Causal Bayesian networks in assessments of wildfire risks: opportunities for ecological risk assessment and management

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The need for causal networks

- **Wildfire risks and losses increased last 100 years**
  - population expansion, land use and management practices, global climate change
- **Extensive efforts modeling the probability and severity of wildfires**
- **Fewer efforts examining causal linkages between wildfires and impacts on ecological receptors and critical habitats**

Images: USFS

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How to model causal linkages of wildfire frequency and severity on ecological systems?

Changes to renewal and succession patterns

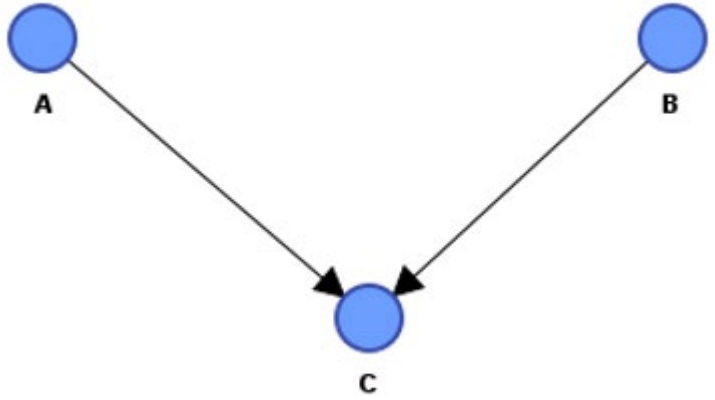
Direct impacts to wildlife and vegetation species and composition

Changes to soil composition

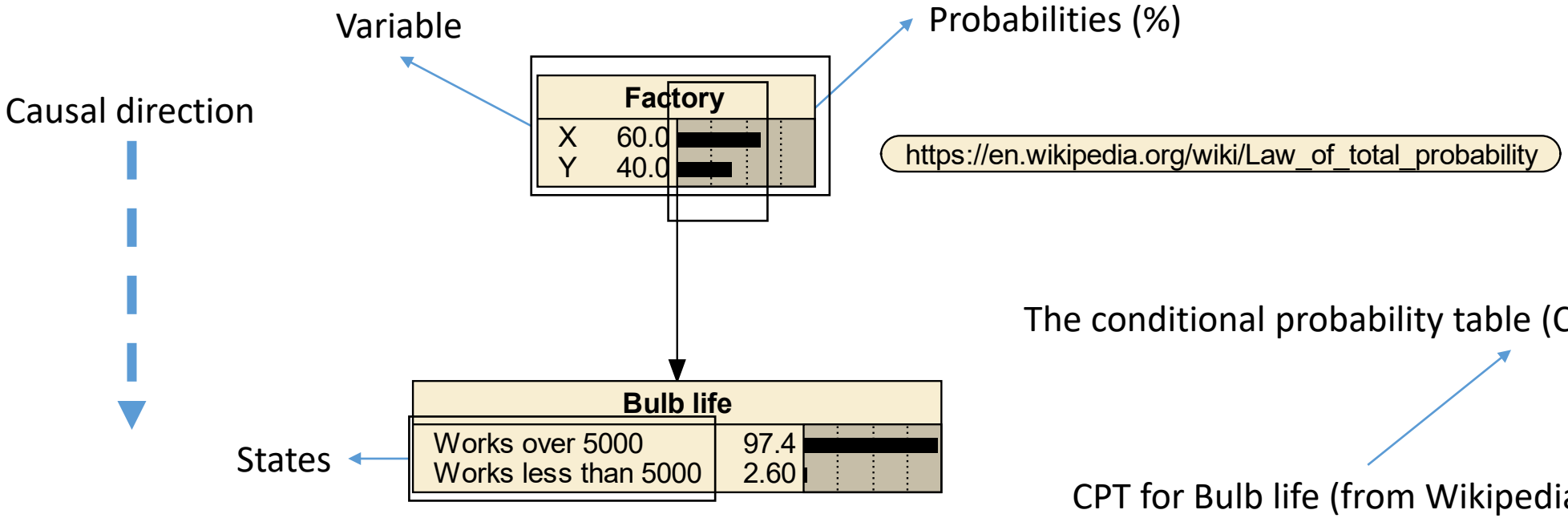
Runoff to aquatic systems

Bayesian networks (BN) in causal analysis

- **BNs: probabilistic tools for graphing and evaluating causal knowledge and uncertainties in complex systems**
  - graphical model: variables as nodes in a directed acyclic graph
  - predict likelihood: possible known causes that contributed to an event
- **Only limited application to the quantitative assessment of ecological risks and impacts of wildfires**



