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August 31, 2015

Gabrielle Kenton and Nancy Lewis
Prescott National Forest
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Subject:
Final Report
FS Agreement Number: 14-CS-11030900-016
Title: Central Arizona Grasslands Conservation Strategy Area Decision Support Tool Development

Please find attached the final report for the Central Arizona Grasslands Conservation Strategy Area Decision Support Tool Development project (FS Agreement # 14-CS-11030900-016).

The Final Report presents final material developed as part of the Central Arizona Grasslands Conservation Strategy Area Decision Support Tool Development project. Delivery of final GIS data with appropriate metadata and documentation will be completed by September 30, 2015.

Sincerely,

Julie Mikolajczyk

Attachment:
Final Report Narrative

Cc: Richard Lawrence, Trevor Buhr, Kelly Wolff-Krauter, Michael Kellett, Paul Sitzmann

Central Arizona Grasslands Conservation Strategy Decision Support Tool Development

Final Report to Prescott National Forest by Arizona Game and Fish Department (Julie Mikolajczyk - Project Manager)

Reporting Period 4/30/2015 – 8/31/2015

Agreement # 14-CS-11030900-016

Executive Summary

The Prescott National Forest is working with stakeholders to identify, characterize, and describe current landscape conditions and values at risk in a way that is reflective of local conditions, resource needs, and resource threats. The plan is to incorporate stakeholders in Forest management decision making processes and prioritize areas on the forest for ecosystem restoration. The process includes:

- Working with partners to identify and prioritize landscapes on the National Forest and adjacent lands.
- Developing the resources, partnerships, and tools needed to suppo1t planning, implementing, and monitoring restoration work.
- Developing performance measures to demonstrate progress in meeting goals and objectives.

The Department and the Forest Service are willing to jointly support the process through investment in GIS and analysis support leading to the development of a criterion based decision support modeling system that performs spatial data analysis for both social and ecological conditions, highlighting opportunities and options for prioritization of land treatments. The Ecosystem Management Decision Support tool (EMDS) is an example of such a system that has been used in supporting landscape management activities ranging from wildland fire risk to wildlife habitat suitability. The two agencies along with other partners have formed an interagency and partner collaborative team to populate and inform a decision tool such as the EMDS.

Challenges in the planning process to be addressed by this cooperative relationship:

- Combined GIS data sources from both agencies
- Integrate social and economic information into a spatial format
- Sustained collaborative planning
- Joint GIS analysis and support of the decision support methodology

Expected outcomes of the tool development of benefit to both agencies:

- A structured decision support process that is portable, repeatable, and transparent
- A spatial product to assist both agencies and inform the prioritization process for areas within the Central Arizona Grasslands Conservation Strategy area boundary for restoration
- Provide a framework for similar projects to be developed for additional landscapes and/or habitats managed by both agencies and/or informing other similar processes

This final report builds on the first progress report for activities between August 19, 2014 and November 30, 2014, the second progress report for activities between December 1, 2014 and April 30, 2015, and summarizes work between May 1, 2015 and August 31, 2015. Work has included hiring a full-time contractor, holding many sessions with stakeholders and partners to provide information about the project and gather input on key factors, gathering spatial data, creating logic models for Tiers 1 and 2, and creating GIS outputs for Tier 1 and Tier 2. A modification to the original agreement was finalized on June 2nd extending this final report due date to August 31, 2015.

Work Completed Between 8/19/2014 and 8/31/2015

Additional Funding:

The Department has supplemented the funds received from the Prescott National Forest (PNF) for this project with funds from the Bureau of Land Management (BLM). Both agencies are signatory agencies on the Central Arizona Grasslands Conservation Strategy (CAGCS) and the development of a decision support tool to help prioritize where management actions should occur on the ground will be of benefit to both.

4/30/2015 Update:

The Department has exhausted the funding provide by the PNF and AGFD (CAGCS) for this project and is currently charging solely to the BLM funding code for contractor time. An invoice is forthcoming.

8/31/2015 Update:

No changes to the budget have occurred in this reporting period.

Staffing:

A team within the Department has been formed that will be the main group responsible for the work completed on this project. This AGFD EMDS team includes:

- Richard Lawrence (GIS Program Manager) provides technical, administrative, and development support to the project.
- Julie Mikolajczyk (Wildlife GIS Specialist) is the project manager, responsible for tasks such as administration of project agreements, funds, and resources, outlining/overseeing the completion of project requirements, communicating progress and project needs to relevant stakeholders and partners, and managing the project team.
- Austin Smith (GIS Specialist) has been contracted through Kelly Temp Services to fill the role of GIS technical lead on this project, responsible for documenting discussions on data needs/parameterization, gathering and manipulating data, creating and updating logic models, and running GIS analyses.

Collectively, the AGFD EMDS team holds regular progress meetings, communicates with relevant stakeholders through knowledge engineering and informational sessions, and completes various tasks leading to the creation of the decision support tool.

4/30/2015 Update:

No significant changes in staffing occurred during this reporting cycle. However, Austin has accepted another full-time role within the Department, and will be ending support on this CAGCS project on May 12. Julie will take over most of the duties for fulfilling the terms of this agreement, and may seek to hire additional staff to assist.

8/31/2015 Update:

As noted above, Austin has moved on to a new position within the GIS Program and is no longer supporting work on this project. In addition to the role of project manager, Julie has also taken on the role of GIS Specialist during this reporting period in order to finalize the deliverables outlined for this contract.

Project Management:
The AGFD EMDS team created a project scope of work, including a timeline for completion of tasks to meet deliverable requirements. An updated version of this timeline is available in Appendix 1 of this progress report.

4/30/2015 Update:
An updated version is included in Appendix 1 of this progress report, replacing the version from 11/30/2014.

8/31/2015 Update:
The project timeline has been removed from Appendix 1 of this report.

Project Kickoff Meetings:
These meetings were informational to ensure that all key players are aware of the project and potential avenues for collaboration in this process.

1	8/28/14	PNF (Gabrielle Kenton, Tom Potter), AGFD (Julie Mikolajczyk, Austin Smith, Richard Lawrence, Trevor Buhr-phone)
2	9/19/14	CAGCS Sponsor Committee (brief update by Richard Lawrence)
3	10/16/14	BLM (Paul Sitzmann, Casey Addy, Josh Tibbetts, Amanda James, Elise Athens), AGFD (Julie Mikolajczyk, Austin Smith, Richard Lawrence)
4	10/22/14	NRCS (Greg Anderson, Marques Munis, Samantha Lawien, Ken Gishi, Jim Harrigan, Jennifer Puttere), AGFD (Julie Mikolajczyk, Austin Smith, Richard Lawrence)
5	11/14/14	PNF Strategic Action Plan Steering Committee

4/30/2015 Update:
No additional project kickoff meetings were held during this reporting cycle.

8/31/2015 Update:
No additional project kickoff meetings were held during this reporting cycle.

Knowledge Engineering Sessions:
While becoming familiar with the software tools associated with the EMDS, the AGFD EMDS team began brainstorming various factors that might influence the prioritization of areas within the CAGCS boundary for restoration projects. Once a flowchart/logic model is populated with concepts, potential data sources, and parameters, more input is sought from groups of experts who can better inform these decisions. Through in-depth meetings where these factors are explored (called knowledge engineering sessions), decisions and points needing further discussion are identified. The sessions held to date are listed below.

1	9/25/14	PNF (Tom Potter), AGFD (Julie Mikolajczyk, Austin Smith, Richard Lawrence)
2	10/14/14	PNF (Tom Potter, Dave Moore), AGFD (Julie Mikolajczyk, Austin Smith, Richard Lawrence)
3	11/4/14	NRCS (Greg Anderson, Marques Munis, Samantha Lawien, Eric Wolfbrandt), PNF (Tom Potter), AGFD (Julie Mikolajczyk, Austin Smith)
4	11/19/14	NRCS (Marques Munis), AGFD (Austin Smith)

4/30/2015 Update:
Additional knowledge engineering sessions were held during this reporting cycle as shown below. Many internal meetings were held amongst just the AGFD EMDS team and are not listed here.

5	12/15/14	PNF (Tom Potter), AGFD (Julie Mikolajczyk, Austin Smith, Richard Lawrence)
6	3/1/14	AGFD EMDS team (Julie Mikolajczyk, Austin Smith), AGFD (Scott Sprague, Kelly Wolff-Krauter, Trevor Buhr, Wade Albrecht, Jesscia Gist), PNF (Gabrielle Kenton, Michael Kellett, Albert Sillas, Dan Garcia), BLM (Paul Sitzman), NRCS (Marques Munis)

8/31/2015 Update:
No additional knowledge engineering sessions were held during this reporting cycle.

<u>Project Update Meetings:</u>
There were also occasions where meetings were held to inform key partners of the status of the project.

1	10/23/14	PNF (Tom Potter, Gabrielle Kenton), AGFD (Julie Mikolajczyk, Austin Smith, Richard Lawrence)
2	10/27/14	AGFD (Julie Mikolajczyk, Austin Smith, Trevor Buhr, Kelly Wolff-Krauter)

4/30/2015 Update:
Additional project update meetings were held during this reporting cycle as shown below. Many internal meetings were held amongst just the AGFD EMDS team and are not listed here.

3	2/3/15	PNF (Tom Potter, Dave Moore, Michael Kellett, Gabrielle Kenton, AGFD EMDS Team (Julie Mikolajczyk, Austin Smith, Richard Lawrence)
4	2/17/15	CAGCS Implementation Team
5	4/2/15	PNF SAP Steering Committee

8/31/2015 Update:
Additional project update meetings were held during this reporting cycle as shown below.

6	5/7/15	CAGCS Implementation Team
7	8/13/15	CAGCS Sponsors

Data Discussion Meetings:

The AGFD GIS team also met with Department staff that collect and manage data relevant to this project, such as pronghorn telemetry data, to begin the process of discussing potential sources of data and issues associated with sharing these data.

4/30/2015 Update:

A few more of these meetings occurred during the reporting cycle. These resulted in access to pronghorn telemetry data for this analysis, survey point data from regional staff, and heritage data from the Heritage Data Management System. Additionally, a distribution model was created for the Western meadowlark as the result of one of these meetings.

8/31/2015 Update:

No additional data discussion meetings were held explicitly for this project during this reporting cycle.

Outputs of Project

Through the meetings described above, the main output to date is a draft logic model outlining Tier 1 of the analysis to be performed. This model is provided as Appendix 1.

From input gathered during the knowledge engineering and other stakeholder meetings, the AGFD EMDS team determined that it would make sense to look at the decision-making process in several distinct, but connected tiers or levels *(Figure 1)*. These tiers will not only allow a more manageable approach to the analysis, but will also make the data processing much more efficient since analyses won't be run on the entire study area at one time. For example, Tier 1 identifies the areas on the landscape that have the potential to be grassland based on factors such as soil suitability, slope, elevation, and other factors. Once the potential grassland areas are identified as the output to Tier 1, Tier 2 subsequently looks only at the areas that have a potential to be grassland and then evaluates them for how suitable they are to be managed as grassland. Tier 2 factors that have been brainstormed to date include factors such as absence of development and contribution to the ecology of the area (wildlife use, landscape connectivity, proximity to protected areas, availability of the water, and other factors). Currently, Tier 3 looks at the feasibility to manage these suitable lands (based on factors such as distance to roads, canopy cover, etc). Tier 4 might not be a "tier", but rather an area-by-area evaluation to determine the best treatment type based on a series of parameters that will best encompass management needs and perhaps unique characteristics of the areas.

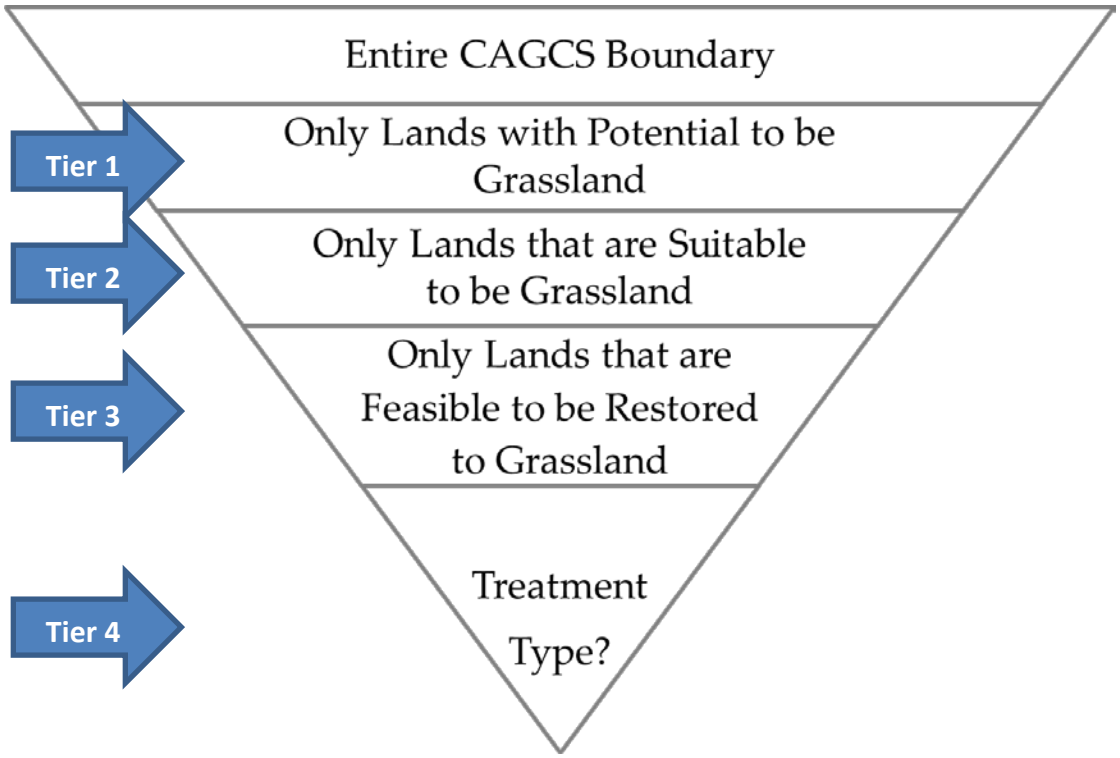


Figure 1: Diagram showing the various tiers of analysis.

