This step-by-step protocol supplements the fire needs assessment methodology http://staceymarion.com/fna/methodology.html. Follow the link to access associated Python and R scripts.

FIRE NEEDS ASSESSMENT PROTOCOL

Input Data Layers

Layer information	*Data layer*	*File*	*Source*
Historical ecosystems, associated fire regime information	LANDFIRE Biophysical Settings Layer, 2016 version	"wiBps200.tiff" (dataset clipped to Wi state boundary)	https://landfire.gov/version_download.php
Current land cover types	LANDFIRE Existing Vegetation Layer, 2016 version	"wiEVT200.tiff" (dataset clipped to Wi state boundary)	https://landfire.gov/version_download.php
State boundary, clipping layer	Wisconsin state boundary	"Wisconsin_State_Boundary_24K.shp"	https://data-wi-dnr.opendata.arcgis.com/datasets/wisconsin-state-boundary-24k
Historic extent of prairie and savanna	Wisconsin original vegetation polygons	"Orig_veg_cover_dissbyoakgrass.shp" (extracted prairie and oak savanna polygons; dissolved)	https://data-wi-dnr.opendata.arcgis.com/datasets/original-vegetation-polygons/explore?location=44.771700%2C-89.835450%2C7.66
Cultivate crops	National Land Cover Database, 2013 and 2016	"NLCD_2013.tiff", "NLCD_2016.tiff"	https://www.mrlc.gov/viewer/
Conservation priority areas	Wisconsin Conservation Opportunity Areas	"WI_COA_clipped.shp " (clipped to include only terrestrial coa's)	https://data-wi-dnr.opendata.arcgis.com/datasets/conservation-opportunity-areas-terrestrial-and-lake/explore
Wildland-urban interface	Wildand-Urban Interface model		http://silvis.forest.wisc.edu/maps/wui
Watershed designations	Wisconsin HUC-12 watershed designations		http://nhd.usgs.gov/wbd.html

1- Summarize historic conditions in Wisconsin

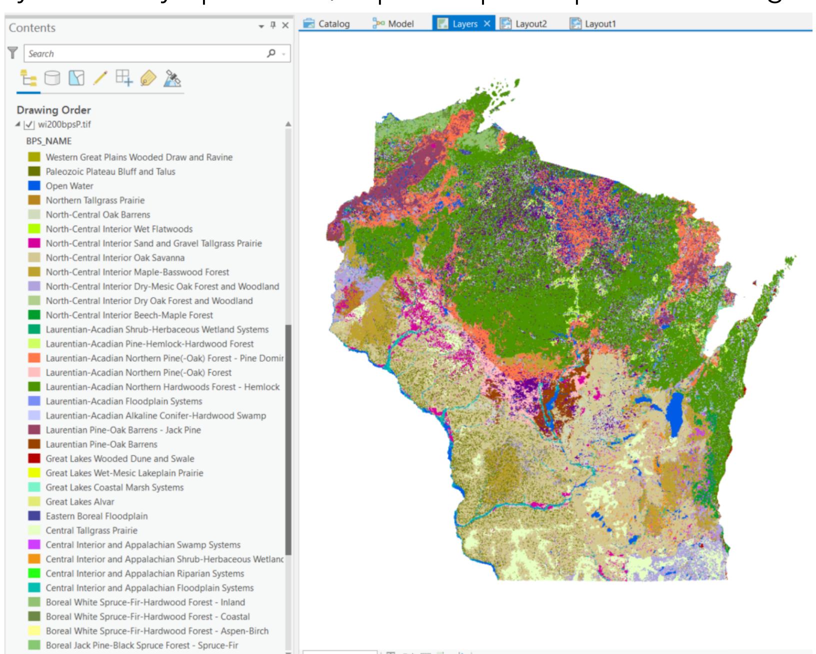
1. Before getting started, I highly recommend creating a [geodatabase in ArcGIS Pro](#) to hold your project.

2. Download Biophysical Settings raster layer from LANDFIRE.gov (LF2016_BPS_200_CONUS). * We used the 2016 Remap (version 2.0.0). Depending on the download version, you may need to download the raster and attribute table separately, and then perform a table join (Add Join (Data Management) Tool). If joining manually, consider joining after clipping the raster to your state boundary.