Bayesian networks as probability calculators



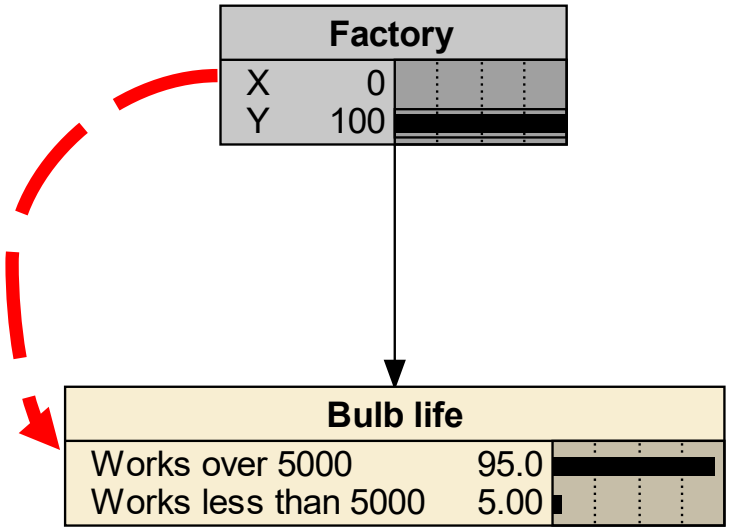
The conditional probability table (CPT) is the engine of the BN

CPT for Bulb life (from Wikipedia link)

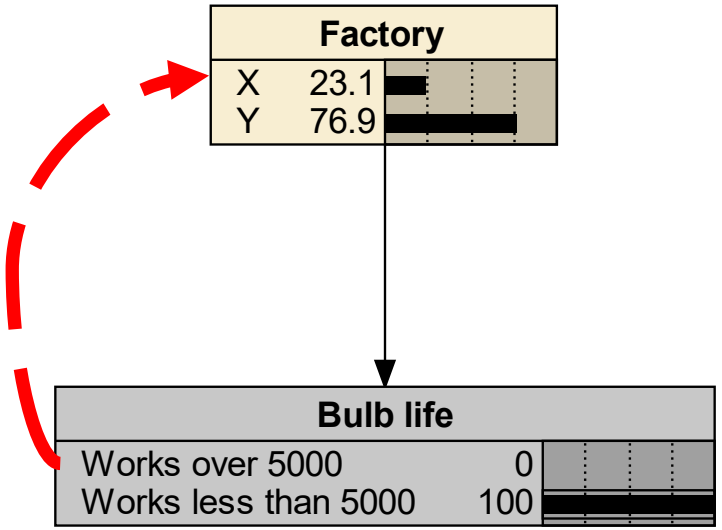
Factory	Works over 5000	Works less than 5000
X	99	1
Y	95	5

Bayesian inference

Predictive inference



Diagnostic inference



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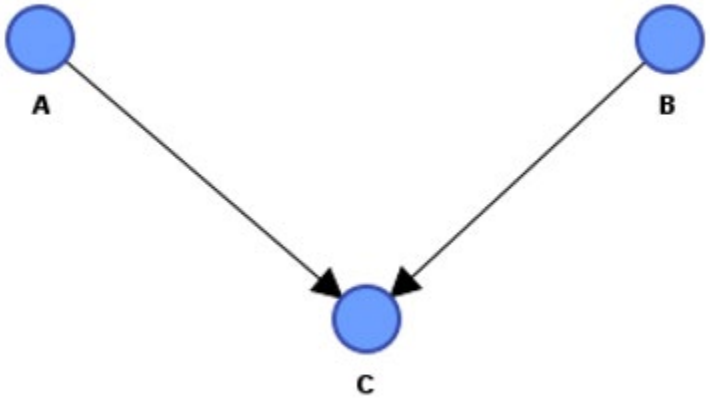
Example BNs in Wildfire Analyses

