Table 1. Predictor variables included in Dakota Skipper global habitat suitability model.

|  |  |  |
| --- | --- | --- |
| Dataset | Covariate | Description |
| Rangeland Analysis Platform Layers (RAP) | PFG | 2018-2021 median perennial forb and grass cover (%) |
| RAP | pfgNPP | 2018-2021 median perennial forb and grass net primary productivity (NPP; lbs/ac) |
| RAP | AFG | 2018-2021 median annual forb and grass cover (%) |
| RAP | afgNPP | 2018-2021 median annual forb and grass NPP (lbs/ac) |
| RAP | SHR | 2018-2021 median shrub cover (%) |
| RAP | shrNPP | 2018-2021 median shrub NPP (lbs/ac) |
| RAP | TRE | 2018-2021 median tree cover (%) |
| RAP | treNPP | 2018-2021 median tree NPP (lbs/ac) |
| RAP | LTR | 2018-2021 median litter cover (%) |
| RAP | BGR | 2018-2021 median bare ground (%) |
| Potentially Undisturbed Lands Layer (PUDL) | grs1\_PUDL | Percent cover grass classification that has spectral qualities associated with potentially undisturbed grasslands, and within a zone of potentially undisturbed lands |
| PUDL | grs2\_PUDL | Percent cover grass classification that has spectral qualities associated with restored grasslands, but within a zone of potentially undisturbed lands |
| PUDL | shrb\_PUDL | Percent cover shrub classification within a zone of potentially undisturbed lands |
| PUDL | grs1\_DIST | Percent cover grass classification that has spectral qualities associated with potentially undisturbed grasslands, but within a zone of disturbed lands |
| PUDL | grs2\_DIST | Percent cover grass classification that has spectral qualities associated with restored grasslands, and within a zone of disturbed lands |
| PUDL | shrb\_DIST | Percent cover shrub classification within a zone of disturbed lands. |
| PUDL | All\_wtr | Percent cover open water classification |
| PUDL | All\_crop | Percent cover crop classification |
| PUDL | All\_fors | Percent cover forest classification |
| PUDL | All\_dist | Percent previously of currently disturbed cover |
| PUDL | All\_grs | Percent all grass classification |
| PUDL | All\_grsshrb | Percent all grass and shrub classification |
| PUDL | PUDL\_grs | Percent all grass classification within a zone of potentially undisturbed lands |
| PUDL | PUDL\_grsshrb | Percent all grass and shrub classification within a zone of potentially undisturbed lands |
| PUDL | DIST\_grs | Percent all grass classification within a zone of disturbed lands |
| PUDL | DIST\_grsshrb | Percent all grass and shrub classification with a zone of disturbed lands. |
| GeoMorpho90 (GM90) | Slope | Rate of change of elevation (degrees) |
| GM90 | Aspect | Angular direction slope face (degrees) |
| GM90 | Aspect\_cosine | Angular direction slope face (continuous) |
| GM90 | Aspect\_sine | Angular direction slope face (continuous) |
| GM90 | Eastness | Sine slope \* cosine aspect |
| GM90 | Northness | Sine slope \* cosine slope |
| GM90 | Convergence | Terrain variable with values ranging from -100 (valleys) to 100 (ridges) |
| GM90 | SPI | Stream power index; upstream catchment area/tangent local slope angle |
| GM90 | CTI | Compound topographic index (or wetness index) is the logarithm of upstream catchment area divided by the tangent of local slope angle and is a proxy for soil moisture availability. |
| GM90 | DX | Slope east-west direction |
| GM90 | DY | Slope north-south direction |
| GM90 | DXX | Derivative of slope east-west direction |
| GM90 | DYY | Derivative of slope north-south direction |