3. Download Wisconsin state boundary shapefile

4. In ArcGIS Pro, Clip to Wisconsin state boundary (Wisconsin_State_Boundary_24K); save to gdb , "wi200Bps.tiff"

5. Symbolize by BpS_Name; Export map = map of historic vegetation conditions.



6. Symbolize by mFRI; Export map = map of historic fire regime

7. Symbolize by FRG_NEW = map of historic fire severity. (Check documentation about fire regime groups at: https://landfire.gov/frg.php)

8. Export the raster attribute table as "wi200bps.csv". Exporting is a counterintuitive step, however, exporting the raster attribute table links raster pixel count ("Count"), enabling us to create area summaries.

9. Calculate area and fire regime summaries in R (bps_stats.R)

```
# BpS summaries
# Our analysis used BpS LANDFIRE 2016, version 2.0.0 (i.e. 200)

library(dplyr)
library(tidyverse)
library(readr)
library(ggplot2)

bps <- read_csv("d:\\wi200bps.csv") # csv is exported attribute table from the wisconsin BpS raster layer

# Part 1 - Area summaries and historical fire regimes

# create variable p as percent of total count, per row.  sum = total count everything combined
bps$sum <- sum(bps$COUNT)
print(bps$sum)

bps <- within(bps, p <- as.numeric(COUNT/bps$sum*100))
head(bps)
head(bps$p)

# Sort data table
# Because our dataset crosses model zones, there are on occasion multiple rows for a BpS for each zone. We want to take the attributes from the BpS-Zone most common in our project extent.
bpsOrder <- bps %>%
  arrange(desc(BPS_CODE), desc(COUNT))
print(bpsOrder)

# Calculate counts by BpS using our sorted dataset
bpsClean <- bpsOrder %>%
  group_by(BPS_NAME) %>%
  summarise(BPS_CODE = first(BPS_CODE), COUNT = sum(COUNT), area = sum(COUNT)*30*30, acres = sum(COUNT)*30*30/4046.86, perArea = sum(p), FRI_ALLFIR = first(FRI_ALLFIR), annual = acres/FRI_ALLFIR, PRC_REPLAC = first(PRC_REPLAC), annRep = annual*PRC_REPLAC, GROUPVEG = first(GROUPVEG)) %>%   ## 30x30 M resolution. 1 acre = 4046.86 sqm Output = acres
  arrange(desc(area))
bpsClean <- bpsClean %>% mutate_if(is.numeric, list(~na_if(., Inf))) %>% replace(is.na(.), 0) # get rid of values calculated as Inf (value/0 = Inf)
print(bpsClean)
write_csv(bpsClean, "d:\\wiBpsSummarized.csv")


# Take a look at just the top 10 most common BpS's i.e. historical vegetation conditions
bps10 <- bpsClean %>% slice (1:10) %>%
  arrange(desc(area))
print(bps10)

# plot
p <- ggplot(bps10) +  geom_bar(aes(x = reorder(BPS_NAME, perArea), y = perArea), stat = 'identity') +
scale_y_continuous(limits=c(0,30))
p + coord_flip()

# Export plot and edit in Adobe Illustrator to match colors of map output

# Part 1B:
# Take a look at where fire occurred most frequently, by major vegetation group
```

```
bpsFireGroup <- subset(bpsClean, GROUPVEG %in% c("Conifer", "Grassland", "Hardwood", "Hardwood-Conifer",
"Riparian")) %>%
  group_by(GROUPVEG) %>%
  summarise(annual = sum(annual)) %>%
  arrange(desc(annual))  # annual = annual acres burned
print(bpsFireGroup)

p <- ggplot(bpsFireGroup) +  geom_bar(aes(x = reorder(GROUPVEG, annual), y = annual), stat = 'identity') +
scale_y_continuous(limits=c(0,2000000))
p + coord_flip()

# Take a look at where fire occurred most frequently, by BpS
bpsFire <- subset(bpsClean, GROUPVEG %in% c("Conifer", "Grassland", "Hardwood", "Hardwood-Conifer",
"Riparian")) %>%
  group_by(BPS_NAME) %>%
  summarise(annual = sum(annual)) %>%
  arrange(desc(annual)) # annual = annual acres burned
print(bpsFire)

bpsFire10 <- bpsFire %>% slice (1:10) %>%
  arrange(desc(annual))

p <- ggplot(bpsFire10) +  geom_bar(aes(x = reorder(BPS_NAME, annual), y = annual), stat = 'identity') +
scale_y_continuous(limits=c(0,2000000))
p + coord_flip()

# Export plot and edit in Adobe Illustrator to match colors of map output

# Part 2 - Summarize historic fire Severity

# Recode fire regime groups
bps$sev <- recode(as.character(bps$FRG_NEW),
          "I-A" = "Low/mixed",
          "I-B" = "Low/mixed",
          "I-C" = "Low/mixed",
          "II-A" = "Replacement",
          "II-B" = "Replacement",
          "II-C" = "Replacement",
          "III-A" = "Low/mixed",
          "III-B" = "Low/mixed",
          "III-C" = "Low/mixed",
          "IV-A" = "Replacement",
          "IV-B" = "Replacement",
          "IV-C" = "Replacement",
          "V-A" = "Any/Replacement",
          "V-B" = "Any/Replacement")

head(bps$sev)


# Percent replacement by veg group - categorical, stacked bar
bpsSev <- bps %>%
  group_by(GROUPVEG, sev) %>%
  summarise(perCount = sum(p)) %>%
  arrange(GROUPVEG)
print(bpsSev, n=nrow(bpsSev))

# subset to remove open water and shrubland which as < 0.1%, and open water which is NA
```

```
p <- ggplot(subset(bpsSev, GROUPVEG %in% c("Conifer", "Grassland", "Hardwood", "Hardwood-Conifer", "Riparian")))
+
  aes(fill = sev, x = reorder(GROUPVEG, perCount), y = perCount) +
  geom_bar(position="stack", stat = "identity")
p + coord_flip()

# Export plot; edit colors in Adobe Illustrator to match map output
```

