 0.73 | 237 | 72.48% |
| | | H5 | 27.68% | 27.90% | 0.85 | 232 | 83.75% |
| | | H7 | 22.77% | 19.93% | 0.47 | 226 | 52.07% |
| | | H8 | 12.67% | 10.81% | 0.77 | 456 | 89.76% |
| | | H9 | 32.12% | 27.95% | 0.58 | 386 | 49.61% |
| | I. Cool temperate and xeric | I2 | 33.12% | 27.50% | 0.53 | 1075 | 47.38% |
| | | I4 | 28.27% | 24.21% | 0.59 | 2330 | 76.92% |
| | | I5 | 27.91% | 24.84% | 0.57 | 4333 | 55.95% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | J1 | 14.87% | 7.15% | 0.49 | 99 | 73.88% |
| | | J2 | N.A. | N.A. | 0.89 | 0 | 0.00% |
| | J. Cool temperate and moist | J3 | 17.70% | 14.95% | 0.71 | 1580 | 96.93% |
| | | J4 | 21.52% | 15.57% | 0.57 | 459 | 55.50% |
| | | J5 | 22.57% | 18.76% | 0.78 | 6188 | 93.67% |
| | | J6 | 14.77% | 14.80% | 0.70 | 10 | 100.00% |
| | | K1 | 24.47% | 19.62% | 0.72 | 16906 | 93.05% |
| | | K2 | 18.11% | 10.85% | 0.25 | 607 | 61.94% |
| | | K3 | 19.75% | 14.94% | 0.62 | 166 | 84.26% |
| | | K4 | 29.30% | 22.93% | 0.61 | 17233 | 76.17% |
| | | K5 | 25.08% | 20.30% | 0.77 | 54429 | 97.15% |
| | | K6 | 22.05% | 16.88% | 0.81 | 938 | 76.07% |
| | K. Warm temperate and mesic | K7 | 17.58% | 14.99% | 0.52 | 4612 | 70.95% |
| | | K8 | 26.25% | 20.22% | 0.62 | 125 | 14.37% |
| | | K9 | 29.46% | 23.48% | 0.77 | 56044 | 92.06% |
| Warm temperate | | K10 | 23.51% | 18.07% | 0.76 | 83145 | 95.57% |
| | | K11 | 16.56% | 13.98% | 0.83 | 1070 | 70.30% |
| | | K12 | 12.66% | 7.49% | 0.16 | 51 | 26.56% |
| | | K13 | 23.42% | 18.22% | 0.77 | 33525 | 75.43% |
| | | L1 | 27.05% | 21.88% | 0.84 | 57196 | 97.24% |
| | | L2 | 24.25% | 23.90% | 0.48 | 1839 | 60.65% |
| | L. Warm temperate and xeric | L3 | 26.15% | 20.54% | 0.84 | 102259 | 97.84% |
| | | L4 | 24.87% | 19.63% | 0.80 | 65291 | 98.38% |
| | | L5 | 26.82% | 23.54% | 0.85 | 7465 | 94.52% |
| | | L6 | 25.39% | 20.31% | 0.85 | 73315 | 99.24% |
| Sub-tropical | M. Hot and mesic | M1 | 14.63% | 6.75% | 0.06 | 748 | 12.86% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | M2 | 18.24% | 12.61% | 0.00 | 6864 | 31.44% |
| | | M3 | 21.71% | 16.08% | 0.88 | 190954 | 99.72% |