| GM90 | Pcurv | Profile curvature; rate of change of slope along a flow line. |
| GM90 | Tcurv | Tangental curvature; rate of change perpendicular to slope gradient. |
| GM90 | Elev\_Stdev | Standard deviation of elevation in a 3x3 moving window. |
| GM90 | VRM | Vector ruggedness measure; captures variability of slope and aspect by measuring the variation of sine and cosine slope in three dimensions (x,y,z) in 3x3 moving window. |
| GM90 | Roughness | Largest absolute difference in elevation between a focal cell and one of its eight neighboring cells. |
| GM90 | TRI | Terrain ruggedness index is the mean absolute difference between a focal cell and its eight neighboring cells. |
| GM90 | TPI | Topographic position index is the difference in elevation between a focal cell and the mean of its eight neighboring cells. |
| GM90 | Dev\_magnitude | Maximum deviation from mean elevation across multiple moving window sizes (3x3 to 4,001x4,001). Deviation is measured as difference of a focal cell elevation and mean elevation of the window, divided by the standard deviation of elevation. |
| GM90 | Dev\_scale | The window size at which the maximum deviation from mean elevation occurred across all window sizes (3x3 to 4,001x4,001). Deviation is measured as difference of a focal cell elevation and mean elevation of the window, divided by the standard deviation of elevation. |
| GM90 | Rough\_magnitude | Maximum rough value across all moving window sizes (3x3 to 4,001x4,0010). Rough is measured as the spherical standard deviation VRM components. |
| GM90 | Rough\_scale | The window size at which the maximum rough value occurred across all moving window sizes (3x3 to 4,001x4,0010). Rough is measured as the spherical standard deviation VRM components. |
| GM90 | DEM | Elevation (m) |
| SoilGrids250 (SG250) | Bdod | Mean bulk density of fine earth fraction (cg/cm3) |
| SG250 | Cec | Mean cation exchange capacity of the soil (mmol/kg) |
| SG250 | Cfvo | Mean volumetric fraction of coarse fragments (> 2 mm; cm3/dm3 (vol%)) |
| SG250 | Clay | Mean proportion of clay particle (< 0.002 mm) in the fine earth fraction (g/kg). |
| SG250 | Nitrogen | Mean total nitrogen (N; cg/kg) |
| SG250 | Phh20 | Mean soil ph (phX10) |
| SG250 | sand | Mean proportion of sand particles (> 0.05 mm) in the fine earth fraction (g/kg) |
| SG250 | silt | Mean proportion of silt particles (>= 0.002 mm and <= 0.05 mm) in the fine earth fraction (g/kg) |
| SG250 | Soc | Mean soil organic carbon content in the fine earth fraction (dg/kg) |
| SG250 | ocd | Mean organic carbon density (gh/dm3) |
| SG250 | ocs | Mean organic carbon stocks (t/ha) |
| AdaptWest Downscaled PRISM and CIMP6 Climate Data (CIMP6) | MAT | Mean annual temperature (°C) |
| CIMP6 | MWMT | Mean temperature of the warmest month (°C) |
| CIMP6 | MCMT | Mean temperature of the coldest month (°C) |
| CIMP6 | TD | Difference between MCMT and MWMT, as a measure of continentality (°C) |
| CIMP6 | MAP | Mean annual precipitation |
| CIMP6 | MSP | Mean summer (May-Sep) precipitation (mm) |
| CIMP6 | AHM | Annual heat moisture index, calculated as (MAT+1))/(MAP/1000) |
| CIMP6 | SHM | Summer heat moisture index, calculated as MWMT/(MSP/1000) |
| CIMP6 | DD\_0 | Degree-days below 0°C (chilling degree days) |
| CIMP6 | DD5 | Degree-days above 5°C (growing degree days) |
| CIMP6 | DD\_18 | Degree-days below 18°C |
| CIMP6 | DD18 | Degree-days above 18°C |
| CIMP6 | NFFD | Number of frost-free days |