10. Formalize maps and associated figures in Adobe Illustrator as desired.

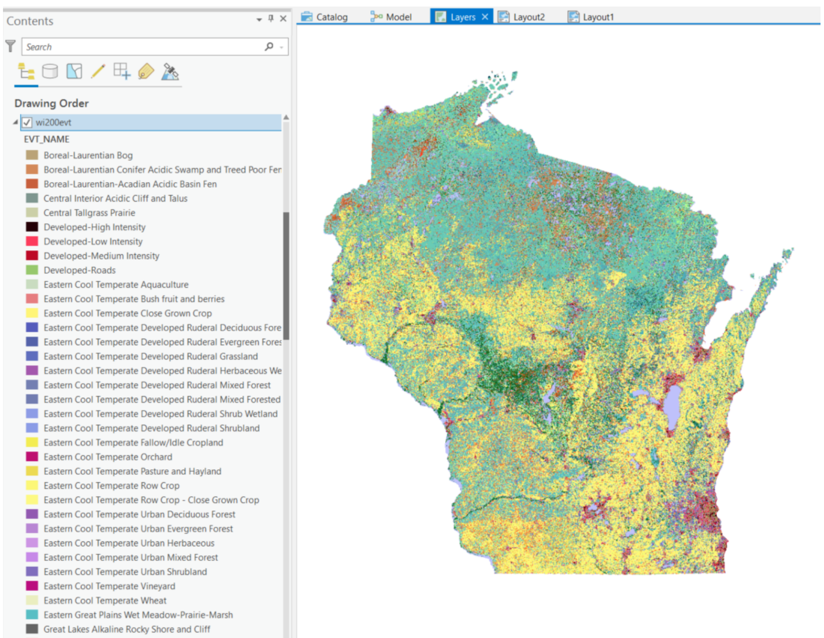
2- Visualize current conditions in Wisconsin, unmodified model output

11. Download Existing Vegetation raster layer from LANDFIRE.gov (LF2016_EVT_200_CONUS). Depending on the download version, you may need to download the raster and attribute table separately, and then perform a table join (Add Join (Data Management) Tool). If joining manually, consider joining after clipping the raster to your state boundary.

12. Download Wisconsin state boundary shapefile (if not downloaded already).

13. Clip to Wisconsin state boundary (Wisconsin_State_Boundary_24K); save to gdb.

14. Symbolize by EVT_PHYS; Export map = map of current vegetation conditions (unmodified model output)



Note: This map visualizes unmodified EVT model output, and therefore does not take in account any vegetation type modifications as detailed in proceeding steps. This visualization, however, can be helpful for the analyst performing the assessment. It is not recommended to use this map for presentation.

3- Summarize current conditions in Wisconsin, modified output

In order to assess current conditions in Wisconsin, we need to modify the EVT model output to incorporate information about fire return intervals. This assessment follows modifications outlined in the 2014 Fire Needs Assessment for Wisconsin (Hmielowski et al 2016). Modification is two part:

1) Crosswalk EVT classifications to historic reference conditions (BpS ecosystems) to infer fire regime information for each EVT classification. Then, join the EVT classifications to Wisconsin Natural Plant Community classifications. Crosswalking to the Natural Plant Community classifications as defined by the Wisconsin Department of Natural Resources allows the assessment to be understood better by the conservation community in Wisconsin. Additionally, the WDNR Natural Plant Community classifications include information about State and Global Rarity, used later in the analysis to determine ecological value of a given community.