| | | M4 | 20.75% | 16.12% | 0.75 | 107821 | 76.58% |
| | | M5 | 20.19% | 7.55% | 0.16 | 389 | 7.95% |
| | | M6 | 28.56% | 21.35% | 0.89 | 170655 | 98.83% |
| | | M7 | 18.23% | 13.41% | 0.00 | 129318 | 84.88% |
| | | M8 | 16.01% | 6.97% | 0.19 | 10901 | 26.47% |
| **Drylands** | N. Hot and dry | N2 | 21.54% | 17.96% | 0.89 | 11000 | 90.08% |
| | | N3 | 15.56% | 11.98% | 0.59 | 21847 | 61.27% |
| | | N4 | 28.57% | 21.30% | 0.83 | 142000 | 96.22% |
| | | N5 | 17.49% | 12.72% | 0.77 | 6955 | 98.89% |
| | | N6 | 21.00% | 17.12% | 0.84 | 60298 | 98.83% |
| | | N7 | 35.03% | 34.45% | 0.74 | 84 | 38.53% |
| | | N8 | 13.91% | 12.13% | 0.36 | 2877 | 38.29% |
| | | N9 | 28.47% | 20.66% | 0.87 | 149098 | 90.81% |
| | | N10 | 30.26% | 26.28% | 0.96 | 76760 | 97.89% |
| | | N11 | 25.82% | 19.39% | 0.84 | 160530 | 90.40% |
| | O. Hot and arid | O1 | 29.40% | 29.63% | 0.82 | 11356 | 80.16% |
| | | O2 | 33.00% | 34.86% | 0.88 | 2199 | 73.57% |
| | | O3 | 31.97% | 29.81% | 0.93 | 2447 | 90.56% |
| | P. Extremely hot and arid | P1 | 29.79% | 28.07% | 0.84 | 1624 | 80.12% |
| | | P2 | 45.25% | 38.51% | 0.93 | 740 | 72.76% |
| | Q. Extremely hot and xeric | Q1 | 37.41% | 24.85% | 0.94 | 358445 | 99.48% |
| | | Q2 | 54.73% | 35.96% | 0.84 | 10337 | 97.64% |
| | | Q3 | 22.43% | 18.16% | 0.82 | 270268 | 97.15% |
| | | Q4 | 36.47% | 23.91% | 0.93 | 935905 | 99.74% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Q5 | 45.78% | 29.09% | 0.77 | 878 | 76.55% |
| | | Q6 | 28.55% | 18.65% | 0.85 | 284736 | 99.17% |
| **Tropical** | R. Extremely hot and moist | R1 | 17.63% | 13.18% | 0.55 | 120738 | 64.03% |
| | | R2 | 39.73% | 28.29% | 0.94 | 183001 | 98.27% |
| | | R3 | 14.40% | 5.81% | 0.12 | 13331 | 88.18% |
| | | R4 | 14.69% | 8.34% | 0.22 | 81264 | 29.46% |
| | | R5 | 32.42% | 23.63% | 0.91 | 220880 | 97.67% |
| | | R6 | 14.03% | 5.52% | 0.11 | 37161 | 79.21% |
| | | R7 | 12.59% | 5.88% | 0.15 | 5538 | 81.20% |
| | | R8 | 13.45% | 5.62% | 0.09 | 26211 | 73.54% |
| | | R9 | 17.25% | 14.50% | 0.49 | 207478 | 93.08% |
| | | R10 | 13.03% | 8.24% | 0.30 | 50064 | 82.53% |