Problem context	Example variables/nodes	Reference(s)
Fire occurrence prediction	Population, distance from roads, distance from settlements, topography, temperature, precipitation, land cover	Bashari et al. (2016); Dlamini (2010); Sevinc et al. (2020)
Fire behavior modeling	Wind direction, fire weather, forest canopy characteristics, fuel model	Norman et al. (2010)
Housing loss prediction	Fire behavior, fire weather, burned area, distance to fire station, land cover, housing type and construction, housing density	Papakosta et al. (2017)
Wildlife habitat characteristics and vulnerability	Habitat suitability, fire size, fire likelihood, time since fire, recolonization potential, genetic risk, population demographics, vegetation cover, predator occurrence	Falke et al. (2015); Hradsky et al. (2017); Zeigler et al. (2019)
Vegetation response to wildfire	Fire frequency, vegetation type	Loftin et al. (2018)
Reduced risk to homes and infrastructure due to fuel mitigation	Housing density, vegetation type, fire weather, fire size, presence of fuel breaks, fuel treatment rate, fire danger index, suppression response	Cirulis et al. (2020); Penman and Cirulis (2020); Penman et al. (2014, 2015, 2020)

Bayesian networks in causal analysis

- **Opportunities for using Bayesian networks for assessing wildfire impacts to ecological systems**
  - explored through levels of causal representation and scenario examination



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Special Series

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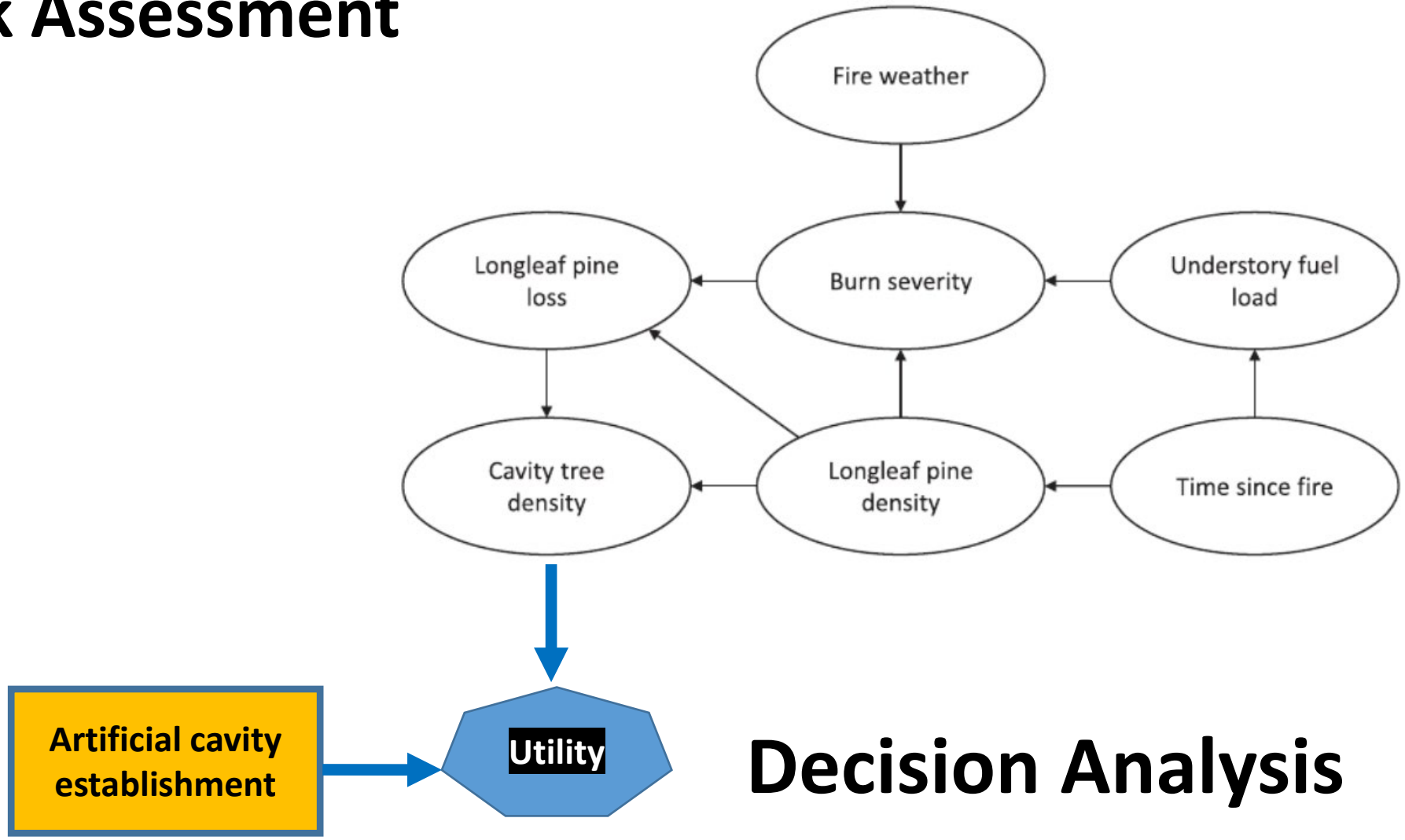
Red Cockaded Woodpecker Habitat Restoration

