Approaches to Assessment of Cumulative Economic Impact of Invasive Plants

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It is becoming increasingly important to effectively utilize scarce resources for invasive species control, and further to communicate the benefits of control to funding agencies, volunteers and stakeholders. Quantitive alternative assessment, such as cost:benefit analysis or multi-criteria optimization, can assist in determining the optimal strategy for control and in clarifying net benefits to society and stakeholder groups. There is a further need to consider the management of more than one invasive species at a time. Many locations have infestations of more than one species. In other cases, control of one invasive is followed by infestation of another. Quantitive alternative assessment for control of multiple invasive species requires the calculation of the cumulative economic impact. Most cumulative assessments assume a linear, independent response: the impact of each species is calculated separately and the results are added. This approach neglects synergistic effects, where the impact of several species is greater than the sum of the impacts of individual species, and saturation effects, where a plateau is reached and additional infestation has little or no additional impact. These effects can cause a linear model to over- or under-estimate the cumulative economic impact. Using structured analysis diagrams, a diagramming method useful in visualizing conceptual models, several existing studies are compared and contrasted. Sources of model and parameter uncertainty are identified in each approach. Finally, we propose a conceptual model for assessing the cumulative economic impact of invasive plants in California's wildlands.

Characteristics of Assessments

- **Approaches**
  - ***Absolute***
  - Compares one scenario (e.g. status quo-Invasive alien species (IAS) present) with ideal (IAS absent)
  - Useful for raising awareness and supporting increased funding for IAS
  - Example: Pimentel et al 2000
  - ***Comparative***
  - Compares feasible alternatives
  - Useful for making control decisions
  - Example: Jetter et al 2003
- **are often mixed inappropriately**

- **Desirable Qualities**
  - ***Transparency***
    - Assessment details accessible to stakeholders
  - ***Inclusive***
    - Stakeholder values and beliefs considered
  - ***Credible***
    - Reliability of Data and Models
  - ***Appropriate***
- **not supported by current frameworks**

Are Hierarchical Diagrams a Useful Tool in Assessment?

- **(+)Transparency**
  - Methodology is easier to understand when read one level at a time
  - Documentation available by hyperlink
- **(+)Credibility**
  - Development of codified procedures
- **(+)Appropriate**
  - Low-cost software is available for smaller projects (B-liner, Gjots)
  - High-functionality software is available for larger projects (GoldSim, METIS)
- **(-)Complexity**
  - Problem is interdisciplinary
  - Lack of clear precedence of levels
  - Connection to mathematical model must be maintained through replanning cycle

Temporal Considerations

- **Flow variables**
  - ***Definition***
    - Goods and services produced over time (e.g. crops, recreation, water distribution)
  - ***Examples***
    - Costanza et al 1997 determine value of ecosystem services as flows
    - Pimentel et al 2000 determine impacts of invasive species in US as flows
  - ***Conditions to Use***
    - Absolute assessments
    - Assessing sustainability
    - Valuation of capital

- **Stock variables**
  - ***Definition***
    - A stock (e.g. a forest) that produces a flow of goods (e.g. new trees) and services (e.g. carbon sequestration)
  - ***Example***
    - Jetter et al 2003 determine net present value of biocontrol of yellow starthistle as the expected increase in the value of rangeland as natural capital stock.
  - ***Conditions to Use***
    - Comparative assessments
    - Comparing finite duration restoration programs to infinite duration controls

Spatial Approaches

- **Lumped Parameters**
  - ***Conditions for Use***
    - Calculation of total benefit to society
    - Linear and additive dependence of economic impact on spatial extent and abundance of species
  - ***Advantages***
    - Ease of calculation
    - Algebraic formulation
    - GIS not required

- **Distributed Parameters**
  - ***Conditions for Use***
    - Assessment of fairness (equity)
    - Nonlinear and/or non-additive dependence of economic impact on spatial extent and abundance of species
  - ***Examples***
  - Saturation: Cattle and horses cannot graze if leafy spurge cover >10-20, yellow starthistle causes 40% reduction in grazing season
    - Coupling: Increased erosion from knapweed + sediment retention by freshwater weeds degrades watershed

Hierarchical Structure: Menu of Levels

- **Study Region**
- **Realms**
- **Administrative Regions**
- **Economics**
  - ***Costs, Losses, Benefits***
  - ***Market, NonMarket***
  - ***Flow, Stock***
  - ***Fixed, Variable***
- **Biomes**
- **Sectors**
  - ***Economic***
  - ***Ecological***
  - ***Demographic***
- **Ecosystem**
  - ***Services***
  - ***Function***
  - ***Organization***
  - ***Structure***
    - Taxonomy

Market Sectors

- **Goods**
  - ***Food***
    - Agricultural Lands
    - Aquatic Habitats
    - Grasslands and Forests
  - ***Non-Food Agricultural***
  - ***Other Potential Renewable Resources***
    - Forests
    - Grass and Woodlands
    - Aquatic Habitats
- **Services**
  - ***Recreation***
- **Stock**
  - ***Natural Capital***
    - Land Value
  - ***Infrastructural Capital***
    - Bridges
    - Buildings
    - Irrigation
    - Hydroelectric Utilities

NonMarket Ecosystem Services

- **Atmosphere**
  - ***Gas regulation***
  - ***Climate regulation***
- **Hydrosphere**
  - ***Water flow regulation***
  - ***Water purification***
  - ***Disturbance regulation (flood)***
- **Lithosphere**
  - ***Erosion control***
- **Biosphere**
  - ***Disturbance regulation (fire)***
- **Anthroposphere**
  - ***Transportation and Access***
  - ***Recreation***
  - ***Cultural***
  - ***Health***

Agricultural Losses to Alien Weeds: Approach 1

- **Goal**
  - Estimate reduction in production losses from current (with aliens) to ideal (without aliens) scenario
- **Assumptions**
  - a) native and alien weed species have equal impact on productivity
  - b) eradication of alien weeds does not cause increased abundance of native weeds
  - ***Variables***
    - L = total current loss in productivity
    - p = alien fraction of weed species
- **Results**
  - Current Losses (with aliens) = L
  - Ideal Losses (without aliens) = $(1-p)L$
  - Impact = pL, *with* $42\% < p < 75\%$
  - ***References***

    - *Pimentel, D., Lach, L., Zuniga, R., & Morrison, D. (2000). Environmental and economic costs of nonindigenous species in the United States. BioScience, 50, 53-65.*
    - *Pimentel, D. (Ed.). (2002). Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and Microbe Species (1 ed.). Boca Raton: CRC Press.*

- **but these assumptions are not valid**

Agricultural Losses to Alien Weeds: Approach 2

Assumptions

- a) native and alien weed species have unequal effect on productivity
- b) eradication of alien weeds does produce increased abundance of native weeds

Variables

- L = total current losses in productivity
- p = alien fraction of weed species
- a = relative impact of alien weeds

Results

$$\text{Impact} = L\frac{p(a-1)}{p(a-1)+1}$$

When are approaches equivalent?

p	a
25%	2.33
50%	3
75%	5

Conclusion

- The estimates obtained in Pimentel ed. 2002 are valid if alien weed species have 3-5 times more effect on crop productivity than native weed species

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