2) Modify vegetation classifications to split or join EVT classifications. For example, I distinguished permanent managed grassland from hayfields/fallow fields in part of a crop rotation (detailed below).

Data outputs include a modified map of natural vegetation, and a modified map of fire-dependent vegetation in Wisconsin.

--- CREATE MAP OF FIRE-DEPENDENT VEGETATION ---

15. Perform Crosswalk: The most time-consuming aspect of a fire needs assessment is creating a three-way crosswalk schema to integrate current vegetation conditions (e.g. EVT layer) with fire regime information from the BpS layer and local plant community descriptions (Wisconsin Natural Heritage Inventory Plant Communities). There is not a one:one relationship between EVT_NAME and BPS_NAME, therefore, subjective connections are made based on the analyst's research and knowledge. Simultaneously, we crosswalked the EVT-BPS crosswalk to the Wisconsin Natural Plant Community descriptions as listed in the Natural Heritage Inventory (part of the national NatureServe classification), however, a single EVT was paired with one or more Natural Plant Communities. The crosswalk was manually compiled in excel for ease of manipulation.

16. Build the crosswalk spreadsheet starting with EVT_NAME and EVT_VALUE. Manually assign an associated BPS_NAME to each EVT_NAME based on best match to BPS attributes, specifically fire regime. Manually assign associated Wisconsin Natural Plant Communities and Rarity Rankings (State Rarity Ranking). Where multiple WI Natural Plant Communities were assigned to a row, average the State Rarity Ranking. The final Rarity ranking reflected the inverse of the State Rarity Ranking such that higher values were associated with higher rarity. (6 - ave(State Rarity Ranking)). In the scenario that fire regime information obtained from best-fit BPS attributes does not reflect fire regime characteristics for the current vegetation (evt) of interest, the fire regime parameters can be manually adjusted based on expert opinion and best available scientific research. For simplicity, our analysis used research and stakeholder input to assign BPS

associations, but we did not manipulate fire regime parameters directly. Future iterations of the fire needs assessment will modify fire regime parameters to portray perceived fire needs to restore, not simply maintain, degraded plant communities. Finally, add a column to distinguish natural vegetation and non-natural vegetation. Non-natural vegetation will be excluded from the analysis.

EVT descriptions:
https://landfire.gov/documents/LANDFIRE_Ecological_Systems_Descriptions_CONUS.pdf

Ruderal community descriptions:
https://landfire.gov/documents/LANDFIRE_Ruderal_NVC_Groups_Descriptions_CONUS.pdf

BpS descriptions: Download zip from https://landfire.gov/bps.php

Cultural community descriptions:
https://landfire.gov/documents/LF-GAPMapUnitDescriptions.pdf

Wisconsin NHI Natural Communities descriptions: https://p.widencdn.net/exmng9/1805Ch7

EVT_NAME, COUNT, and EVT_VALUE are attributes from the LANDFIRE EVT raster.

WI_Nat_Comm (Wisconsin Natural Plant Community classifications) were manually assigned to best match modeled EVTs. The State and Global rarity rankings as found on the Wisconsin NHI webpage are listed in the Rarity_Desc column. I calculated the Rarity index to reflect 6-average(State Rarity Ranking).

