# Supplementary Data 3. Methods for Plains bison habitat suitability index

A bison summer habitat suitability index (HSI) model was created to estimate extent and relative quality of remaining habitat across the historic distribution of bison in North America. The model was adapted from the summer HSI model developed by Steenweg et al. (2016) for Banff National Park, Canada. Their model (hereafter referenced as the “Banff model”) were based largely on coefficients for habitat variables averaged from other bison habitat models reported in the literature. To the extent possible, I cross-walked attributes from the best available spatial data layers to each of their input variables and applied their coefficients to weight variables to produce the final HSI. However, several modifications were necessary to adapt the Banff model to a continental scale. Primary modifications are:

* Modified land cover type scores – The Banff model ranked forest cover of all types relatively low compared with herbaceous cover which is consistent with habitat conditions in the Banff region. However, at the continental scale open canopy forests (most notably ponderosa pine and aspen) support understories of productive herbaceous cover that provides high quality forage for ungulates. Therefore, I adjusted the habitat scores for low density or open canopy ponderosa pine and aspen forest cover types.
* Add enhanced vegetation index (EVI) – EVI provides an estimate of plant biomass and was added to the model to identify areas where vegetation is too sparse to support large populations of bison regardless of land cover type.
* Removed distance to water – see explanation for the winter range model.
* Removed fire – Fire is a major driver of forage quality and quantity and was included in the Banff models. However, because fire and many of its effects on vegetation are ephemeral, it is not appropriate for a model intended for broad spatial and temporal scales.

## Geographic extents and spatial constraints: The geographic extent of the summer model includes the area within a 500 km buffer around the historic bison range as drawn by Hornaday (1889). The model was further constrained by removing current roads and areas of cropland on, or crossing, private land to eliminate areas where bison restoration is likely to conflict with current land use.

## Model Input Variables and Data Sources:

### Land Cover Type Source:

* 2018 LANDFIRE's (LF) Existing Vegetation Type (EVT) – U.S. portion of study area (LANDFIRE. 2018).
* North American Land Change Monitoring System (NALCMS) – Canada & Mexico portions of study area. (North American Land Change Monitoring System. 2020)

Land cover layers reclassified to habitat suitability scores (HSS) according to the following tables:

Table 1. LANDFIRE's (LF) Existing Vegetation Type (EVT) to HSS reclassification.

|  |  |
| --- | --- |
| EVT class | HSS\* |
| Sparsely vegetated | 0 |
| Open tree canopy | 0.51 |
| Closed tree canopy | 0.32 |
| Dwarf-shrubland | 0.25 |
| Shrubland | 0.44 |
| Sparse tree canopy | 0.51 |
| Herbaceous - shrub-steppe | 0.44 |
| Herbaceous - grassland | 0.66 |
| Non-vegetated | 0 |
| No Dominant Lifeform | 0 |

Table 2. North American Land Change Monitoring System (NALCMS) to HSI reclassification.

|  |  |  |
| --- | --- | --- |
| **Value** | **Class** | **HSS** |
| 1 | Temperate or sub-polar needleleaf forest | 0.36 |
| 2 | Sub-polar taiga needleleaf forest | 0.36 |
| 3 | Tropical or sub-tropical broadleaf evergreen forest | 0 |
| 4 | Tropical or sub-tropical broadleaf deciduous forest | 0.27 |
| 5 | Temperate or sub-polar broadleaf deciduous forest | 0.27 |
| 6 | Mixed Forest | 0.31 |
| 7 | Tropical or sub-tropical shrubland | 0.44 |
| 8 | Temperate or sub-polar shrubland | 0.44 |
| 9 | Tropical or sub-tropical grassland | 0.66 |
| 10 | Temperate or sub-polar grassland | 0.66 |
| 11 | Sub-polar or polar shrubland-lichen-moss | 0 |
| 12 | Sub-polar or polar grassland-lichen-moss | 0 |
| 13 | Sub-polar or polar barren-lichen-moss | 0 |
| 14 | Wetland | 0 |
| 15 | Cropland | 0 |
| 16 | Barren Lands | 0 |
| 17 | Urban and Built-up | 0 |
| 18 | Water | 0 |
| 19 | Snow and Ice | 0 |

## Percent Slope

* Source: The Shuttle Radar Topography Mission (SRTM) – Void filled SRTM Plus
<https://www2.jpl.nasa.gov/srtm/>
* Methods: Calculated percent slope from SRTM elevation values. Converted to HSS values using the follow function:

$$Slope HSS= -0.0000610101010101046 × Percent Slope^{3} + 0.00439393939393963 ×Percent Slope^{2} - 0.101414141414145 ×Percent Slope + 0.922121212121229$$



**Figure 1. Smoothing function used to convert raw percent slope values to HSS.**

## Enhanced Vegetation Index (EVI)

* Source: MODIS Terra Daily EVI Google Earth Engine image collection
<https://developers.google.com/earth-engine/datasets/catalog/MODIS_MOD09GA_006_EVI#description> (Gorelick et al., 2017)(Gorelick et al. 2017, Vermote, and Wolfe, 2015)
* Methods: Calculated the 30-year mean of the annual maximum EVI. The Google Earth Engine code for calculation can be accessed here: <https://code.earthengine.google.com/?scriptPath=users%2Fbbrock_wcs%2FMODIS_EVI%3AMODIS_MEAN_YEARLY_MAXEVI> (Brock, unpublished)
EVI values were converted to HSS using the following function:

$$EVI Habitat Suitability Score=MINIMUM(1, 3.3333 ×EVI^{2}+ 3.333 ×EVI)$$



**Figure 2. Smoothing function used to convert raw EVI values to HSS.**

## Final habitat suitability index calculations

Raw habitat suitability index (HSI) score was calculated using the following equation. Where $summer LC HSI$ is the habitat suitability estimates based on landcover type(Tables 1 and 2), $summer EVI HSI$ are habitat suitability estimates derived from Enhanced Vegetation Index (EVI) derived from MODIS Terra Daily EVI Google Earth Engine image collection (Figure 2), $summer slope HSI$ is habitat suitability estimates derived from percent slope derived from Shuttle Radar Topography Mission (SRTM) – Void filled SRTM Plus https://www2.jpl.nasa.gov/srtm/ (Figure 1)

$$Summer HSI= (summer LC HSS ×summer EVI HSS×0.66)+(summer slope HSS×0.33)$$

Raw HSI values > than a maximum slope threshold were removed by setting cells to NULL. Thresholds uses where the maximum summer slope was set to 35. Finally, areas of conflict with human land uses as described previously under Geographic Extent and Spatial Constraints were removed by setting cells to NULL.

## Contiguous Habitat Patches

Area of contiguous habitat was calculated to estimate the potential area potentially available for restoring bison in each case study area. Suitable habitat was estimated by slicing summer HSI scores into two equal interval classes and extracting cells in the top 50% of HSI values. This is likely a conservative estimate of suitable habitat as it excludes some areas where bison were historically documented to occur. Grid cells of suitable habitat within 0.5 km of the nearest eight neighboring cells were considered connected. This distance was based on movements of bison that regularly occur in Yellowstone National Park. The total area of each contiguous patch of suitable habitat was calculated and patches ≥ 121.5 km2 (30,000 ac) were retaining as potential restoration areas. This area threshold is somewhat arbitrary but chosen to represent areas large enough to support relatively minimal management and allow sufficient free range of movement to allow somewhat natural grazing patterns.

# References

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