Forget the Hoe: Managing Invasive Plant Species with Dynamic Programming

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Abstract: Bromus Tectorum (hereafter Cheatgrass) is one of the most widespread invasive species on U.S. rangelands. Cheatgrass decreases agricultural yields, decreases animal performance, and increases the frequency and intensity of fires. We present a bio-economic model of stocking cattle on these rangelands to show that land managers can manage invasions using direct control on the invasive species, altering stocking regimes, or using combinations of direct control and changes in stocking rates.

**Ecological Model**

Cheatgrass simulates field experiments that provide the data to parameterize the economic model.

**Dynamic Programming**

Dynamic Programming (Bellman, 1953) solves complex decisions by breaking the problem up into a sequence of small, simple decisions known as decision steps. This is done by defining a set of value functions, $V(t)$, where the value depends on the state(s) of the system. The Bellman equation allows researchers to solve for the set of value functions. The diagram on the left is an example of a problem that can be solved with Dynamic Programming (e.g. shortest distance problem).

The Bellman equation is the mathematical tool used to solve Dynamic Programming problems. The Bellman equation operationalizes the Principle of Optimality. As long as the states of the problem are well defined, discrete, and finite, the Bellman equation can be solved by exploiting the recursive nature of the equation.

The solution to a Dynamic Programming problem is the control that an decision maker should choose in order to maximize the given objective. Following this decision rule for each state creates an optimal path. The table at left is an example of such a decision rule. The table is intuitive and simple for land managers to use as a decision aid.

**Economic Model**

Conceptual Bio-Economic model. The diagram displays the economic and biological interactions expressed in the mathematical model.

**Economic Results**

Here we see the optimal path of invasion under three different starting stocking values. In each case the present value marginal cost of reducing invasion equals the discounted stream of marginal benefits that accrue from the reduction of the marginal unit of invasion. Given the current invasion level, the benefits of pursuing all possible fire treatments toward un-invaded range conditions.

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