The main output of Tier 1 to date is the knowledge model, or knowledge base (kb) that has been constructed using NetWeaver 2.0 Developer. The benefits of this tool have been the ability to diagram, document, and prioritize each tier and the contributing nodes and data links in a way that makes them reusable. The main drawback of NetWeaver 2.0 has been that the entire model cannot be depicted at once. Thus, we have turned to other tools to graphically represent each tier when we wish to see the entire structure of the model.

4/30/2015 Update:
Slight modifications to the statements above have been made. Most notably, it was thought that the modeling could be performed on subsets of the CAGCS boundary area when moving between the tiers. However, processing would not be significantly improved if this were to happen, and a threshold cutoff for inclusion as a potential grassland would have to be agreed upon before performing the Tier 2 analysis. For flexibility in modeling and in choosing different thresholds, Tier 2 and later models were run on the entire CAGCS boundary.

Additionally, as the AGFD EMDS team moved away from an analysis with EMDS to a more flexible approach using ArcGIS and ModelBuilder (see Project-Related Issues and Risk Analysis sections below), NetWeaver became less relevant. While the idea of capturing decision points in a logic model persist between the two methods, NetWeaver's limitations on graphical outputs and the redundant (and in some ways more explicit) capture of GIS analysis workflow steps within ModelBuilder have led the team to choose to move away from using NetWeaver for this process.

The Tier 1 logic model has been finalized and is shown in Appendix 1 (replacing the draft version presented in the first progress report). This logic model was simplified through the knowledge engineering and other meetings and has been translated into a GIS analysis output which can be seen in Appendix 4F. The AGFD EMDS team feels that the results of Tier 1 adequately captures areas of grassland potential, but recognizes that this model could be further improved with consistent soil data between Prescott National Forest and the NRCS's Ecological Site Descriptions. Appendix 4G shows buffered and dissolved pronghorn telemetry and survey data placed on top of the final Tier 1 analysis (note that this wildlife data is not available across the entire area, so it should only be used to visualize how well the model identifies grasslands where pronghorn have been observed). A brief description of the GIS analysis steps is presented in Appendix 3 and will be expanded if necessary for the final report and data handoff.

The Tier 2 logic model has also been drafted and is shown in Appendix 2. In the very near future, the AGFD EMDS team will work to finalize the Tier 2 logic model structure and analysis for application to the 2015/2016 disbursement of the Central Arizona Grasslands Conservation Strategy funds within the analysis area. The logic model began with several additional factors not presented here, including impacts to grasslands from grazing, climate change, and invasive species. However, this logic model was simplified when it was determined that the effects of these factors would more appropriately fall into Tier 3 (feasibility) or site-specific management decisions.

8/31/2015 Update:
The Tier 2 logic model has been finalized and is shown in Appendix 2 (replacing the draft version presented in the second progress report). Factors evaluated in Tier 2 include current development status, distance to protected lands, connectivity, and human modification. This logic model has been translated into a GIS analysis output which can be seen in Appendix 4L. The AGFD EMDS team feels that the results of Tier 2 adequately captures areas of grassland suitability, but recognizes that this model could be further improved with the incorporation of data from additional ground-truth activity. A brief description of the GIS analysis steps is presented in Appendix 3 and will be expanded if necessary for the data handoff (September 30, 2015).

Project-Related Issues

Shortly after the agreement with PNF was finalized, the Department was unable to approve a request to staff a position dedicated to the project. However, the AGFD team was able to hire Austin Smith as a contractor through Kelly Temp Services. While this was initially approved by the Prescott National Forest, modification to the original agreement was required given that funds were going to a subcontractor rather than being received by Department personnel. This modification was discussed, approved, and then signed into completion on 11/17/2014.

As the AGFD EMDS team has been working with the EMDS, data, and knowledge base, a number of processing and data issues have arisen. AGFD EMDS staff members currently are working with the University of Redlands' EMDS team to resolve these issues. Austin Smith has been in close contact with Steve Paplanus, the current developer associated with the EMDS project. Steve is working on updating

EMDS from version 4.0 to 5.0. This version is currently in pre-beta and Steve has been using CAGCS data and an early version of our logic model as a test dataset for use in the beta development process. The older versions were not capable of running at the scale and spatial complexity that we were attempting in our analysis and ended up crashing the program.

As mentioned, limitations of the graphical interface of NetWeaver 2.0 have been problematic as well. However, we have been able to work around this limitation by using other tools that allow us to draw an entire knowledge base's logical structure. This has required us to keep two versions of the logical structure, however, and the diagram software does not allow for links to datasets like NetWeaver.

4/30/2015 Update:
Due to the timing of this agreement, at the end of December 2014, the AGFD EMDS team evaluated alternative ways to complete the analysis. The first method was a raster-based analysis using ModelBuilder and built-in raster-based fuzzy logic analysis tools. The benefit of this method is that processing can be relatively fast, but raster analysis results in a loss of transparency between subsequent analysis steps since raster attributes are limited. A second method was developed by the Conservation Biology Institute (CBI) called Environmental Evaluation Modeling Systems (EEMS). EEMS is designed to work with vector data and is available by request from CBI as an ArcGIS toolbox with custom scripts. This is a useful method, but the data had to be pre-processed outside of the EEMS environment, resulting in some "hidden" steps that render the process limited in repeatability, a key requirement for this analysis. With these pros and cons in mind, the AGFD EMDS team moved forward with performing a raster analysis but also created a transparent vector-based analysis using ArcGIS and ModelBuilder (loosely based on the EEMS scripts) so that they two methods and outputs could be compared.

The AGFD EMDS team and PNF discussed the issue of a lack of a functional EMDS product at the progress update meeting on February 2nd and it was mutually agreed that the AGFD team would not wait for EMDS to become available. After discussing some of the pros and cons of the raster-based analysis versus the vector-based analysis, it was jointly decided that the transparency in feature attributes would be extremely valuable and the AGFD EMDS team left with the decision to perform the analysis using a tessellation of hexagons summarizing underlying datasets based on the logic designs.

[As of April 15th, 2015 EMDS version 5 is still in beta testing. Steve Paplanus has been stabilizing version 5 to correct bugs in the application and update code as necessary.]

8/31/2015 Update:
There were no significant project-related issues during this reporting period besides the aforementioned transition of our dedicated GIS Specialist from this project. A full release of EMDS 5 is now available.

Risk Analysis

The biggest risk we are facing for this project is related to the EMDS usability issues described above. If we do not have a functioning version of EMDS in hand before middle to late December, the AGFD EMDS team will need to explore other options such as EEMS and ArcGIS model builder as a means to

produce the spatial data outputs. The power of having documented knowledge bases cannot be understated. The logic and documentation evident in these models provide enough information for a knowledgeable GIS analyst to be able to construct the exercise "long-hand" using ArcGIS and ArcGIS Model Builder.

4/30/2015 Update:
With the decision to move forward with a customized ArcGIS ModelBuilder analysis, the previously identified risk was addressed. However, customizing an analysis adds a significant amount of trial and error to the process (evaluating results every step along the way, determining the appropriate scale of analysis, etc.) in addition to creating the logic model itself. These factors, along with the previously identified staffing changes, could result in a delay in outputs, though the AGFD team will do everything possible to make sure the project stays on schedule.

8/31/2015 Update:
No further risks have been identified for completing the work as outlined in the Challenge Cost Share Agreement between AGFD and PNF. However, several recommendations for future work have been presented in the Future Work section below.

Future Work

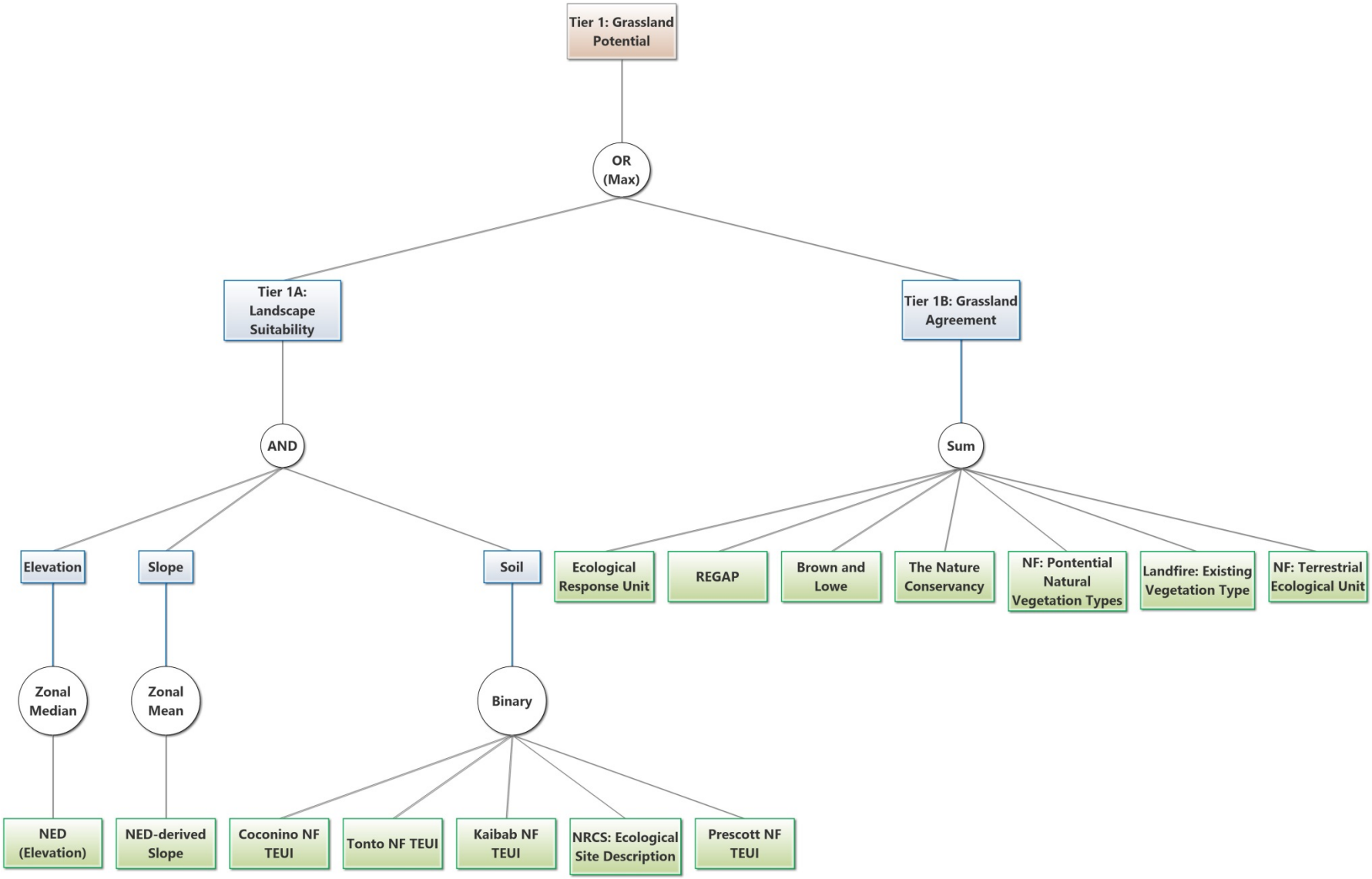
Prior to March 30, the AGFD EMDS team will attempt to run the Tier 1 model in EMDS (given EMDS issue resolution by end of December). Several more knowledge engineering sessions will be held to further refine and finalize the logic models for Tiers 2 and 3. A summary of the work to be completed, along with specific milestones, has been presented in Appendix 1 (Project Timeline).

4/30/2015 Update:
Prior to June 30, the AGFD EMDS team will have Tiers 1 and 2 output as final GIS datasets, and a final logic model for Tiers 3 (and 4 if necessary) will be completed. If at all possible, Tier 3 will be run via GIS as well. The final progress report on June 30th will have content similar to this report, and a final set of model and dataset documentation will be provided prior to the conclusion of the Agreement on September 30, 2015.