\* The classification names are derived from Metzger et al., 2013

" Spatial Variation of Coefficient, results estimated by GSI

† Spatial variation of Coefficient, results estimated by yearly integral NDVI

‡ The coefficient of determination between pixel observations of GSI and yearly integral NDVI

# Appendix 2: Fit statistics of CE production against GSI

Table 4. Fit statistics of CE production against GSI in three model forms for each country. Models are trained by provincial observations.

| Model 1: Linear Form | Prob. Of coefficients | | coefficients | | Adjusted R-squared | F-statistic | Prob. (F-statistic) | DW stat | Num. |
|---|---|---|---|---|---|---|---|---|---|
| | C | GSI | C | GSI | | | | | |
| Benin | 0 | 0 | 251799.1 | 0.3664 | 0.3089 | 49.7165 | <0.0001 | 1.2371 | 110 |
| Burkina Faso | 0.0011 | 0 | 126677.9 | 0.4902 | 0.5537 | 128.8036 | <0.0001 | 2.0201 | 104 |
| Cameroon | 0 | 0.0001 | 428487.9 | 0.4768 | 0.2586 | 18.0891 | 0.0001 | 2.2467 | 50 |
| Ghana | 0 | 0 | 488565.4 | 0.7118 | 0.1479 | 18.1836 | <0.0001 | 2.1751 | 100 |
| Mali | 0.0012 | 0 | 284564.1 | 0.2833 | 0.4357 | 48.8685 | <0.0001 | 0.9872 | 63 |
| Niger | 0 | 0.0515 | 558491.5 | 0.5870 | 0.0356 | 3.9123 | 0.0515 | 2.2585 | 80 |
| Nigeria | 0 | 0 | 757075.4 | 1.1129 | 0.4481 | 60.2686 | <0.0001 | 1.7614 | 74 |
| Togo | 0 | 0.0001 | 193724.8 | 0.8157 | 0.2761 | 19.6906 | 0.0001 | 3.2743 | 50 |
| Zambia | 0.0892 | 0.1306 | 200072.2 | 0.6130 | 0.0830 | 2.5392 | 0.1306 | 2.2435 | 18 |
| Ethiopia | 0.21 | 0 | -226754.6 | 0.9666 | 0.8970 | 340.5913 | <0.0001 | 2.2504 | 41 |

| Model 2: Exponential Form | Prob. Of coefficients | | coefficients | | Adjusted R-squared | F-statistic | Prob. (F-statistic) | DW stat | Num. |
|---|---|---|---|---|---|---|---|---|---|
| | C | LN(GSI) | C | LN (GSI) | | | | | |
| Benin | 0 | 0 | 8.2892 | 0.3687 | 0.4191 | 79.6267 | <0.0001 | 1.1994 | 110 |
| Burkina Faso | 0 | 0 | 3.2927 | 0.7240 | 0.6587 | 199.7756 | <0.0001 | 1.5206 | 104 |
| Cameroon | 0 | 0.0088 | 10.8869 | 0.1871 | 0.1165 | 7.4609 | 0.0088 | 2.1223 | 50 |
| Ghana | 0.8382 | 0 | -0.1867 | 1.0542 | 0.6866 | 217.8617 | <0.0001 | 1.5693 | 100 |
| Mali | 0 | 0 | 7.4197 | 0.4335 | 0.8252 | 293.7496 | <0.0001 | 0.9229 | 63 |
| Niger | 0.0003 | 0 | 3.8051 | 0.7985 | 0.4718 | 71.5670 | <0.0001 | 2.1280 | 80 |
| Nigeria | 0 | 0 | 8.6247 | 0.4158 | 0.3902 | 47.7135 | <0.0001 | 1.8871 | 74 |
| Togo | 0 | 0.0159 | 10.5448 | 0.1736 | 0.0967 | 6.2432 | 0.0159 | 2.7832 | 50 |
| Zambia | 0.0065 | 0.467 | 9.9846 | 0.1976 | -0.0269 | 0.5553 | 0.4670 | 2.1881 | 18 |
| Ethiopia | 0.2843 | 0 | -1.2109 | 1.0269 | 0.7856 | 147.5830 | <0.0001 | 1.3900 | 41 |