| CIMP6 | FFP | Frost-free period |
| CIMP6 | bFFP | Julian date on which frost-free period begins |
| CIMP6 | eFFP | Julian date on which frost-free period ends |
| CIMP6 | PAS | Precipitation as snow (mm) |
| CIMP6 | EMT | Extreme minimum temperature over 30 years |
| CIMP6 | EXT | Extreme maximum temperature over 30 years |
| CIMP6 | Eref | Hargreave’s reference evaporation |
| CIMP6 | CMD | Hargreave’s climate moisture index |
| CIMP6 | MAR | Mean annual solar radiation (MJ m-2 d-1) |
| CIMP6 | RH | Mean annual relative humidity (%) |
| CIMP6 | CMI | Hogg’s climate moisture index (mm) |
| CIMP6 | DD1040 | Degree-days above 10°C and below 40°C |
| CIMP6 | Tave\_wt | Winter (Dec to Feb) mean temperature (°C) |
| CIMP6 | Tave\_sp | Spring (Mar to May) mean temperature (°C) |
| CIMP6 | Tave\_sm | Summer (June to Aug) mean temperature (°C) |
| CIMP6 | Tave\_at | Autumn (Sept. to Nov) mean temperature (°C) |
| CIMP6 | PPT\_wt | Winter (Dec to Feb) mean precipitation (mm) |
| CIMP6 | PPT\_sp | Spring (Mar to May) mean precipitation (mm) |
| CIMP6 | PPT\_sm | Summer (June to Aug) mean precipitation (mm) |
| CIMP6 | PPT\_at | Autumn (Sept. to Nov) mean precipitation (mm) |
| Sentinel-2 (S2) | TCg | Tasselled cap transformation for greenness (Shi and Xu 2019).  (-0.3599 \* B) + (-0.3533 \* G) + (-0.4734 \* R) + (0.6633 \* N1) + (0.0087 \* S1) + (-0.2856 \* S2) |
| S2 | TCb | Tasseled cap transformation for brightness (Shi and Xu 2019).  (0.3510 \* B) + (0.3813 \* G) + (0.3437 \* R) + (0.7196 \* N1) + (0.2396 \* S1) + (0.1949 \* S2) |
| S2 | TCw | Tasseled cap transformation for wetness (Shi and Xu 2019).  (0.2578 \* B) + (0.2305 \* G) + (0.0883 \* R) + (0.1071 \* N1) + (-0.7611 \* S1) + (-0.5308 \* S2) |
| S2 | NDVIr | Normalized difference vegetation index (Rouse et al. 1974).  (N1 - R) / (N1 + R) |
| S2 | NDVIb | Normalized difference vegetation index (Wang et al. 2007).  (N1 - B) / (N1 + B) |
| S2 | NDVIg | Normalized difference vegetation index (Wang et al. 2007).  (N1 - G) / (N1 + G) |
| S2 | NDVIre | Normalized difference vegetation index (Gitelson and Merzlyak 1994).  (N1 - RE1) / (N1 + RE1) |
| S2 | NDVIresw | Normalized difference vegetation index (Radoux et al. 2016).  (RE2 - S2) / (RE2 + S2) |
| S2 | NBR | Normalized Burn Ratio (Coffelt and Livingston 2002).  (N1 - S2) / (N1 + S2) |
| S2 | NDMI | Normalized difference moisture index (Wilson and Sader 2002).  (N1 - S1) / (N1 + S1) |
| S2 | SAVI | Soil adjusted vegetation index (Huete 1988; L=0.5).  (1.0 + L) \* (N - R) / (N + R + L) |
| S2 | MSAVI | Modified soil adjusted vegetation index (Qi et al. 1994).  0.5 \* (2.0 \* N1 + 1 - (((2 \* N1 + 1) \*\* 2) - 8 \* (N1 - R)) \*\* 0.5) |
| S2 | EVI | Enhanced vegetation index (Huete et al. 1997; g=2.5, C1=6, C2=7.5, L=1).  g \* (N1 - R) / (N1 + C1 \* R - C2 \* B + L) |
| S2 | CIg | Chlorophyll index green (Gitelson et al. 2003).  (N1 / G) - 1.0 |
| S2 | Cire | Chlorophyll index red edge (Gitelson et al. 2003).  (N1 / RE1) - 1.0 |
| S2 | BAIS2 | Sentinel-2 Burn area index (Filipponi 2018).  (1.0 - ((RE2 \* RE3 \* N2) / R) \*\* 0.5) \* (((S2 - N2)/(S2 + N2) \*\* 0.5) + 1.0) |
| S2 | SeLI | Sentinel-2 LAI green index (Pasqualotto et al. 2019).  (N2 - RE1) / (N2 + RE1) |
| S2 | S2REP | Sentinel-2 red edge position (Frampton et al. 2013).  705.0 + 35.0 \* ((((RE3 + R) / 2.0) - RE1) / (RE2 - RE1)) |
| S2 | TTVI | Transformed triangular vegetation index (Xing et al. 2020).  0.5 \* ((865.0 - 740.0) \* (RE3 - RE2) - (N2 - RE2) \* (783.0 - 740)) |