8/31/2015 Update:
No additional funding has been identified for any further work under this Challenge Cost Share Agreement between Arizona Game and Fish Department and Prescott National Forest. However, in order to see this project to a stage where it can fully utilized by the Central Arizona Grasslands Conservation Strategy Implementation Team, additional funding from CAGCS has been allocated to continue this work. Identified deliverables for this next fiscal year will be a complete development of the logic models and GIS outputs for Tiers 3 and 4. Additionally, a map viewer will also be created to allow for visualization of the various inputs and outputs in an online environment outside of ArcGIS Desktop. To complete these tasks, stakeholder brainstorming sessions and knowledge engineering sessions will be held to flesh out the logic and variables for Tiers 3 and 4. Continued participation and contribution by PNF staff is a highly valued resource that will ensure that PNF input, guidance, and priorities are included in these tiers.

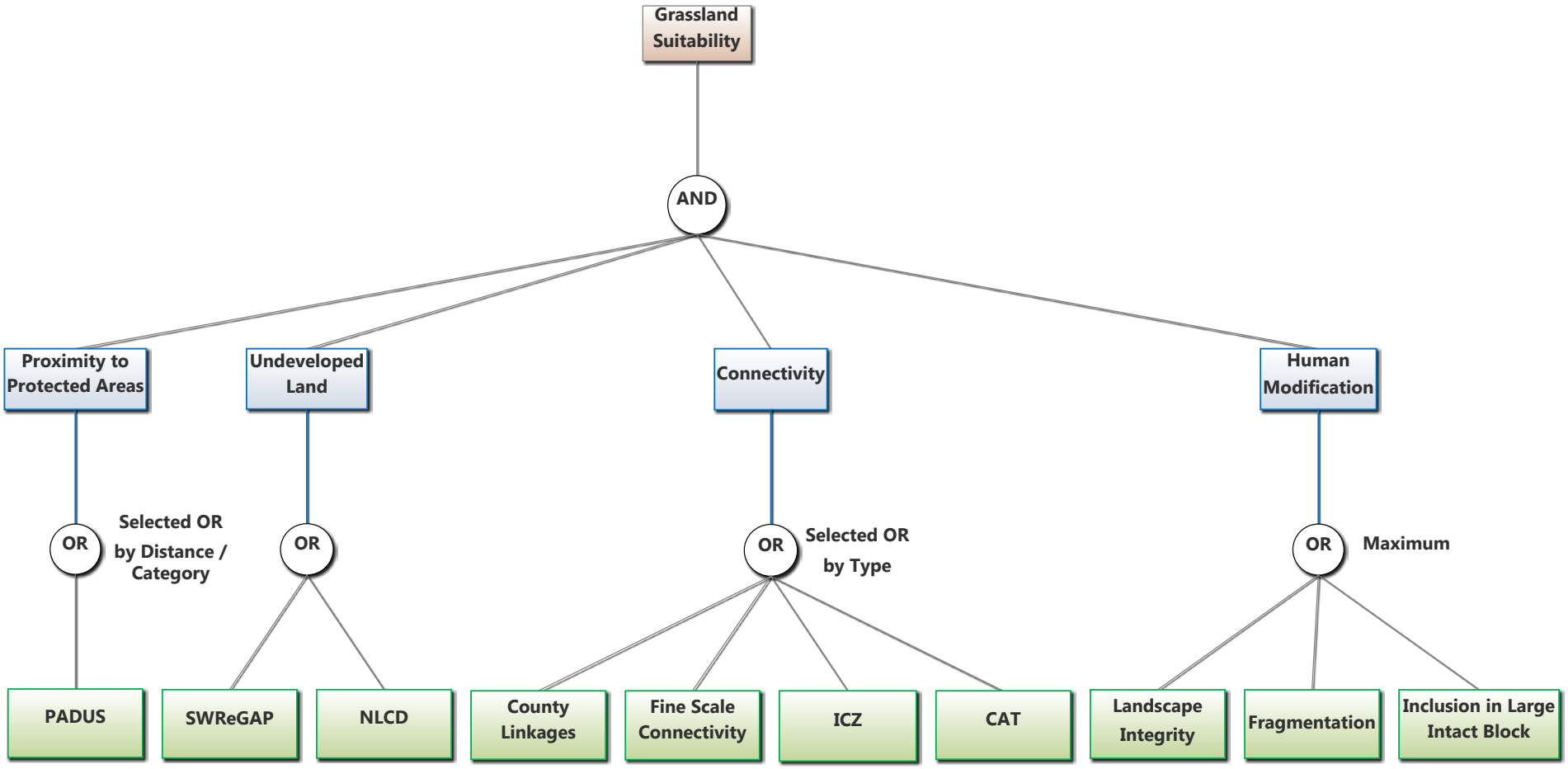
Appendix 1: Final Logic Model, Tier 1

Question: How much potential does the landscape have for supporting grassland vegetation?



Appendix 2: Final Logic Model, Tier 2

Question: How suitable is this area for grassland vegetation? (NOTE: A full documentation including data source and formulae used will be provided with the final data delivery).



Appendix 3: Tiers 1 and 2 Analysis Criteria and Methodology

This section includes a preliminary documentation of the Tiers 1 and 2 analyses. A more detailed and final version of this documentation will be available in later progress reports.

Tier 1: Grassland Potential

Within the Central Arizona Grasslands Conservation Strategy (CAGCS) boundary, Tier 1 determines the potential for the landscape to support grassland vegetation. A value of 1 in this analysis means "highest potential" and a value of 0 means "lowest potential". Various factors were considered and evaluated, then re-scaled to 0 to 1 value according to additional criteria and thresholds. The Tier 1 analysis considered four variables: elevation, slope, soil, and grassland agreement.

Tier 1A: Soil

The soil analysis is based on soil data characteristics from the Forest Service and National Resources Conservation Service (NRCS). The original CAGCS boundary included only the Prescott and Tonto National Forests, but our analysis included a 1 mile buffer to ensure that summarizations were accurate at the edges of the study area. Adding this buffer resulted in needing data from the Kaibab and Coconino National Forests as well. Independent consultation with Andy Casillas (USFS Region 3 Supervisory Soil Scientist), Tom Potter (PNF GIS Analyst), and Dave Moore (PNF Soil Scientist) has led the team to conclude that the Terrestrial Ecological Unit Inventory (TEUI) data is the optimal chose for soil data on USFS lands. The TEUI data field used was "System Type" which lists the vegetation classification for each map unit. Marques Munis (NRCS) provided similar guidance for the SSURGO Ecological Site Descriptions (ESD) dataset. If a map unit was considered to be suitable for grassland to grow based on these soil data, it was given a score of 1. All other map units in the study area were given a score of 0.

Tier 1A: Elevation

Elevation was obtained from 10 meter National Elevation Dataset (NED), published through 2013, and downloaded 2014. Elevation is a key factor in determining whether an area will have the potential to support grassland, so classes were created and assigned a range of values from 0 to 1 as indicated below (determined through literature review and expert consultation).

Elevation Class	Minimum possible score	Maximum possible score
3000 feet – 6500 feet	1	1
< 3000 feet	0	1
> 6500 feet	0	1

Tier 1A: Slope

A slope layer was derived from 10 meter National Elevation Dataset (NED), published through 2013, and downloaded 2014. Slope is also a key factor in determining whether an area will have the potential to support grassland, so classes were created and assigned a range of values from 0 to 1 as indicated below.

Slope Class	Minimum possible score	Maximum possible score
0% - 3%	1	1
3% - 15%	0.75	0.95
15% - 50%	0.5	0.75
50% - 100%	0	0.5
100% - Maximum%	0	0

<u>Tier 1A - Soil & Elevation & Slope</u>

To combine these three datasets, a fuzzy logic combinatorial function of Fuzzy AND was applied. This formula took the scores between 0 and 1 of the three factors as follows:

*Minimum + [(Mean – Minimum) * (Minimum +1)] / 2*

Once the Fuzzy AND was created for the soil, elevation, and slope factors, an additional factor was brought in to help mitigate for some of the potential uncertainty with the previous three factors (in particular soil since we used a proxy rather than true soil characterization with criteria such as depth, moisture, composition, etc.).

Tier 1B - Grassland Agreement

Many datasets already exist that indicate where grasslands occur within our CAGCS boundary. Within these datasets, a value of 1 was assigned to any category indicating grassland. All of scores were added together, resulting in a maximum score of 5 (meaning that all datasets agree that this area is grassland) and a minimum score of 0 (meaning that none of these datasets characterize this area as grassland), though only the areas where 3 or more datasets agreed were assigned a score. These scores were rescaled from 0 to 1 and this score is referred to as "grassland agreement".

- Southwest Regional Gap Analysis Project (ReGAP)
- Landfire 2010 Existing Vegetation Type (EVT)
- PNF (by NRCS) Ecological Response Units (ERU)
- The Natural Conservancy (TNC) grasslands
- Brown and Lowe (BL)

Tier 1 - (Tier 1A: Soil & Elevation & Slope) & (Tier 1B - Grassland Agreement)

To combine Tiers 1A and 1B, a fuzzy logic combinatorial function of Fuzzy OR was applied. This formula simply takes the maximum value between the columns. In this case, since the Tier 1A data already combined the first three factors, the Tier 1A field was compared to the grassland agreement field and the maximum of these two fields is assigned to the Tier 1 field.

Tier 2: Grassland Suitability

Within the Central Arizona Grasslands Conservation Strategy (CAGCS) boundary, Tier 2 determines the suitability of the landscape to support grassland vegetation restoration treatments. A value of 1 in this analysis means "highest suitability" and a value of 0 means "lowest suitability". Various factors were analyzed and rescaled from 0 to 1 according to the criteria described below. The Tier 2 analysis considered four variables: current development, distance to protected lands, connectivity, and human modification.

Tier 2: Distance to Protected Areas

The Protected Areas Database of the United States (PADUS) is arguably the most comprehensive dataset representing protection status of lands in the United States. This dataset is managed by the USGS National Gap Analysis Program and while there was a version that was managed by the Conservation Biology Institute, the USGS version is considered to be the official version and was used for this analysis.

Per the PADUS metadata, the GAP Status Code is the identifies categories of protected status:

> *The GAP Status Code is a measure of management intent to conserve biodiversity defined as: Status 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management. Status 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance. Status 3: An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging, OHV recreation) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area. Status 4: There are no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout or management intent is unknown. See the PADUS Standards Manual for a summary of methods.*

GAP Status Code 1 and 2 were combined into a single dataset. GAP Status Code 3 was treated separately. GAP Status Code 4 was not considered a protected area for this analysis. These 2 datasets were each buffered to 1.5, 3, and 5 miles and the final scores were assigned as shown in the table below.

GAP Status Code	Buffer Distance	Final score
1 and 2	0 miles (within)	1.00
	1.5 miles	0.95
	3 miles	0.90
	5 miles	0.85
3	0 miles (within)	0.95
	1.5 miles	0.90
	3 miles	0.85
	5 miles	0.80
Everything else	Outside of these buffers	0.75

Assigning a value of 0.75 to all hexagons outside of all protected areas results in a boost to hexagons in or near a protected area, but does not lead to a penalty for hexagons falling outside of these areas when final scores are calculated.

Tier 2: Undeveloped Land

Undeveloped lands were classified from the most recent NLCD (National land cover dataset) and ReGAP (Regional Gap Analysis Project) vegetation/land cover datasets. The data were reclassified as shown in the tables below. Given that the Landfire dataset is derived in part from both the ReGAP landcover dataset and NLCD, Landfire was not included separately.

<u>NLCD:</u>

Old Value/Category	New Value
0 / Unclassified	0.00
11 / Open Water	0.25
21 / Developed, Open Space	0.10
22 / Developed, Low Intensity	0.00
23 / Developed, Medium Intensity	0.00
24 / Developed, High Intensity	0.00
31 / Barren Land	0.10
81 / Hay/Pasture	0.25
82 / Cultivated Crops	0.25
Everything Else	1.00

ReGAP Land Cover:

Old Value/Category	New Value
110 / Open Water	0.25
111 / Developed, Open Space – Low Intensity	0.10
112 / Developed, Medium – High Intensity	0.00
113 / Barren Lands, Non-specific	0.10
114 / Agriculture	0.25
117 / Recently Mined or Quarried	0.10
Everything Else	1.00

Tier 2: Connectivity

Several connectivity datasets have been created by the Arizona Game and Fish Department. These include the 2006 Arizona's Wildlife Linkages Assessment, Arizona Missing Linkages modeled linkage designs, County-wide stakeholder linkages for several counties in Arizona, and a statewide dataset created in 2012 using the Connectivity Analysis Toolkit, from which Important Connectivity Zones were derived.

The 2006 Linkages (more information available at http://www.azdot.gov/business/environmental-planning/programs/wildlife-linkages) was a statewide assessment created with stakeholder input and identified mostly potential linkage zones. Within the CAGCS area, these zones focused around barriers where opportunities for restoring connectivity occur, and as such, were not included in this analysis.