| Model 3: Binominal Form | Prob. Of coefficients | | | coefficients | | | Adjusted R-squared | F-statistic | Prob. (F-statistic) | DW stat | Num. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | GSI^2 | GSI | C | GSI^2 | GSI | | | | | |
| Benin | 0 | 0 | 0 | 178340.9 | -9.46E-07 | 1.3352 | 0.4528 | 46.0894 | <0.0001 | 1.5482 | 110 |
| Burkina Faso | 0.5785 | 0.068 | 0 | 34721 | -1.79E-07 | 0.8105 | 0.5640 | 67.6203 | <0.0001 | 1.9908 | 104 |
| Cameroon | 0 | 0.0561 | 0.3044 | 597307.8 | 8.43E-07 | -0.5625 | 0.2999 | 11.4973 | 0.0001 | 2.0751 | 50 |
| Ghana | 0.0427 | 0 | 0 | -204641.6 | -4.01E-06 | 4.7138 | 0.5389 | 58.8587 | <0.0001 | 1.8408 | 100 |
| Mali | 0.274 | 0 | 0 | 85229.18 | -2.40E-07 | 1.0415 | 0.6211 | 51.8194 | <0.0001 | 1.1592 | 63 |
| Niger | 0 | 0.4165 | 0.2354 | 522253.7 | -2.18E-06 | 1.7755 | 0.0314 | 2.2816 | 0.1090 | 2.2711 | 80 |
| Nigeria | 0 | 0.3651 | 0.1858 | 863753.8 | 1.90E-07 | 0.6729 | 0.4468 | 30.4789 | <0.0001 | 1.6834 | 74 |
| Togo | 0 | 0 | 0.0002 | 395011.3 | 1.45E-05 | -3.5085 | 0.5273 | 28.3264 | <0.0001 | 2.9073 | 50 |
| Zambia | 0.0495 | 0.1892 | 0.3054 | 446516.1 | 4.92E-06 | -2.2263 | 0.1314 | 2.2863 | 0.1359 | 2.3901 | 18 |
| Ethiopia | 0.2333 | 0.7803 | 0 | -259225 | -5.36E-09 | 1.0130 | 0.8944 | 166.2075 | <0.0001 | 2.2533 | 41 |

Table 5. Fit statistics of CE production against GSI in three model forms with or without constant term. Models are trained by all provincial observations.

| | Model | Adjusted R-squared | F-statistic | Prob. (F-statistic) | Durbin-Watson stat | Num.[*] |
|---|---|---|---|---|---|---|
| **Linear Model** | Y = 0.7152*X + 255358.8 | 0.5498 | 734.9938 | <0.0001 | 1.1395 | 602 |
| | Y = 0.8229*X | 0.5431 | | | 0.8715 | 602 |
| **Exponential Model** | LN(Y) = 0.5605*LN(X) + 5.9711 | 0.4652 | 549.9076 | <0.0001 | 1.5002 | 632 |
| **Binominal Model** | Y = (4.69E-08)*$X^2$ + 0.4428*X + 368566.9 | 0.5779 | 412.3572 | <0.0001 | 1.1927 | 602 |
| | Y = (1.54E-08)*$X^2$ + 0.7500*X | 0.5454 | | | 0.8678 | 602 |

*Data come from countries whose models passed the significant test (P ≤ 0.005). Additionally, 10 observations of Mozambique were added into the data pool.

Table 6. Fit statistics of CE production against GSI in three model forms with or without constant term. Models are trained by all national observations.

| | Model | Adjusted R-squared | F-statistic | Prob. (F-statistic) | Durbin-Watson stat | Num. |
|---|---|---|---|---|---|---|
| **Linear Model** | $Y = 1.3663*X - 1067679$ | 0.6431 | 824.5926 | <0.0001 | 1.0347 | 458 |
| | $Y = 1.2742*X$ | 0.6364 | | | 0.8860 | 458 |
| **Exponential Model** | $LN(Y) = 0.7604*LN(X) + 3.3718$ | 0.6996 | 1065.089 | <0.0001 | 0.5901 | 458 |
| **Binominal Model** | $Y = (7.37E-08)*X^2 - 0.2192*X + 2217655$ | 0.8005 | 917.7229 | <0.0001 | 1.3174 | 458 |
| | $Y = (5.81E-0.8)*X^2 + 0.2463*X$ | 0.7785 | | | 1.4760 | 458 |

