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Oregon Juniper Priorities Process: Combining Juniper Data Objectives and Constraints to Determine Specific Planning Unit Priorities

The process of prioritization inherently implies that one places more importance or value of one feature over another. However, in the context of spatial priorities, specific locations may be inherently more valuable than others based on the number of features that are found in any given location. Identification of priorities when considering multiple objectives and constraints, particularly at the regional scale, entails selecting those locations that represent the greatest potential for juniper treatment while avoiding those places that are environmentally vulnerable or potentially could be more costly (i.e. steep slopes). However, in doing so, it's essential to avoid omitting those locations that may be critical for sensitive species such as sage grouse or pygmy rabbit. In this sense merely searching for locations where the juniper occurs most densely falls short of developing multi-objective solutions. Traditional approaches to prioritization tend to default to this "index and weight" approach which tends to pit one objective against another and favors those locations where multiple objectives exist rather than considering each location in the context of a broader specified objective.

There are a multitude of approaches to multi-objective decision making that have gained traction in the last decade that attempt to account for some of the limitations of the more traditional index and weight approach to prioritization. Many of these approaches stem from the decision sciences and have become increasingly more sophisticated as they have been extended to account for geographic space in the context of spatial decisions. Of the wide array of spatially explicit decision support approaches, we evaluated three separate techniques to determine the most applicable for the problem at hand given the extent and available data. The three approaches we evaluated included: fuzzy logic, Bayesian belief networks and a target based approach known as a computational heuristic. The following table briefly summarizes the pros and cons of each approach.

Method	Pros	Cons
Target Based	Optimal (or close to) solution. Easily re-producible. Handles un-standardized data.	Can be difficult to explain. Difficult to handle uncertainty and missing data.
Fuzzy Logic	Can explicitly model uncertainty and it's effects. Good model for abstract relationships or where data is lacking.	Conceptually difficult to grasp, requires development of a knowledge base (time intensive), difficult to integrate into an on-line system.
Bayesian Belief Networks	Once the model is developed, it's simple to re-run. Easy to explain. Represents uncertainty in terms of probabilities.	Expert driven may require re-convening group of experts if values are used to drive the process. Requires definition of all possible outcomes

We used a multi-objective decision support model based on computational heuristics to identify regional priorities at the 5th field, watershed scale, hereafter referred to as Planning Unit. We chose the heuristic because it was able to handle un-standardized data from disparate sources and because it is relatively easy to update as new data become available. While both the fuzzy logic and Bayesian approaches are effective at handling uncertainty, they both are limited in that they require input from a wide variety of experts. These experts then would need to be re-convened as new data becomes available, limiting the flexibility and adaptability of the tool.

The heuristic draws on a simulated annealing algorithm to approximate an optimal configuration (or prioritization schematic) given a mathematically defined set of objectives (referred to as an objective function). This target based approach allows for the selection of a set of planning units based on avoiding those areas that are within sensitive habitat, subject to the condition that targets for juniper treatment included in the analysis are met.

We chose a simulated annealing approach as the primary modeling framework imbedded in the decision support tool. We use an existing, well vetted and freely available third party software called Marxan (Ball and Poisingham 2001) that implements a simulated annealing algorithm. The model is used to approximate a close to optimal configuration of high priority planning units while achieving land management preferences (for example, avoiding planning units with predominance of steep slopes).

This spatial simulated annealing analysis selects discrete planning units defined by a juniper phases as well as areas to avoid across the study area in order to achieve the target acreage for each juniper phase specified by the user through the decision support tool (DST).

Target acreages are based on the underlying data specific to each phase (ILAP data).
For a description of the units for all data, including juniper phase data, please see the readme.txt file contained in the reports shapefile.

An objective function is calculated based on meeting these goals targets while minimizing "costs" associated with selecting planning units in that are within sensitive habitat or potentially expensive for treatment (i.e. steep slope). This technique iterates through a million possible priority configurations and recalculates the objective function after each run. Initially, the algorithm temperature is high, allowing a wide range of possible priority configurations whether or not the objective function improves. As progress is made through the one million iterations, the temperature cools and only changes that improve the objective function are accepted. This process helps to avoid local minima in the early rounds and finds progressively more efficient solutions in later iterations.

The objective function can be expressed as follows:

$$minZ = \sum_{n=1}^{p} C_c \times \sum_{n=1}^{p} P_s$$

Where:
p: Planning unit (5th field huc)
C: costs associated with priority constrains (c) (e.g. steep slope)
P: penalty incurred for not meeting the specified target of species n.

The resulting priority planning units represent an approximation of the optimum configuration of planning units given user specified preferences for management objectives.