There are several Arizona Missing Linkage datasets in the CAGCS study area. These are the Hualapai-Peacock Linkage (http://corridordesign.org/dl/linkages/reports/Hualapai-Peacock-Kingman_LinkageDesign.pdf), the Granite Mountains-Black Hills Linkage (http://corridordesign.org/dl/linkages/reports/Granite_Mountain-Black_Hills_LinkageDesign.pdf), and the Black Hills-Munds Mountain Linkage (http://corridordesign.org/dl/linkages/reports/BlackHills-Munds-VerdeRiver_LinkageDesign.pdf). More information on these linkages can be found within the reports referenced above.

The county-wide stakeholder linkages were another stakeholder-input process that captured not just barriers to wildlife movement, but known movement areas as well. The county reports represented in the CAGCS study area are the Coconino County Wildlife Connectivity Assessment (http://www.azgfd.gov/w_c/documents/CoconinoCountyLinkageReportFINAL4Mar2011.pdf), the Maricopa County Wildlife Connectivity Assessment

(http://www.azgfd.gov/w_c/documents/FinalMaricopaLinkagesReport_2012.pdf), and the Yavapai County Wildlife Connectivity Assessment (http://www.azgfd.gov/w_c/documents/YavapaiCoWildlifeConnectivityAssessment_FINAL.pdf). It is possible that some linkages would be identified from a Mohave County Wildlife Connectivity Assessment, but no workshops were completed for that county, nor are there any current plans to hold a workshop for that County. Only movement areas were included in this analysis—barriers to wildlife movement were excluded.

Finally, a statewide connectivity assessment was created in 2012 through a partnership between AGFD and University of Arizona (Arizona Landscape Integrity and Wildlife Connectivity Assessment; additional report available on request from Julie Mikolajczyk). This analysis produced a landscape integrity data layer (used in the human modification dataset described below) and a statewide output of connectivity potential across the state based on a cost surface of human modification on the landscape. This statewide output (termed CAT for the Connectivity Analysis Toolkit software used to perform the analysis) was used in our analysis. The CAT layer has scores orders of magnitude lower than other data in our analysis. For example, the range of CAT scores in the CAGCS boundary ranged from a minimum of 0.000024 to a maximum of 0.007559. To make the scores more comparable to other datasets, linear transformations were applied according to the chart below.

Original CAT Score	New minimum value	New maximum value
0.040679 – 0.007559	0.75	1.00
0.000024 – 0.007499	0	0.75

As part of the statewide connectivity project, this CAT layer was also summarized into Important Connectivity Zones (ICZs) which were the top 5% of CAT values in the state, buffered to include one hexagon on either side. Since the analysis process included a network-based, least cost approach, many of these ICZs are linear in nature.

These datasets collectively make up the connectivity portion of Tier 2 as categorized below:

Linkage Type	Value
Within Arizona Missing Linkage	1.00
Within ICZ	1.00
Within County Linkage	0.90
CAT score	CAT score

Tier 2: Human Modification

In order to identify areas that have been modified by humans, three datasets were combined together. These included the Landscape Integrity dataset briefly mentioned above, a large intact blocks dataset, and several fragmentation metrics.

Through a partnership between AGFD and University of Arizona (Arizona Landscape Integrity and Wildlife Connectivity Assessment), a statewide raster layer depicting many factors representing a modification to the landscape by humans was created. Factors representing 18 different categories of modification were spatially represented and summarized to show human modification, and inversely landscape integrity, in Arizona. This landscape integrity dataset was used in the current analysis and had values within the study area of 20 (most degraded) to 100 (most intact). A linear transformation was performed so that the minimum value of 20 was given a score of 0 and the maximum value of 100 was given a score of 1.

Derived from the landscape integrity dataset was a series of Large Intact Blocks or LIBs. These intact blocks of land are contiguous areas of at least 5,000 hectares with minimal human modification. They have been grouped into two categories: 1 – landscape integrity score = 100; 2 – landscape integrity score > 97. A binary classification assigning a score of 1 to hexagons that fell within a category 1 LIB and assigning a score of 0.9 to hexagons in the category 2 LIB.

The last set of data used for this category represents fragmentation. Fragmentation is challenging to model, because it has connotations specific to an individual animal, species, or taxa. However for the purposes of this analysis, fragmentation is measured by looking at spatial patterns in the landscape according to human modification and landscape integrity, thus having the assumption that a more intact landscape without regard to vegetation assemblage is more beneficial than having a landscape that has human structures limiting vagility by various wildlife species. Fragmentation can be represented by measuring the size, shape, and configuration of blocks of land. A group of 10 different metrics were evaluated, but 3 were chosen to best represent fragmentation for this analysis: core area index (CAI), circle, and effective mesh size (MEFF). A brief description of these metrics is in the table below and additional information on the analyses to create these metrics is available upon request to Julie Mikolajczyk. Factors were rescaled from 0 to 1 to match the other factors in this analysis.

Metric Name	Factor Represented	Description
Core Area Index (CAI)	Shape, Configuration	CAI measures the percentage of each patch that is classified as core area. This is a meaningful statistic given the independence from area and perimeter calculations. It essentially brings out the effect of patch and core area shape and configuration.
Effective Mesh Size (MEFF)	Size	MEFF can be interpreted as an expression of the probability that any two random points within a reporting unit are connected and the area they occur within can be crossed without encountering a physical barrier to movement. It can also be explained as an area-weighted mean patch size and can characterize the subdivision of the landscape independently of its size.
Related Circumscribing Circle (CIRCLE)	Shape	CIRCLE measures the elongation of a patch by calculating the ratio of patch area to the area of the smallest circle that can fit inside the patch. A narrow and elongated patch will have a relatively high CIRCLE value. Values close to 0 indicate a shape close to a circle, while a value approaching 1 indicates an elongated, linear patch.

Tier 2: Grassland Suitability (Distance to Protected Areas & Current Development & Connectivity & Human Modification)

To combine these four datasets, a fuzzy logic combinatorial function of Fuzzy AND was applied. This formula took the scores between 0 and 1 of the three factors as follows:

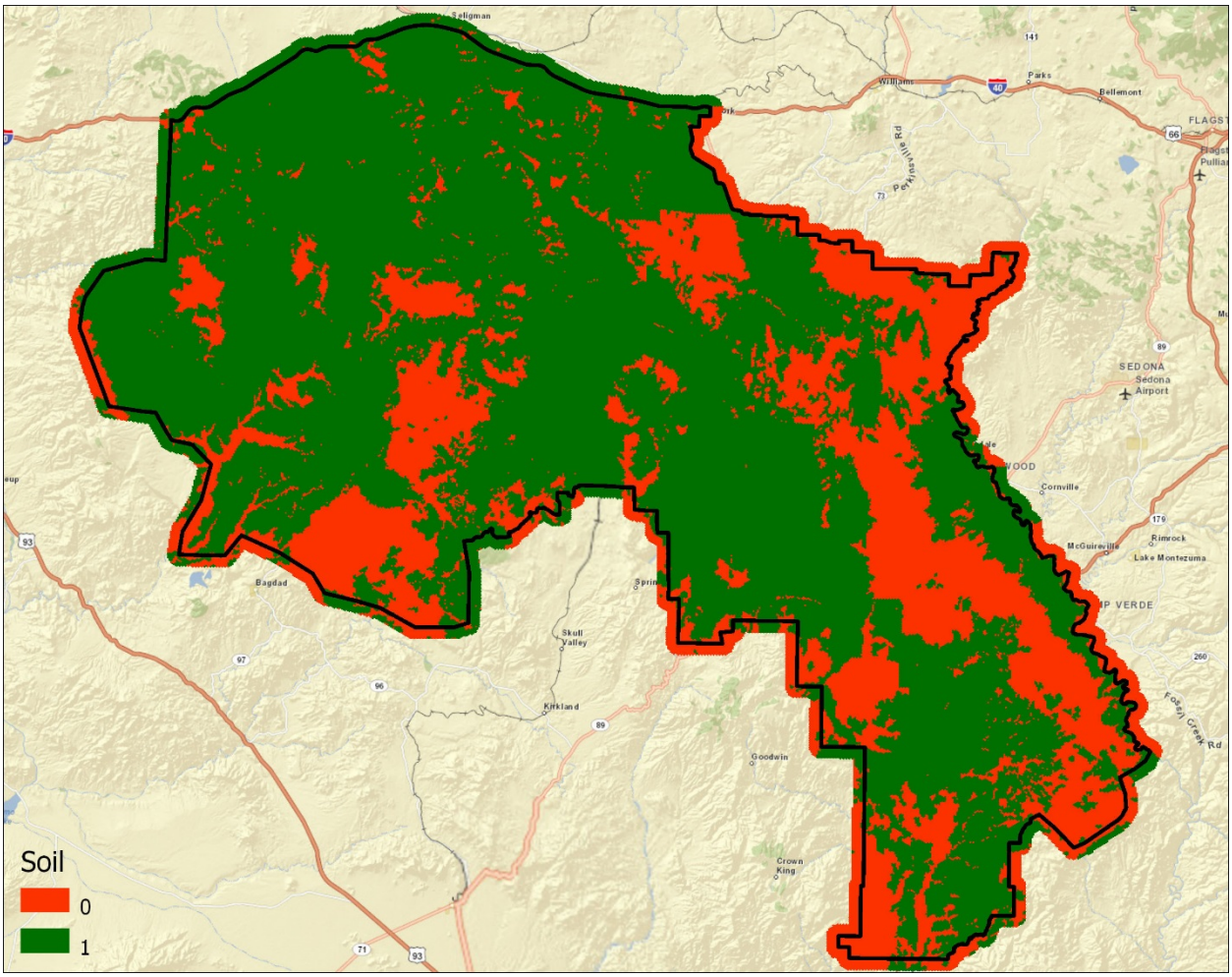
*Minimum + [(Mean – Minimum) * (Minimum +1)] / 2*

Tiers 1 and 2: Grassland Potential & Grassland Suitability

The last step for this phase of the analysis was to combine the two tiers of analysis together. This was done using the same combinatorial function of Fuzzy AND referenced above, but using just the Tier 1 and Tier 2 output values. The results of this output can be seen in Appendix 4M and 4N.

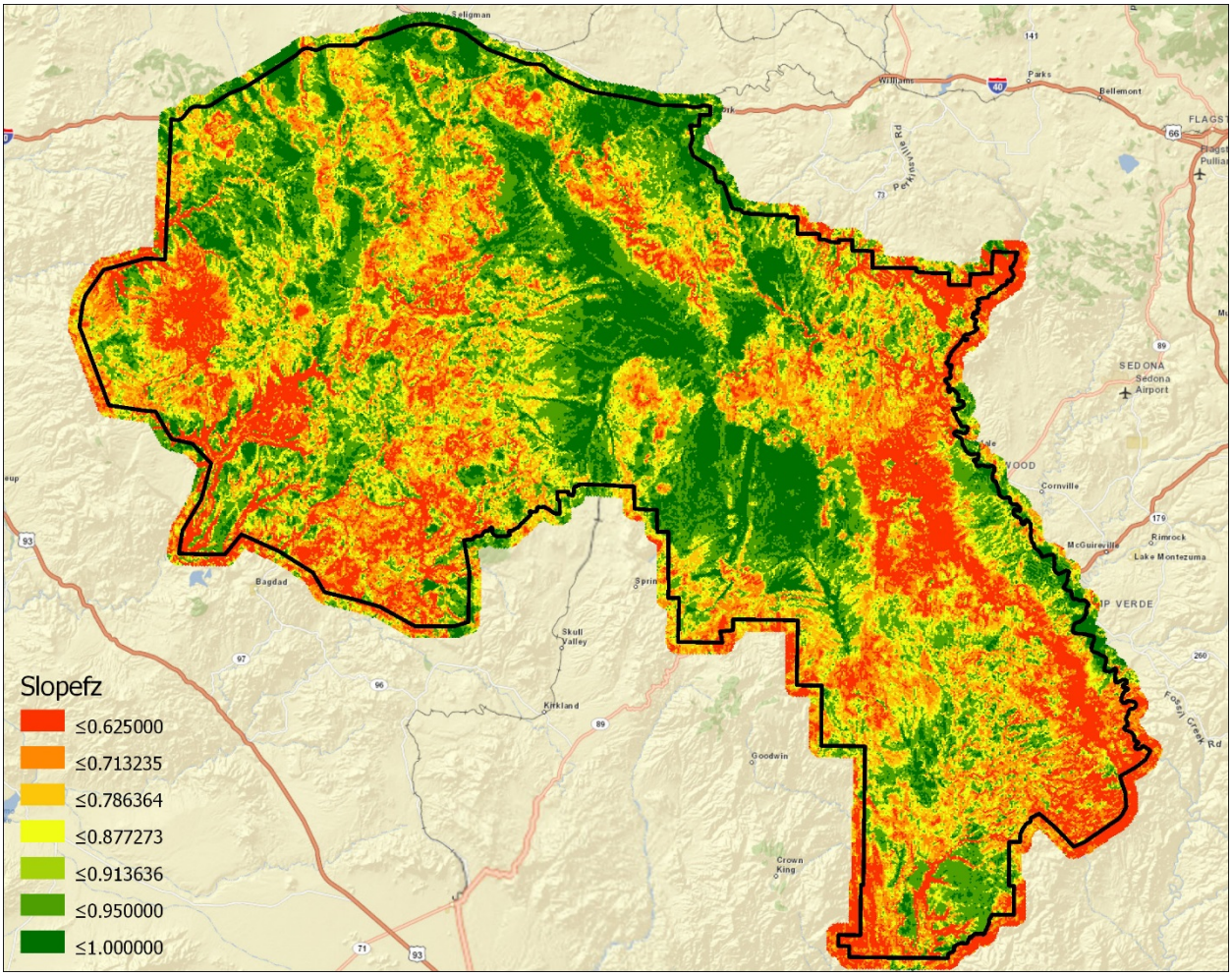
Appendix 4: Maps

A: Map of Tier 1 (Soil)