1	EVT_NAME	COUNT	EVT_VALUE	natVeg	EVT_PHYS	WI_Nat_Comm	Rarity	Rarity_Desc	BPS_NAME
2	Eastern Cool Temperate Row Crop	30,394,505	7974	0	Agricultural	> ------- Exclude -------------	0		> ------- Exclude -------------
3	Laurentian-Acadian Northern Hardwoods Fores	27,157,302	7302	2	Hardwood	Northern Dry-mesic Forest; North Mesic Forest	2.5	G3, S3; G4, S4	Laurentian-Acadian Pine-Hemloc
4	North-Central Interior Dry Oak Forest and Woo	11,166,927	7311	2	Hardwood	Southern Dry Forest	3	G4, S3	North-Central Interior Dry Oak Fo
5	Eastern Cool Temperate Close Grown Crop	10,171,083	7975	0	Agricultural	> ------- Exclude -------------	0		> ------- Exclude -------------
6	Laurentian-Acadian Alkaline Conifer-Hardwood	9,619,154	7481	2	Riparian	Northern Hardwood Swamp	3	G4, S3	Laurentian-Acadian Alkaline Coni
7	Eastern Cool Temperate Pasture and Hayland	6,676,214	7977	1	Agricultural	Surrogate Grassland	0	N/A	* Separate managed grassland ar
8	Northern Tallgrass Prairie	5,147,827	7420	2	Grassland	Mesic prairie; Dry-mesic prairie; Wet-mesic Prairie	4.3	G2, S1; G3, S2;	Northern Tallgrass Prairie
9	Developed-Roads	5,116,105	7299	0	Developed-Roads	> ------- Exclude -------------	0		> ------- Exclude -------------
10	Northern & Central Native Ruderal Forest	4,506,522	9315	2	Conifer-Hardwood	Southern Mesic Forest; Southern Dry-mesic Forest	3	G3, S3; G4, S3	Central Interior and Appalachian
11	Boreal-Laurentian Conifer Acidic Swamp and Tr	3,913,339	9056	2	Riparian	Poor fen; Central Poor Fen	3	G3G$, S3	Boreal Acidic Peatland Systems
12	Northern & Central Native Ruderal Flooded & S	2,930,673	9314	2	Riparian	Floodplain Forest; Northern Hardwood Swamp	3	G3, S3; G4, S3	Laurentian-Acadian Floodplain Sy
13	North-Central Interior Graminoid Alkaline Fen	2,389,288	9682	2	Riparian	Calcerous Fen	3	G3, S3	Central Interior and Appalachian
14	North-Central Interior and Appalachian Rich Sw	2,246,993	9178	2	Riparian	Shrub-carr; Southern Sedge Meadow; Emergent Ma	2.7	G5, S3; G4, S3;	Central Interior and Appalachian
15	Laurentian-Acadian Northern Pine-(Oak) Forest	2,125,635	7239	2	Conifer-Hardwood	Central Sands Pine-Oak Forest; Northern Dry Forest	3	G3, S3	Laurentian-Acadian Northern Pin
16	Laurentian-Acadian Northern Pine Forest	2,120,268	7362	2	Conifer	Northern Dry Forest; Central Sands Pine-Oak Forest	3	G3, S3	Laurentian-Acadian Northern Pin
17	North-Central Interior and Appalachian Acidic P	2,001,483	9177	2	Riparian	White Pine-Red Maple Swamp; Southern Tamarack	4	G3G4, S2	Central Interior and Appalachian

natVeg is a manually assigned column.
0 = non natural vegetation to be excluded
1 = requires further modification -- see methodology
2 = natural vegetation

BPS_NAME is manually assigned to best match the EVT and WI Natural Plant Community classifications. If joining associated fire regime information using BPS_NAME as a join factor, confirm that exact spelling is used.

17. Following protocol from the [2014 Wisconsin Fire Needs Assessment](https://) (Hmielowski et al. 2016), we identified the following vegetation types requiring further manipulation in arcGIS:
    a. "Recently logged…" and "Recently burned…" vegetation types will be converted to adjacent land cover.

    b. Non-natural vegetation (e.g. Developed-roads, Developed-low intensity, Developed-medium intensity, Developed-high intensity) will be removed.

    c. Agricultural vegetation will be excluded with the exception of EVT's representing possible managed grassland (e.g. "Eastern Cool Temperate Pasture and Hayland," "Eastern Cool Temperate Developed Ruderal Grassland"). Grassland, hereafter, "Managed Grassland" will be separated from hayland if occurring within the historical extent of tallgrass prairie and savanna, *and*, if not classified as Row Crop agriculture in the 2013 or 2019 National Land Cover Database. The resulting "Managed Grassland" EVT to be included in the fire needs assessment represents plausible permanent grassland or CRP parcels providing potential habitat for native prairie species and grassland birds (Hmielowski et al. 2016).

    d. See steps 20-21.