Table 7. Cross-validated coefficients of comparison between predicted and actual CE production. 10-fold cross validation is applied on two observations: 1) all provincial and national observations; 2) all national observations. Leave-one-year-out cross validation is applied on all national observations. Nigerian observations are excluded.

| | | Linear Model | Power Model | Binominal Model |
|---|---|---|---|---|
| | | $R^2$ | $R^2$ | $R^2$ |
| **10-fold cross validation** | Provincial, National Obs. | 0.5781 | 0.4253 | 0.5828 |
| | National Obs. | 0.4337 | 0.3843 | 0.466 |
| **Leave-one-year-out cross validation** | 2001 | 0.4702 | 0.5158 | 0.5163 |
| **(National Observations)** | 2002 | 0.3809 | 0.4088 | 0.4159 |
| | 2003 | 0.4609 | 0.4552 | 0.4989 |
| | 2004 | 0.3768 | 0.4031 | 0.4242 |
| | 2005 | 0.5628 | 0.4509 | 0.5848 |
| | 2006 | 0.3625 | 0.3947 | 0.4255 |
| | 2007 | 0.5033 | 0.4617 | 0.514 |
| | 2008 | 0.4191 | 0.3393 | 0.4513 |
| | 2009 | 0.4135 | 0.2704 | 0.4431 |
| | 2010 | 0.3881 | 0.2594 | 0.4298 |
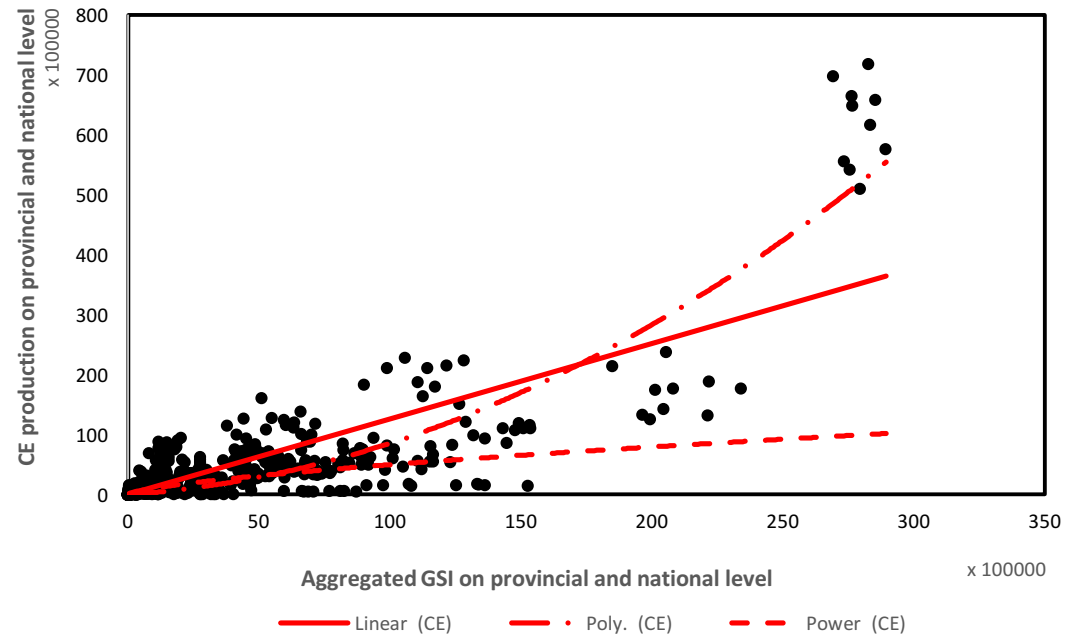
Fig. 7. Scatter plots between all provincially and nationally aggregated GSI and corresponding provincial and national CE production. The red line is linear model fitting, the dashed line is exponential model fitting, and the long-dashed-dotted line is binomial model fitting.