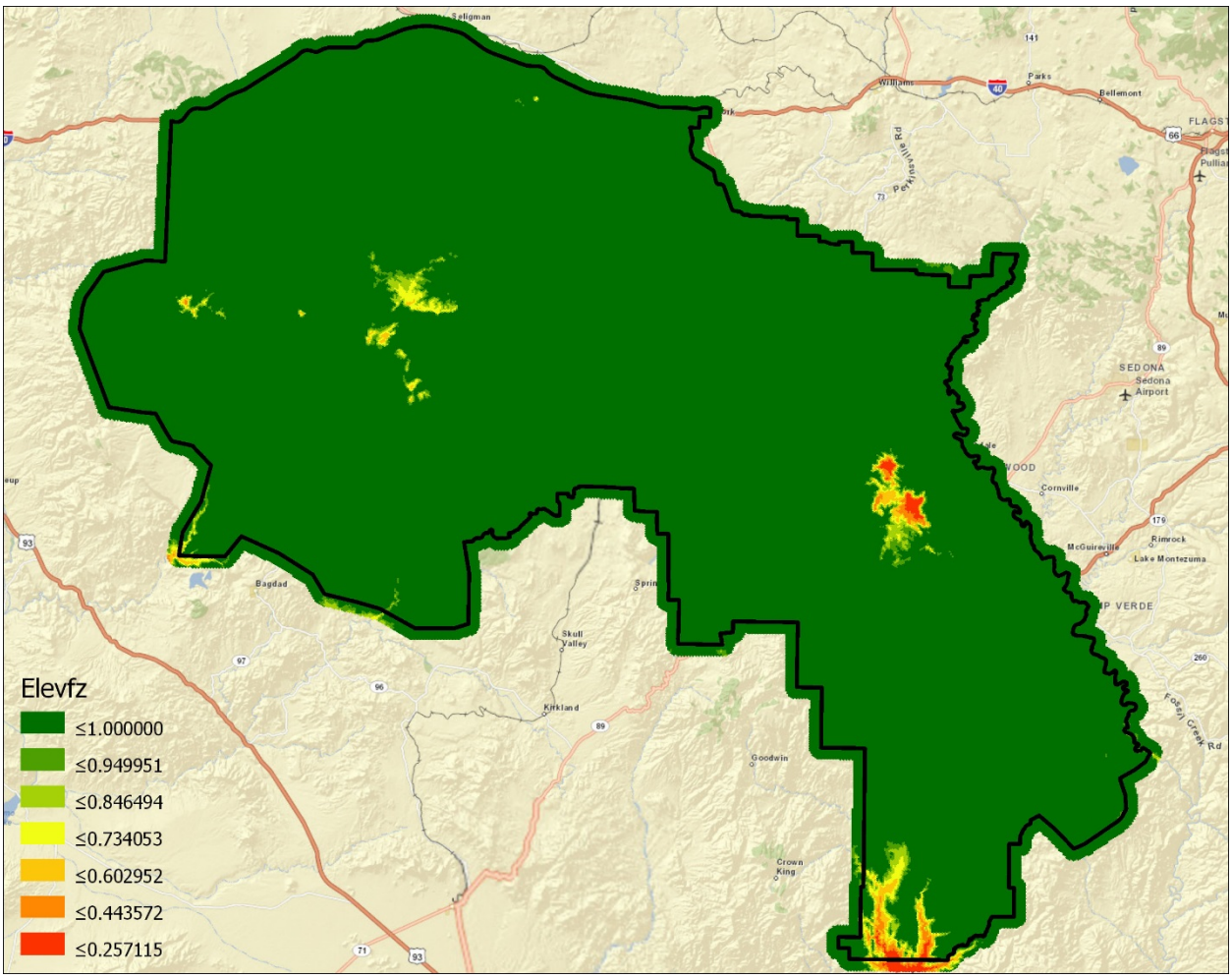
Appendix 4A: Map showing Tier 1 grassland potential factor soil. A value of 0 indicates an area where the soil is not suitable for grassland vegetation, while a value of 1 indicates an area where the soil is suitable for grassland vegetation.

B: Map of Tier 1 (Slope)



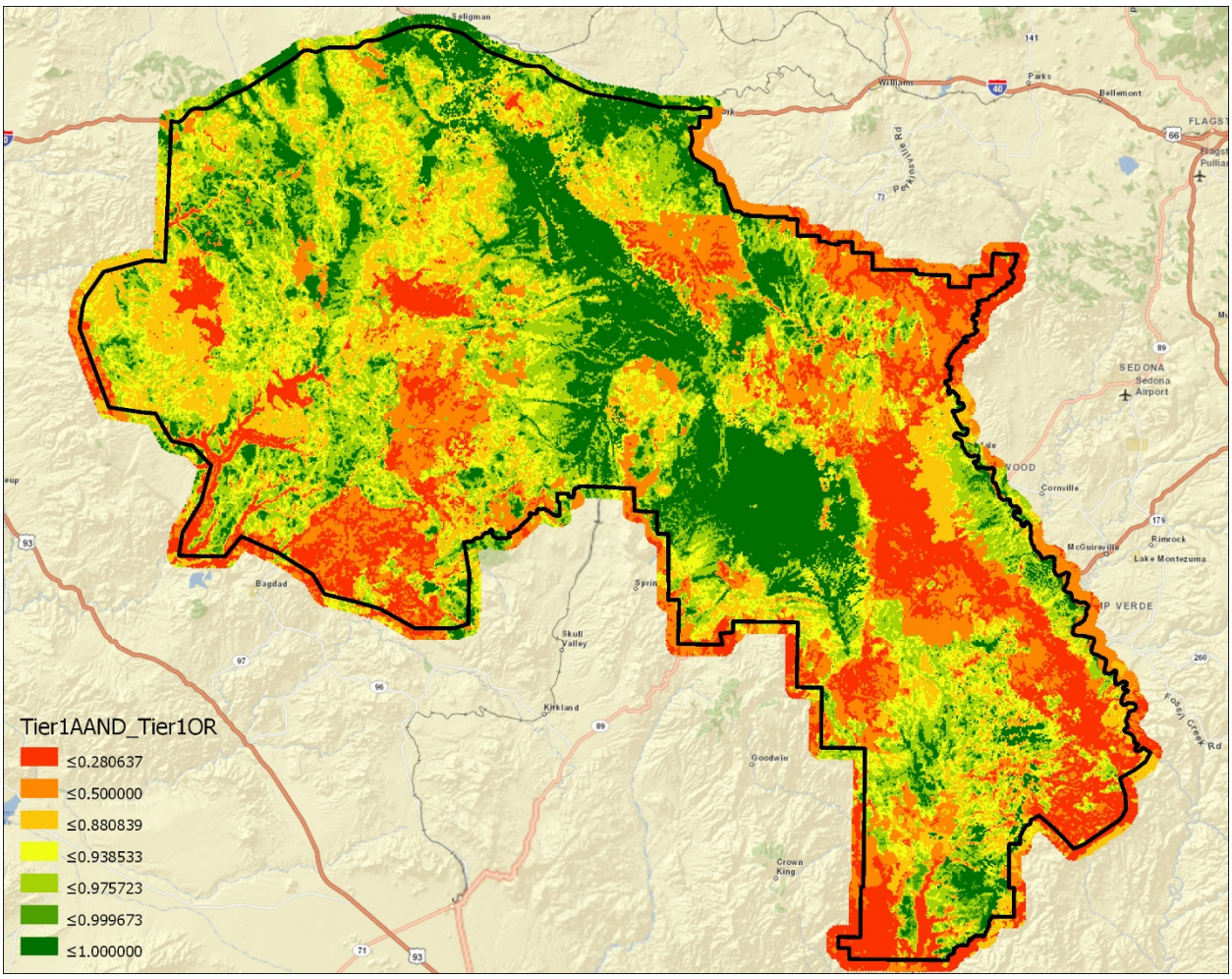
Appendix 4B: Map showing Tier 1 grassland potential factor slope. A value of 0 indicates an area where the slope is not as suitable for grassland vegetation, while a value of 1 indicates an area where the slope is more suitable for grassland vegetation. Data are shown using a quantile classification scheme with 7 bins.

C: Map of Tier 1 (Elevation)



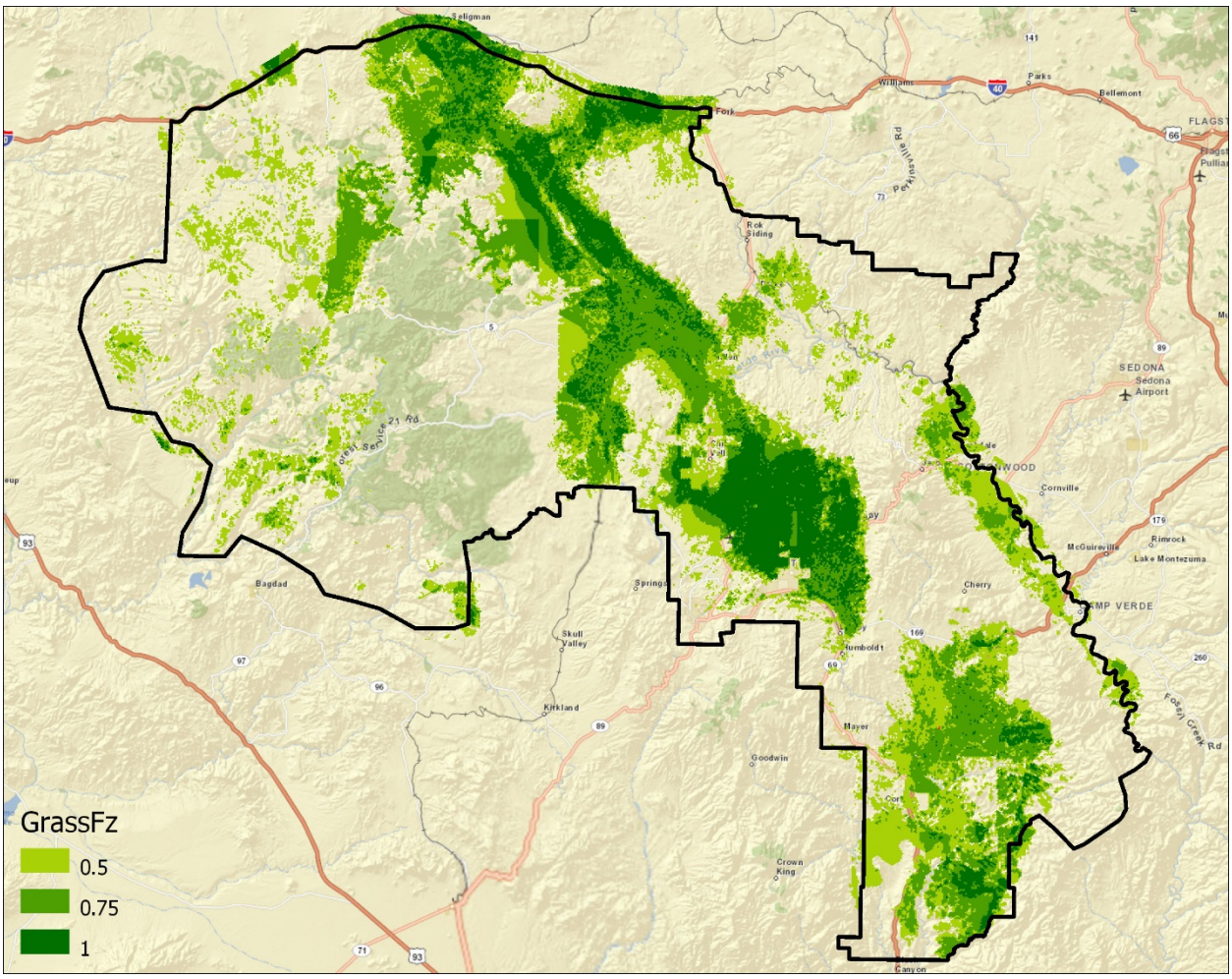
Appendix 4C: Map showing Tier 1 grassland potential factor elevation. A value of 0 indicates an area where the elevation is not as suitable for grassland vegetation, while a value of 1 indicates an area where the elevation is more suitable for grassland vegetation. Data are shown using a natural breaks classification scheme with 7 bins.