18. Join the crosswalk csv to the EVT attributes and BPS attributes. (crosswalkJoin.R)

```
library(dplyr)
library(tidyverse)
library(readr)
library(ggplot2)

# Select bps name row with the highest count; use for FRI information ** So, using most abundant bps--zone row for FRI.
This is preferable to averaging or selecting just a single zone
# bpsFRI <- bps %>%
#   group_by(BPS_NAME) %>%
#   slice(which.max(COUNT))
# print(bpsFRI)
# write_csv(bpsFRI, "d:\\wi200bpsFRI.csv")

# JOIN EVT ATTRIBUTES

cross <- read_csv("d:\\crosswalkAug9.csv")  # use final crosswalk file. see master sheet on google docs
evtAtt <- read_csv("d:\\wi200evtT.csv")  # this is the output of EVT raster joined with EVT attributes. Info gathered from
join is Count info

# join evt attributes

# left join keeps all rows from x (crosswalk), and all columns from x and y (evt attributes)
# join on evt numerical code (VALUE, EVT_VALUE)


join <- cross %>% left_join(evtAtt, by = c("EVT_VALUE" = "VALUE"))
```

```
# Drop unwanted rows

join <- select (join,-c(OBJECTID,VALUE_1,EVT_N,COUNT,R,G,B,RED,GREEN,BLUE))
#join <- join %>% .[1:108,]  # odd excel bug: spreadsheet has 1000 rows; most empty
print(join)


# JOIN BPS ATTRIBUTES

bpsFRI <- read_csv("d:\\wi200bpsFRI.csv")

# join bpsFRI data to evt table. bpsFRI dataset has a single row per BPS_NAME

# left join keeps all rows from x (evt), and all columns from x and y (bps)

#inner_join(x, y, by = NULL, copy = FALSE, suffix = c(".x", ".y"),...)

join2 <- join %>% left_join(bpsFRI, by = c("BPS_NAME" = "BPS_NAME"))

# Drop unwanted rows

join2 <- select (join2,-c(OBJECTID,VALUE,COUNT,OID_1,VALUE_1,R,G,B,RED,GREEN,BLUE,sum,p))
join2 <- join2 %>% .[1:108,]  # remove extra rows (excel bug)
join2 <- rename(join2, EVT_NAME = EVT_NAME.x)  # ditch join appendage
Join2 <- join2 %>% replace(is.na(.), 0) # replace NA's with 0's
print(join2)
write_csv(join2, "d:\\crosswalkJoinAug9.csv")

# csv output has all EVT200 and BPS200 attributes excluding duplicate attributes, count, oid, objectid, and color scheme
(Most information is not needed)
```

19. The joined crosswalk attribute table will later be joined with our evt raster.

20. Identify natural vegetation in Wisconsin by modifying the EVT raster layer. Exclude open water, developed areas, mines, agricultural except "Eastern Cool Temperate Pasture and Hayland" (see step 24), and recently burned and logged areas (see step 20). See step 21 for separating 'pasture' from 'hayland'.

21. Exclude "Recently Burned…" and "Recently Logged…" and convert to the vegetation landcover type (EVT_NAME) that shares the greatest perimeter.

    ArcGIS Shrink Tool using a 9x9 neighborhood.
    Using arcpy Python environment:

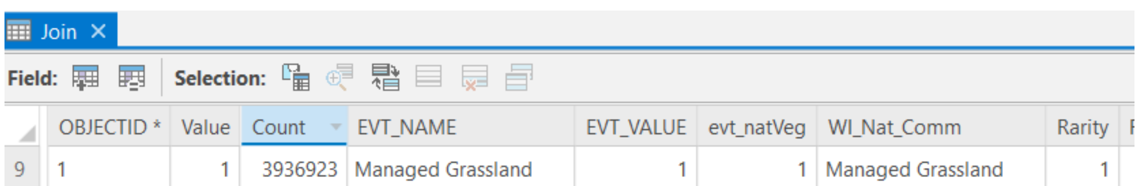
```python
import arcpy
from arcpy import env
from arcpy.sa import *


out_raster = arcpy.sa.Shrink("wi200evt", 9, [7195,7196,7197,7198,7199,7200,7191,7192,7193],
"MORPHOLOGICAL");
```

```
out_raster.save(r"C:\Users\Stacey Marion\Documents\ArcGIS\Projects\fna\fna.gdb\Shrink_wi200evt")
```

22. From “Eastern Cool Temperate Pasture and Hayland”, separate hay/fallow field from plausible managed grassland by: excluding areas not within the historic extent of prairie/savanna (orig_veg_cover_dissbyoakgrass.shp), and excluding areas classified as “Cultivated Crop” in either the National Land Cover Database (NLCD) imagery in 2013 or 2019. Rename the remaining area “Managed Grassland” and assign an EVT_VALUE of 1.

```
HistVeg = Raster('HistVeg_Raster')

EVT = Raster('Shrink_wi200evt')

nlcd = Raster('Extract_NLCD1')  # this is the name of the .tiff clipped to wi. Repeat for 2013, 2019

MaskHist = Con(((HistVeg==1) & (EVT==7977)), 1, EVT)  # EVT value 1 for “Managed Grassland”

MaskHist.save("MaskHist")

MaskNLCD = Con(((MaskHist==1) & (nlcd!=82)), 1, MaskHist) # value of 82 represents”Cultivated Crop”

MaskNLCD.save("MaskNLCD")
```