Literature Cited for S2 Indices; special thanks to Montero et al. (2022) for providing the useful package “spectral” for Google Earth Engine.

Amatulli, G., McInerny, D., Sethi, T., and Domisch, S. (2020). Geomorpho90m, empirical evaluation and accuracy assessment of global high-resolution geomorphometric layers. *Scientific Data* 7:162. doi: 10.1038/s41597-020-0479-6

Coffelt, J. L., and Livingston, R. K. (2002). *Second U.S. Geologic Survey wildland fire workshop: Los Alamos, New Mexico, October 31-November 3, 2000*. U.S. Geologic Survey, Denver, CO.

Filipponi, F. (2018). BAIS2: Burned area index for Sentinel-2. *Proceedings* 2:364. doi: 10.3390/ecrs-2-05177

Frampton, W. J., Dash, J., Watmough, G., and Milton, E. J. (2013). Evaluating the capabilities of Sentinel-2 for quantitative estimation of biophysical variables in vegetation. *ISPRS Journal of Photogrammetry and Remote Sensing* 82, 83-92. doi: 10.1016/j.isprsjprs.2013.04.007

Gitelson, A. A., Kaufman, Y. J., and Merzlyak, M. N. (1996). Use of green channel in remote sensing of global vegetation EOS-MODIS. *Remote Sensing of Environment* 58, 289-298. doi: [10.1016/S0034-4257(96)00072-7](https://doi.org/10.1016/S0034-4257(96)00072-7)

Gitelson, A. A., Gritz, Y., and Merzlyak, M. N. (2003). Relationships between leaf chlorophyll content and spectral reflectance and algorithms for non-destructive chlorophyll assessment in higher plant leaves. *Journal of Plant Physiology* 160, 271-282. doi: 10.1078/0176-1617-00887

Gitelson, A. A., and Merzlyak, M. N. (1994). Spectral reflectance changes associated with autumn senescence of Aesculus hippocastanum L. and Acer platanoides L. leaves. Spectral features and relation to chlorophyll estimation. *Journal of Plant Physiology* 143, 286-292. doi: [10.1016/S0176-1617(11)81633-0](https://doi.org/10.1016/S0176-1617(11)81633-0)

Gitelson, A. A., Merzlyak, M. N., and Chivkunova, O. B. (2001). Optical properties and nondestructive estimation of anthocyanin content in plant leaves. *Photochemistry and Photobiology* 74,38-45. doi: 10.1562/0031-8655(2001)074%3C0038:OPANEO%3E2.0.CO;2

Huete, A. R. (1988). A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment* 25, 295-309. [doi: 10.1016/0034-4257(88)90106-X](https://doi.org/10.1016/0034-4257(88)90106-X)

Huete, A. R., Li, H. Q., Batchily, K., and van Leeuwen, W. (1997). A comparison of vegetation indices over a global set of TM images for EOS-MODIS. *Remote Sensing of Environment* 59, 440-451. doi: 10.1016/S0034-4257(96)00112-5

Montero, D., Aybar, C., Mahecha, M. D., Wieneke, S. (2022). spectral: Awesome Spectral Indices deployed via the Google Earth Engine Javascript API. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XLVIII-4/W1-2022. Free and Open Source Software for Geospatial (FOSS4G) 2022 Academic Track, 22-28 August, 2022, Florence, Italy. doi: 10.5194/isprs-archives-XLVIII-4-W1-2022-301-2022

Pasqualotto, N., Delgido, J., Van Wittenberghe, S., Rinaldi, M., and Morno, J. (2019). Multi-crop green LAI estimation with new simple sentinel-2 LAI index (SeLI). *Sensors* 19:904. doi: 10.3390/s19040904

Qi, J., Chehbouni, A., Huete, A. R., Kerr, Y. H., and Sorooshian, S. (1994). A modified soil adjusted vegetation index. *Remote Sensing of Environment* 48, 119-126. doi: 10.1016/0034-4257(94)90134-1

Radoux, J., Chomè, G., Jacques, D. C., Waldner, F., Bellemans, N., Matton, N., Lamarche, C., D’Andrimont, R., and Defourny, P. (2016). Sentinel-2’s potential for sub-pixel landscape feature detection. *Remote Sensing*, 8:488. doi: 10.3390/rs8060488

Rouse, J. J. Jr., Hass, R. H., Schell, J. A., and Deering, D. W. (1974). *Monitoring vegetation systems in the Great Plains ERTS*. NASA. Goddard Space Flight Center 3d ERTS-1 Symp., Vol. 1, Sect. A.

Shi, T., and Xu, H. (2019). Derivation of tasseled cap transformation coefficients for Sentinel-2 MSI at-sensor reflectance data. *IEEE* 12, 4038-4048. doi: [10.1109/JSTARS.2019.2938388](https://doi.org/10.1109/JSTARS.2019.2938388)

Wang., F., Huang, J., Tang, Y., and Wang, X. (2007). New vegetation index and its application in estimating leaf area index of rice. *Rice Science* 14, 195-203. doi: 10.1016/S1672-6308(07)60027-4

Wilson, E. H., and Sader, S. A. (2002). Detection of forest harvest type using multiple dates of Landsat TM imagery. *Remote Sensing of Environment* 80, 385-396. doi: 10.1016/S0034-4257(01)00318-2

Xing, N., Huang, W., Xie, Q., Shi, Y., Ye, H., Dong, Y., Wu, M., Sun, G., and Jiao, Q. (2020). A transformed triangular vegetation index for estimating winter wheat leaf area index. *Remote Sensing* 12:16. doi: 10.3390/rs12010016