D: Map of Tier 1 A (Soil & Slope & Elevation)



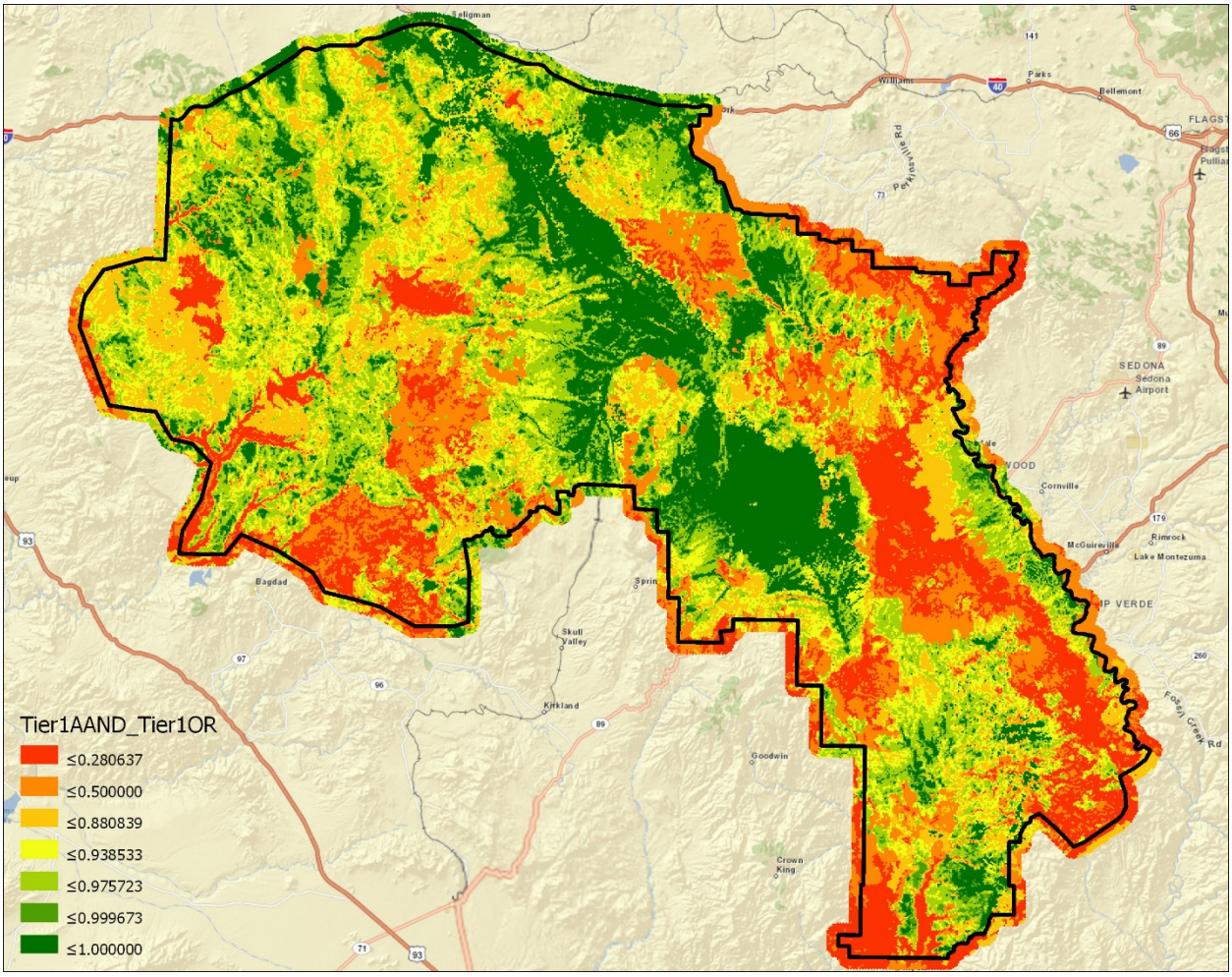
Appendix 4D: Map showing Tier 1 grassland potential combining the factors soil, slope, and elevation. A value of 0 indicates an area where these factors together indicate that an area does not have as much potential for grassland vegetation, while a value of 1 indicates an area that has significant potential for grassland vegetation. Data are shown using a quantile classification scheme with 7 bins.

E: Map of Tier 1 (Grassland Agreement)



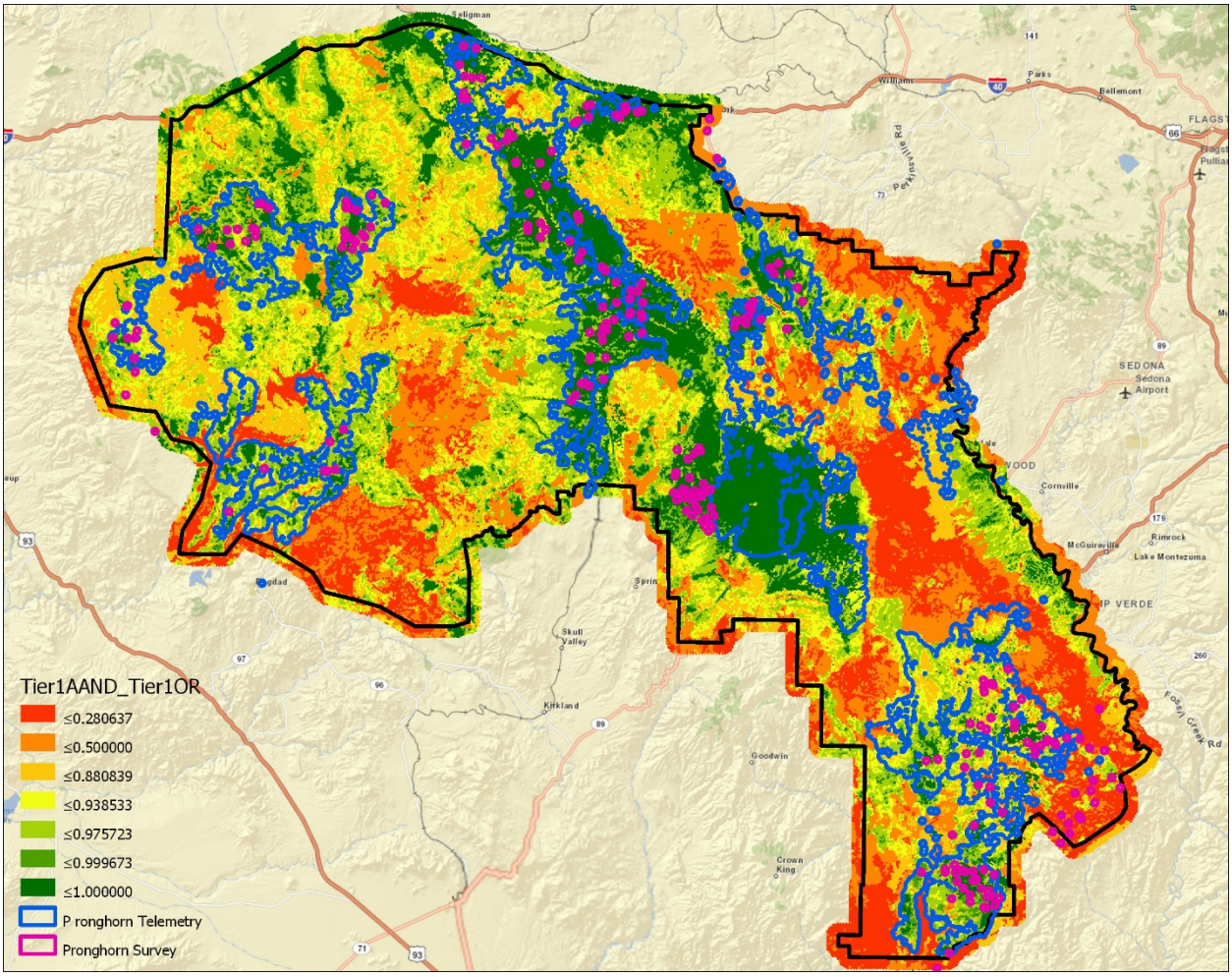
Appendix 4E: Map showing Tier 1 grassland potential factor grassland agreement. A value of NoData (no color in this map) indicates an area where fewer than 3 previously created datasets representing grassland vegetation agreed that an area was a grassland. A value of 0.5 was given when 3 datasets agreed; 0.75 when 4 datasets agreed, and 1.0 when all five datasets agreed.

F: Map of Tier 1 Final Output (Tier 1 A & Grassland Agreement)



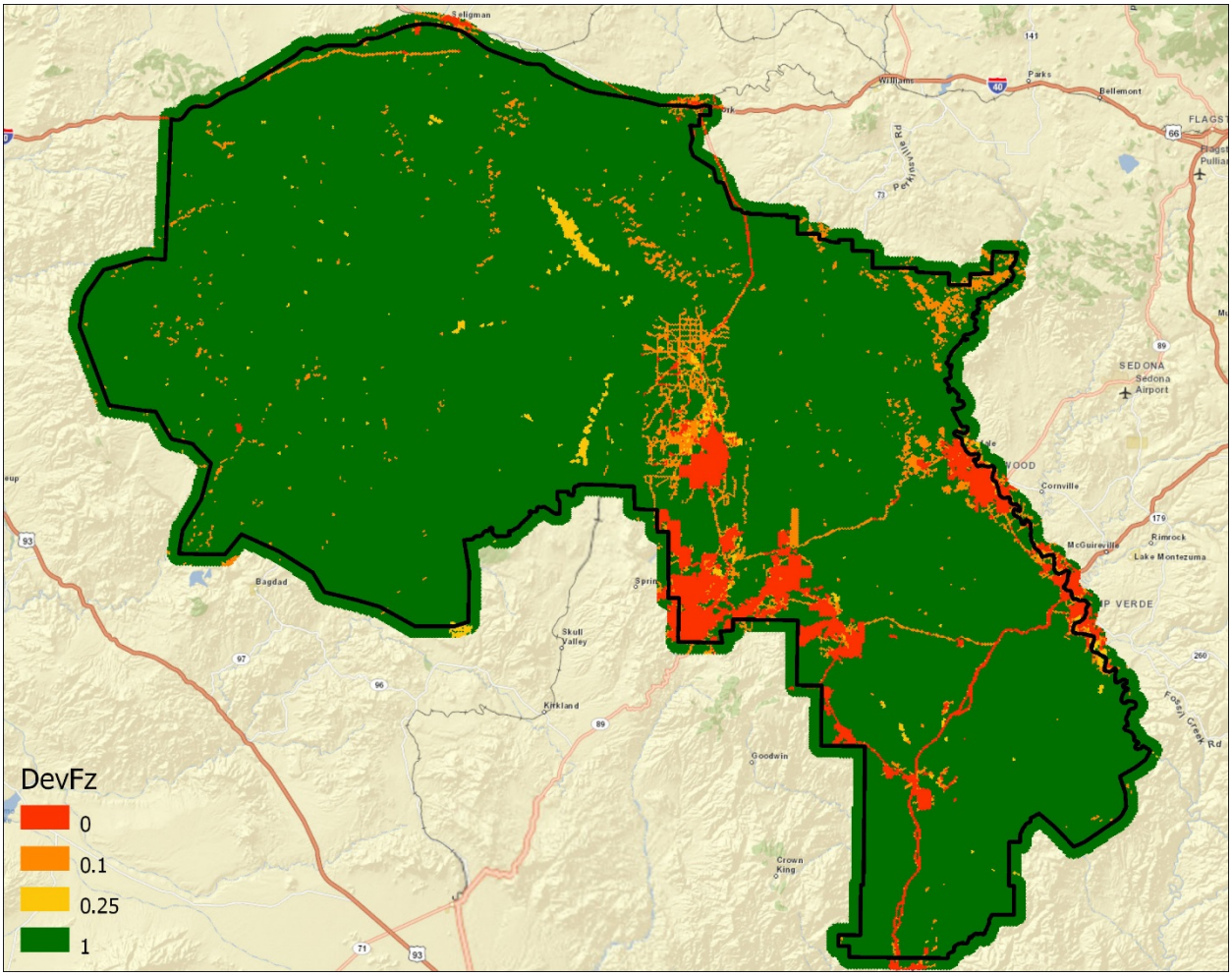
Appendix 4F: Map showing Tier 1 grassland potential combining Tier 1A and T1B (grassland agreement). A value of 0 indicates an area where these factors together indicate that an area does not have as much potential for grassland vegetation, while a value of 1 indicates an area that has significant potential for grassland vegetation. Data are shown using a quantile classification scheme with 7 bins.