23. Manually assign EVT_NAME “Managed Grassland” to row where EVT_VALUE = 1



	OBJECTID *	Value	Count	EVT_NAME	EVT_VALUE	evt_natVeg	WI_Nat_Comm	Rarity
9	1	1	3936923	Managed Grassland	1	1	Managed Grassland	1

24. Join our raster output (i.e. manipulated raster) with crosswalk attribute table (csv)

```
#arcpy.management.JoinField(in_data, in_field, join_table, join_field, {fields})

inData = MaskNLCD

inField = "Value"

joinTable = "crosswalkJoinAug15.csv"

joinField = "EVT_VALUE"

Join = arcpy.JoinField_management(inData, inField, joinTable, joinField)

Join.save(‘wiModifiedEvt’) # saves raster to working environment (i.e. geodatabase)

# Load Join to map
```

25. Calculate area summaries using the modified landcover type dataset. Export Join (wiModifiedEvt.tif) attribute table as csv.

26. Calculate area summaries in R (evt_stats.R)

```
# EVT summaries
# Our analysis used EVT LANDFIRE 2016, version 2.0.0 (i.e. 200)

library(dplyr)
library(tidyverse)
library(readr)
library(ggplot2)

evt <- read_csv("d:\\wiModifiedEvt.csv") # csv is exported attribute table from the wisconsin EVT raster
layer

# Note:  these summaries reflect the "as model output" version of evt summaries prior to any crosswalk
modification
# therefore, any areas later parsed out from agriculture as managed grassland are still counted within
"Agricultural" in this summary

# create variable p as percent of total count, per row
evt$sum <- sum(evt$COUNT)
print(evt$sum)

evt <- within(evt, p <- as.numeric(COUNT/evt$sum*100))
head(evt)
head(evt$p)

# Primary summaries of interest are the most abundant evts and evt vegetation groups present on today's
landscape.
# In Wisconsin, for example, much of the landscape is represented by Developed, Agricultural, Ruderal, or
Exotic communities

# Summarize by most common evt's
evtClean <- evt %>%
  group_by(EVT_NAME) %>%
  summarise(area = sum(COUNT)*30*30, acres = sum(COUNT)*30*30/4046.86, perArea = sum(p),
EVT_PHYS) %>%   ## 30x30 M resolution. 1 acre = 4046.86 sqm Output = acres
  arrange(desc(area))
print(evtClean)

evt10 <- evtClean %>% slice (1:10)
print(evt10)

p <- ggplot(evt10) +  geom_bar(aes(x = reorder(EVT_NAME, perArea), y = perArea), stat = 'identity') +
scale_y_continuous(limits=c(0,20))
p + coord_flip()

# Summarize by evt vegetation groups (e.g. developed, agricultural, exotic, riparian, etc.)
```

```
evtGroup <- evt %>%
  select (everything()) %>%
  mutate(Group = case_when (
    EVT_PHYS == "Agricultural" ~ "Agricultural",
    EVT_PHYS == "Riparian" ~ "Riparian",
    EVT_PHYS == "Hardwood" ~ "Hardwood",
    EVT_PHYS == "Developed" ~ "Ruderal",  # see EVT descriptions.  "Developed" includes vegetated
communities with no historical reference, e.g. ruderal
    EVT_PHYS == "Conifer" ~ "Conifer",
    EVT_PHYS == "Conifer-Hardwood" ~ "Conifer-Hardwood",
    EVT_PHYS == "Open Water" ~ "Open Water",
    EVT_PHYS == "Developed-Roads" ~ "Developed",
    EVT_PHYS == "Exotic Herbaceous" ~ "Exotic",
    EVT_PHYS == "Developed-Low Intensity" ~ "Developed",
    EVT_PHYS == "Developed-Medium Intensity" ~ "Developed",
    EVT_PHYS == "Developed-High Intensity" ~ "Developed",
    EVT_PHYS == "Grassland" ~ "Grassland",
    EVT_PHYS == "Exotic Tree-Shrub" ~ "Exotic",
    EVT_PHYS == "Shrubland" ~ "Shrubland",
    EVT_PHYS == "Quarries-Strip Mines-Gravel Pits-Well and Wind Pads" ~ "Quarries-Strip Mines-Gravel
Pits-Well and Wind Pads",
    EVT_PHYS == "Sparsely Vegetated" ~ "Sparsely Vegetated"
    ))

evtGroup <- evtGroup %>%
  group_by(Group) %>%
  summarise(area = sum(COUNT)*30*30, acres = sum(COUNT)*30*30/4046.86, perArea = sum(p)) %>%   ##
30x30 M resolution. 1 acre = 4046.86 sqm Output = acres
  arrange(desc(area))
print(evtGroup)

evt10 <- evtGroup %>% slice (1:10)

p <- ggplot(evt10) +  geom_bar(aes(x = reorder(Group, perArea), y = perArea), stat = 'identity') +
scale_y_continuous(limits=c(0,35))
p + coord_flip()

# Export plot and edit in Adobe Illustrator
```

27. From the modified landcover type raster (wiModifiedEvt.tif), create a natural vegetation raster excluding open water, developed areas, mines, and agricultural types.

```
#use extract to create new raster

#ExtractByAttributes(in_raster, where_clause)

Natural = ExtractByAttributes(Join, '"evt_natVeg" >= 1')

Natural.save('Natural') # saves raster to working environment (i.e. geodatabase)
```

*Export attribute table as final joined natural vegetation layer with all attributes needed for further analysis

--- CALCULATE QUANTITATIVE SUMMARIES FOR FIRE NEEDS ---

28. Export raster attribute table as final joined natural vegetation layer with all attributes needed for further analysis.

29. Calculate fire regime summaries for natural vegetation landcover types (modified EVT_NAME) (final_stats.R)

```
# Fire regime summaries

library(dplyr)
library(tidyverse)
library(readr)
library(ggplot2)

final <- read_csv("d:\\wiModifiedEvt.csv") # final fire dependent vegetation areas  (joinAug10.csv = export
from raster.  new evt classification, joined with all evt, bps attributes + count data)

# create variable p as percent of total count, per row
final$sum <- sum(final$Count)
print(final$sum)

final <- within(final, p <- as.numeric(Count/final$sum*100))
head(final)
head(final$p)

# Calculate annual burning needs

# annualAll ~ based on mean FRI (FRI_ALLFIR), expected annual burning needs (units = acres)

finalFRI <- final %>%
  group_by(EVT_NAME) %>%
  summarise(WI_Nat_Comm, area = sum(Count)*30*30, acres = sum(Count)*30*30/4046.86, FRI_ALLFIR_1,
annualALL = (acres/FRI_ALLFIR_1), FRI_REPLAC_1, PRC_REPLAC_1, annualREPLAC =
(annualALL*PRC_REPLAC_1/100), FRI_MIXED_1, PRC_MIXED_1, annualMIXED =
(annualALL*PRC_MIXED_1/100), FRI_SURFAC_1, PRC_SURFAC_1, annualSURFAC =
(annualALL*PRC_SURFAC_1/100)) %>%
  arrange(desc(annualALL))
finalFRI <- finalFRI %>% mutate_if(is.numeric, list(~na_if(., Inf))) %>% replace(is.na(.), 0) # remove Inf (0/Value;
replace with 0)
finalFRI <- finalFRI %>% arrange(desc(annualALL)) # re-sort
print(finalFRI)


write_csv(finalFRI, "d:\\finalFRIAug15.csv")

final10 <- finalFRI %>% slice (1:10) %>%
  arrange(desc(annualALL))
```

```
p <- ggplot(final10) +  geom_bar(aes(x = reorder(EVT_NAME, annualALL), y = annualALL), stat = 'identity') +
scale_y_continuous(limits=c(0,250000))
p + coord_flip()
```

4- Create prioritization schema for prioritization of prescribed fire in Wisconsin

Further analysis will help prioritize where best to apply fire. Application of prescribed fire can be prioritized based on potential ecological benefit. On a landscape scale, we can consider ecological rarity as a metric of how endangered a community is. By identifying communities with high rarity and frequent fire return intervals, we can determine the communities that are most threatened by fire suppression.

After determining the highest priority areas for prescribed fire application for ecological benefit, we will incorporate the effort and feasibility of performing prescribed fire. Management effort captures resources needed to adequately manage frequently burned vegetation by considering the number of individual units (patches of fire-dependent vegetation) and the required number of fire applications. Feasibility of prescribed fire application considers proximity of fire-dependent patches to developed areas, assuming that patches closer to developed areas have a lower probability of successfully maintaining ecological value. By combining indices of maximum ecological benefit, management effort, and management feasibility, we will present a comprehensive prioritization scheme for prescribed burning application.

See 2014 Wisconsin Fire Needs Assessment (Hmielowski et al. 2016) for original protocol.