G: Map of Tier 1 Final Output with Pronghorn Telemetry and Survey Data



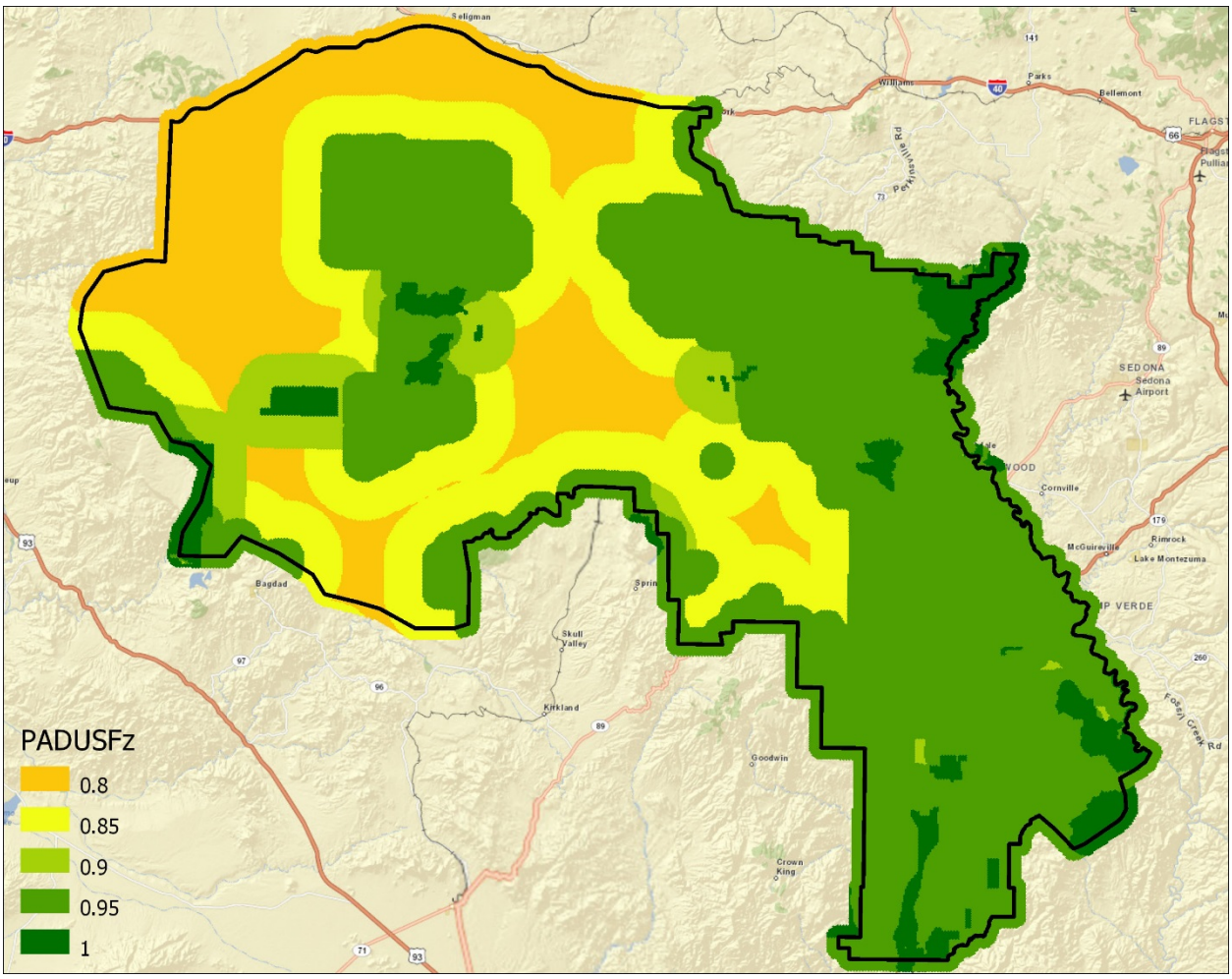
Appendix 4G: Map showing Tier 1 grassland potential combining Tier 1A and T1B (grassland agreement). A value of 0 indicates an area where these factors together indicate that an area does not have as much potential for grassland vegetation, while a value of 1 indicates an area that has significant potential for grassland vegetation. Data are shown using a quantile classification scheme with 7 bins. Shown on top in blue is pronghorn telemetry data and in purple is available pronghorn survey data. Note that this wildlife data is not available across the entire area, so it should only be used to visualize how well the model identifies potential grassland areas where pronghorn have been observed.

H: Map of Tier 2 (Current Development)



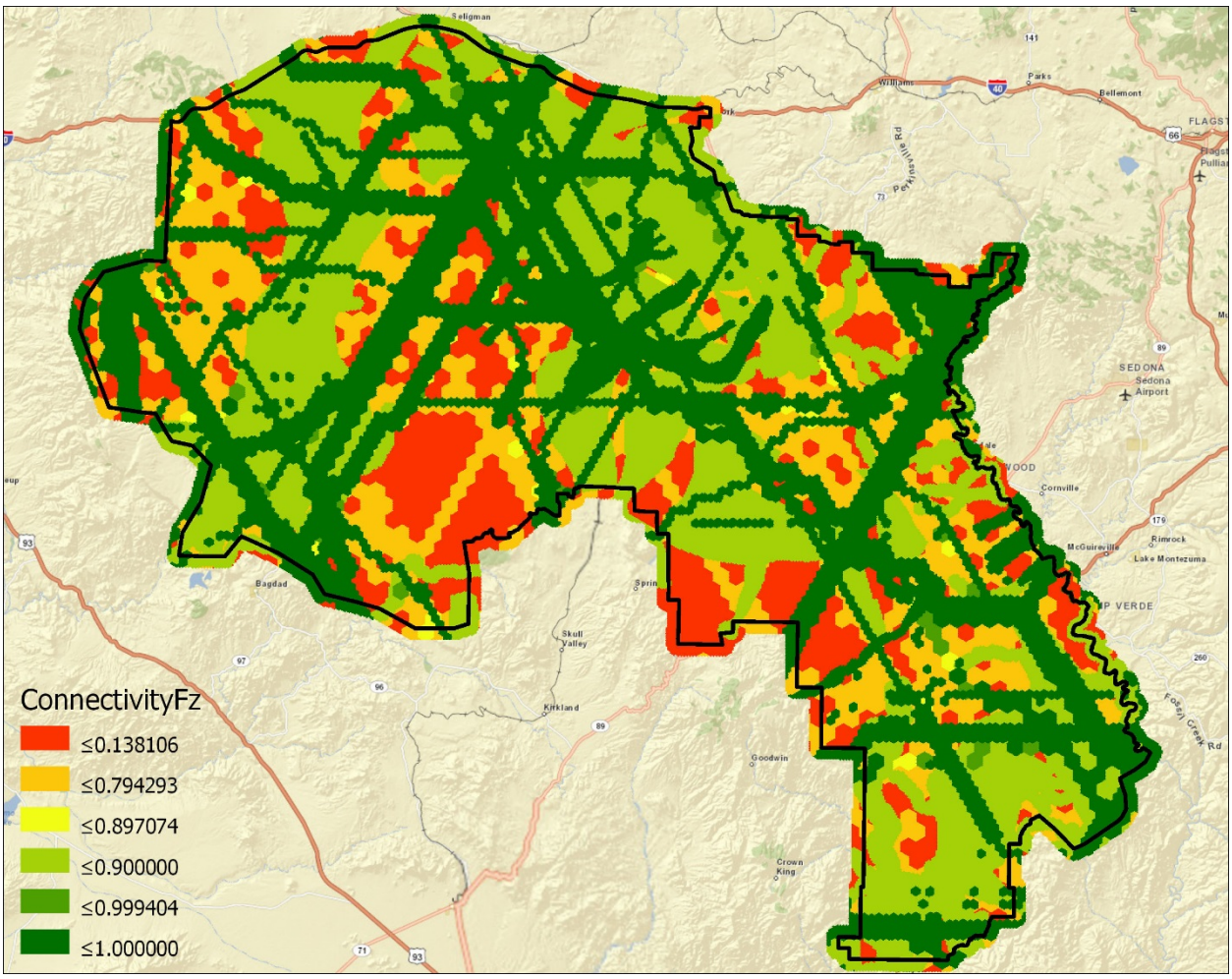
Appendix 4H: Map showing Tier 1 grassland suitability factor current development. Values of 0, 0.1, and 0.25 indicate areas where landcover data indicate existing development, while a value of 1 indicates an area where the landcover is more suitable for grassland vegetation (not developed).

I: Map of Tier 2 (Distance to Protected Lands)



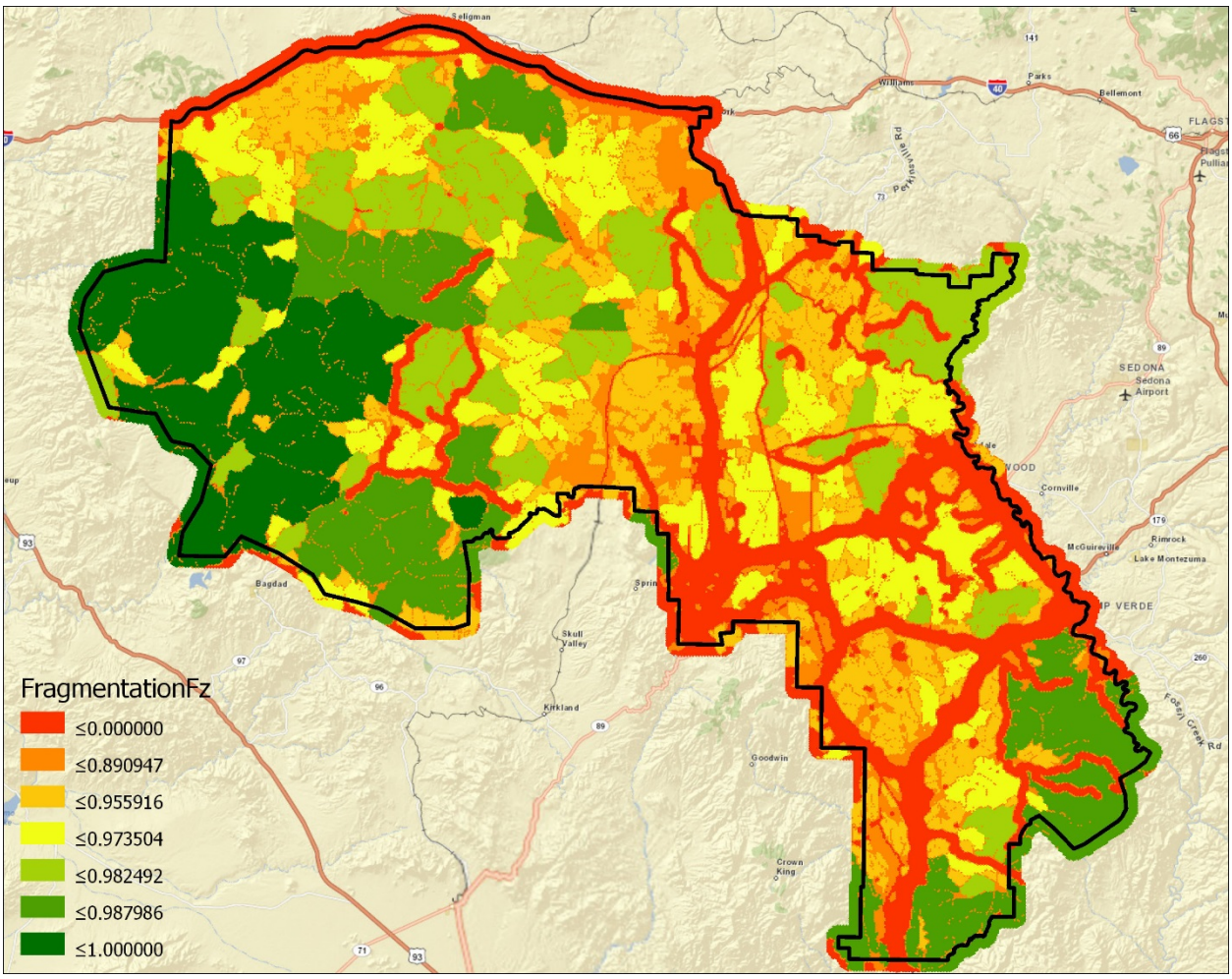
Appendix 4I: Map showing Tier 1 grassland suitability factor distance from protected areas. Values of 0.8 indicate areas further than 5 miles from any protected areas, and other values increasing with decreasing distance to protected areas.

J: Map of Tier 2 (Connectivity)



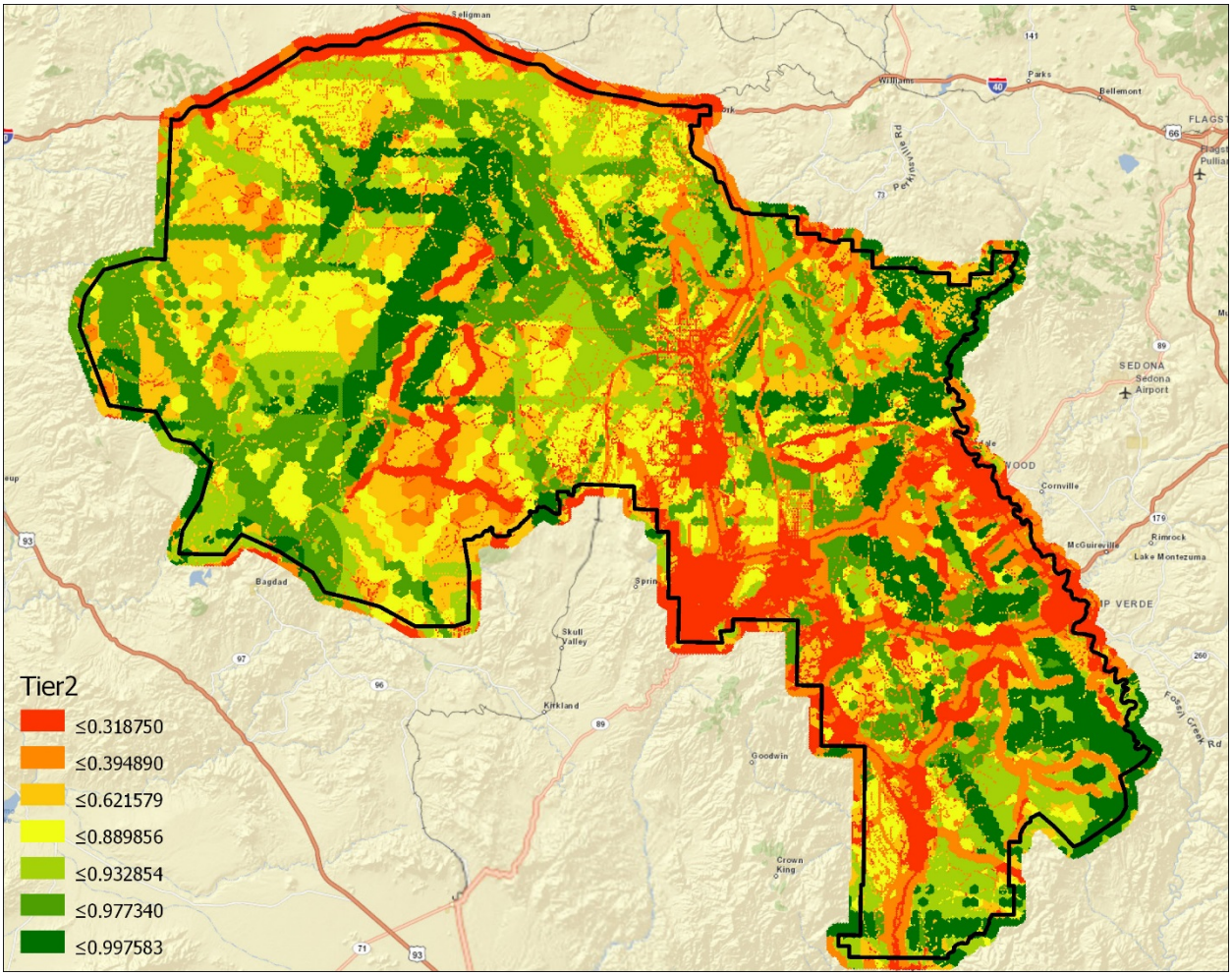
Appendix 4J: Map showing Tier 1 grassland suitability factor connectivity. A value close to 0 indicates an area less suitable for grassland restoration due to limited representation from various connectivity datasets. While a value of 1 indicates an area that has significant suitability for grassland restoration activities due to increased potential for landscape connectivity, and therefore an assumed increased permeability for wildlife. Data are shown using a quantile classification scheme with 6 bins.

K: Map of Tier 2 (Human Modification)



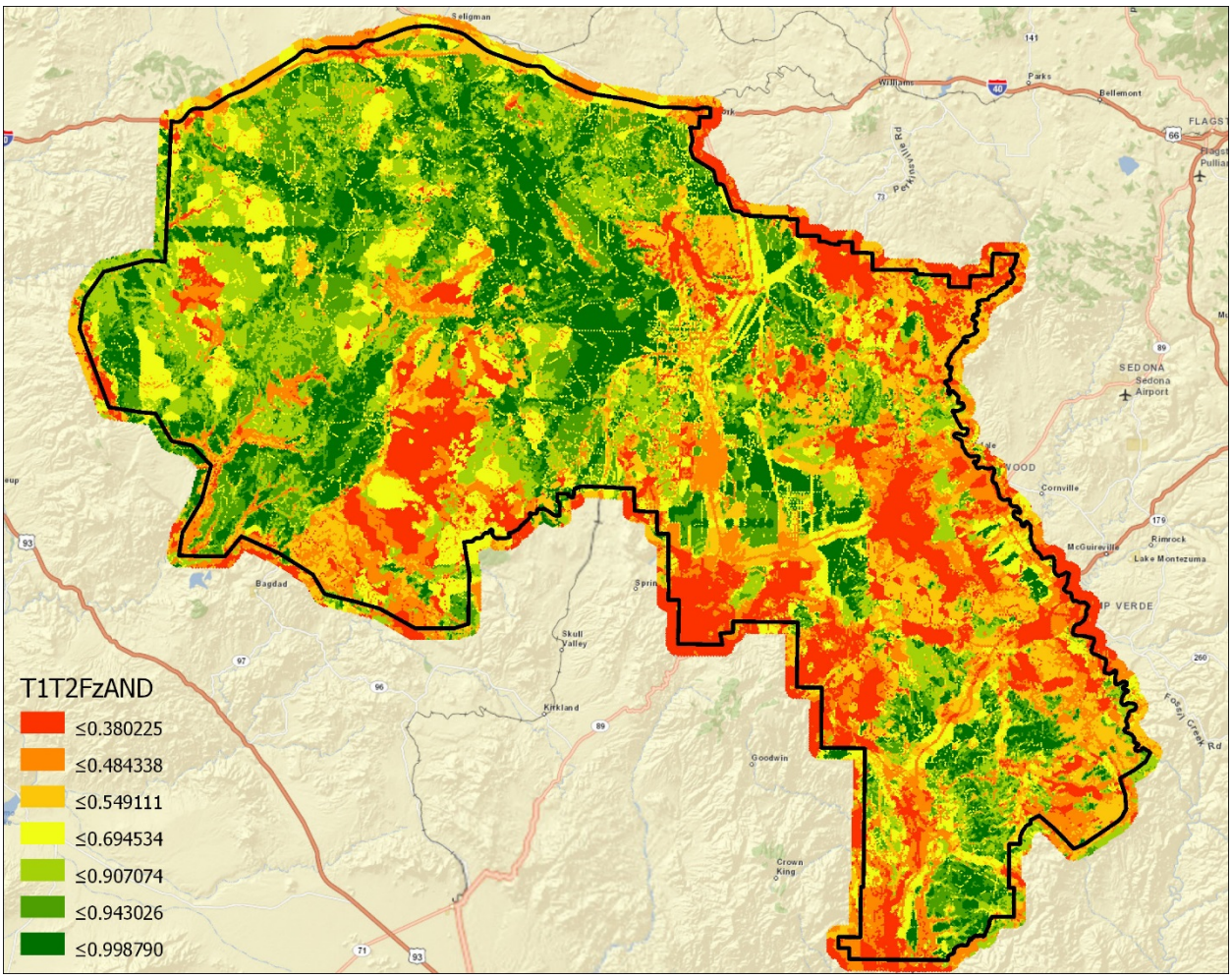
Appendix 4K: Map showing Tier 1 grassland suitability factor human modification. A value close to 0 indicates an area less suitable for grassland restoration due to increased presence of human modification and fragmentation. A value of 1 indicates an area that has significant suitability for grassland restoration activities due to a lesser amount of fragmentation and human modification. Data are shown using a quantile classification scheme with 7 bins.

L: Map of Tier 2 Final Output (Development & Distance to Protected Lands & Connectivity & Human Modification)



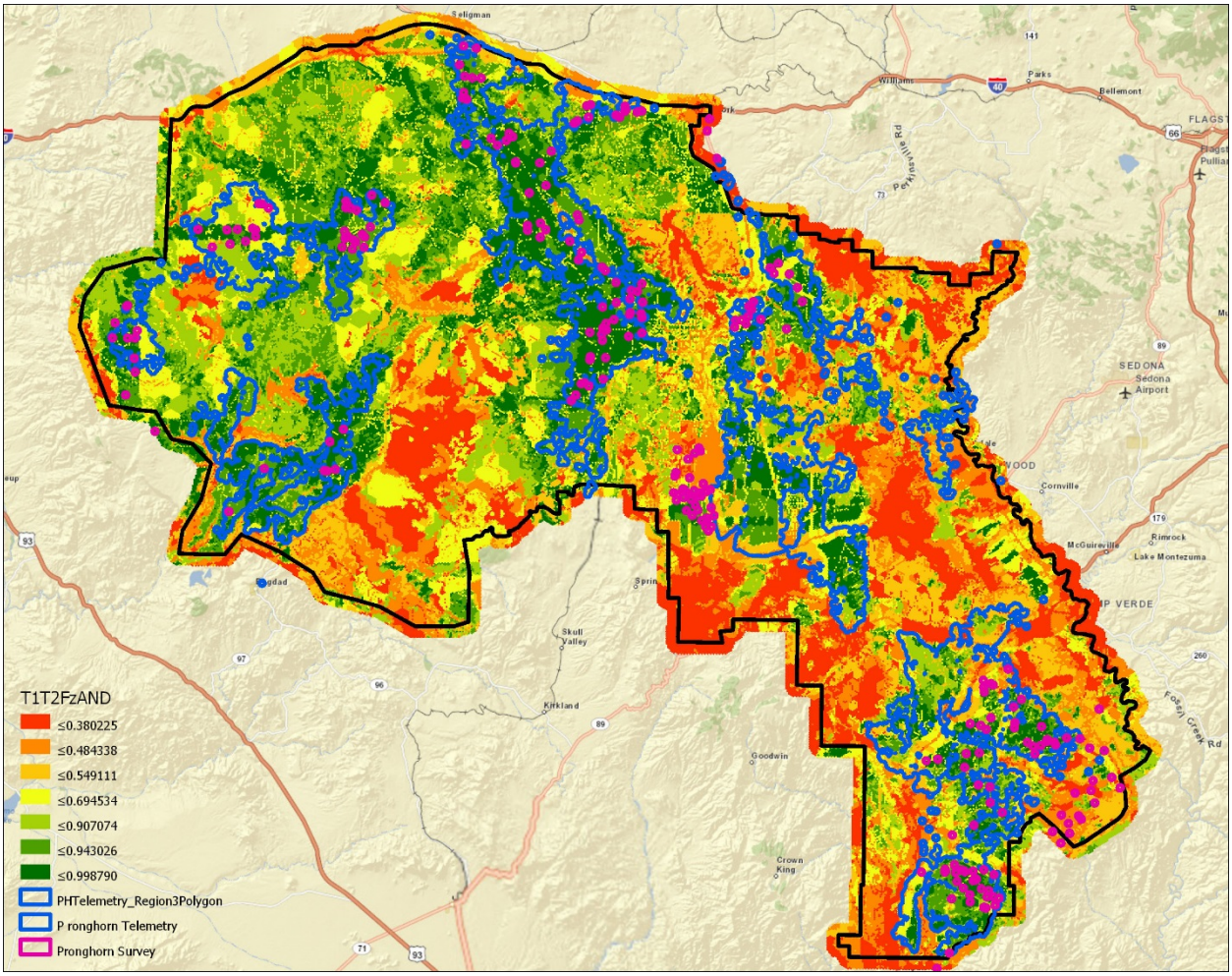
Appendix 4L: Map showing Tier 2 grassland suitability combining the factors current development, distance from protected areas, connectivity, and fragmentation. A value close to 0 indicates an area where these factors together indicate that an area is not as suitable for grassland restoration, while a value of 1 indicates an area that is more suitable for grassland restoration. Data are shown using a quantile classification scheme with 7 bins.

M: Map of Tier 1 Final Output and Tier 2 Final Output



Appendix 4M: Map showing Tier 1 grassland potential and Tier 2 grassland. A value close to 0 indicates an area where these factors together indicate that an area has less potential for grassland vegetation and is not as suitable for grassland restoration, while a value of 1 indicates an area that has more potential for grassland vegetation and is more suitable for grassland restoration. Data are shown using a quantile classification scheme with 7 bins using a Fuzzy AND combinatorial formula. A change in one or more of the component factors (including the introduction of a weighting system) could result in a change in the final output of these datasets.

N: Map of Tier 1 Final Output and Tier 2 Final Output with Pronghorn Telemetry and Survey Data



Appendix 4M: Map showing Tier 1 grassland potential and Tier 2 grassland. A value close to 0 indicates an area where these factors together indicate that an area has less potential for grassland vegetation and is not as suitable for grassland restoration, while a value of 1 indicates an area that has more potential for grassland vegetation and is more suitable for grassland restoration. Data are shown using a quantile classification scheme with 7 bins using a Fuzzy AND combinatorial formula. A change in one or more of the component factors (including the introduction of a weighting system) could result in a change in the final output of these datasets. Shown on top in blue is pronghorn telemetry data and in purple is available pronghorn survey data. Note that this wildlife data is not available across the entire area, so it should only be used to visualize how well the model identifies potential grassland areas where pronghorn have been observed.