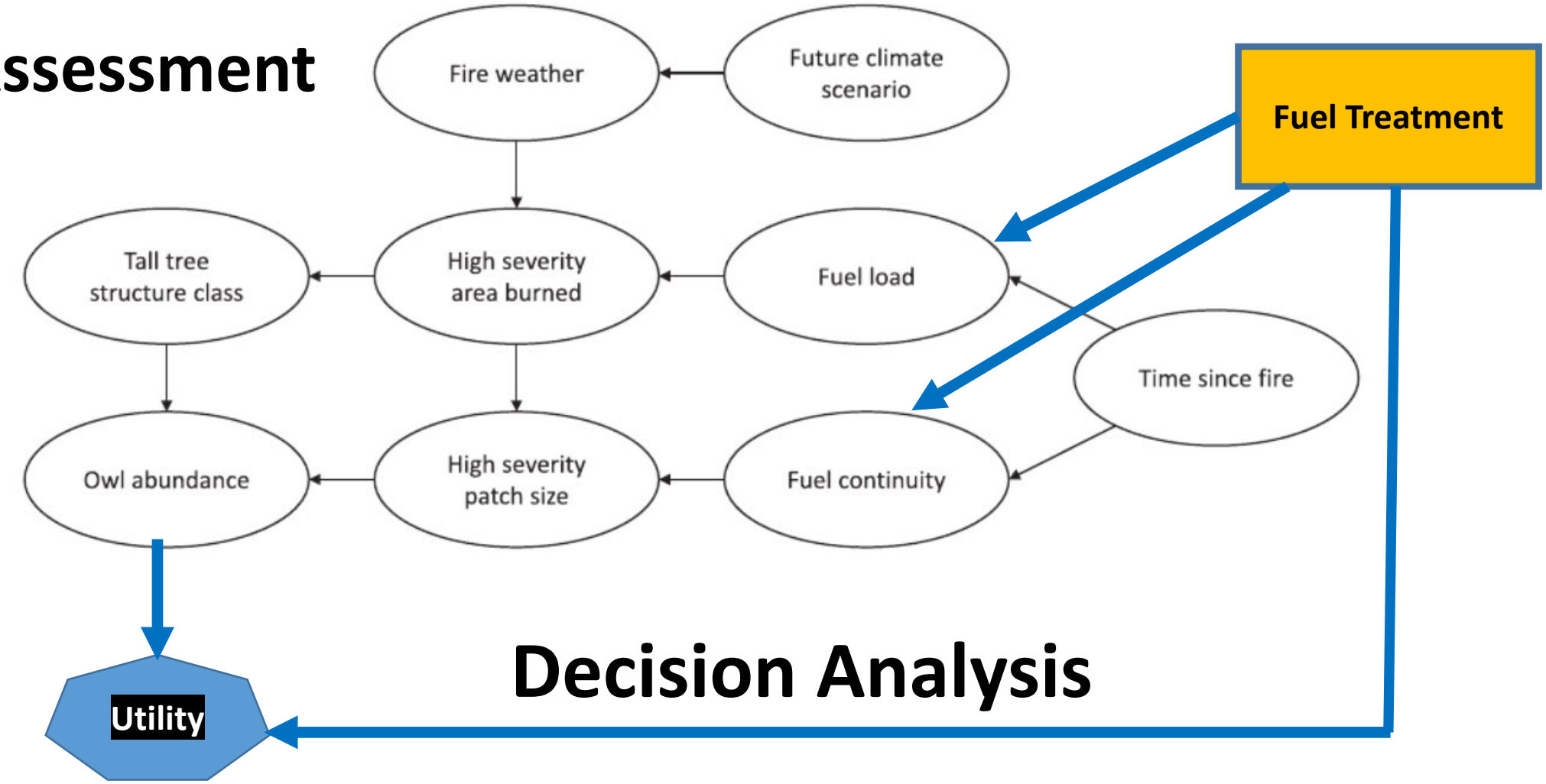
Risk Assessment



Decision Analysis

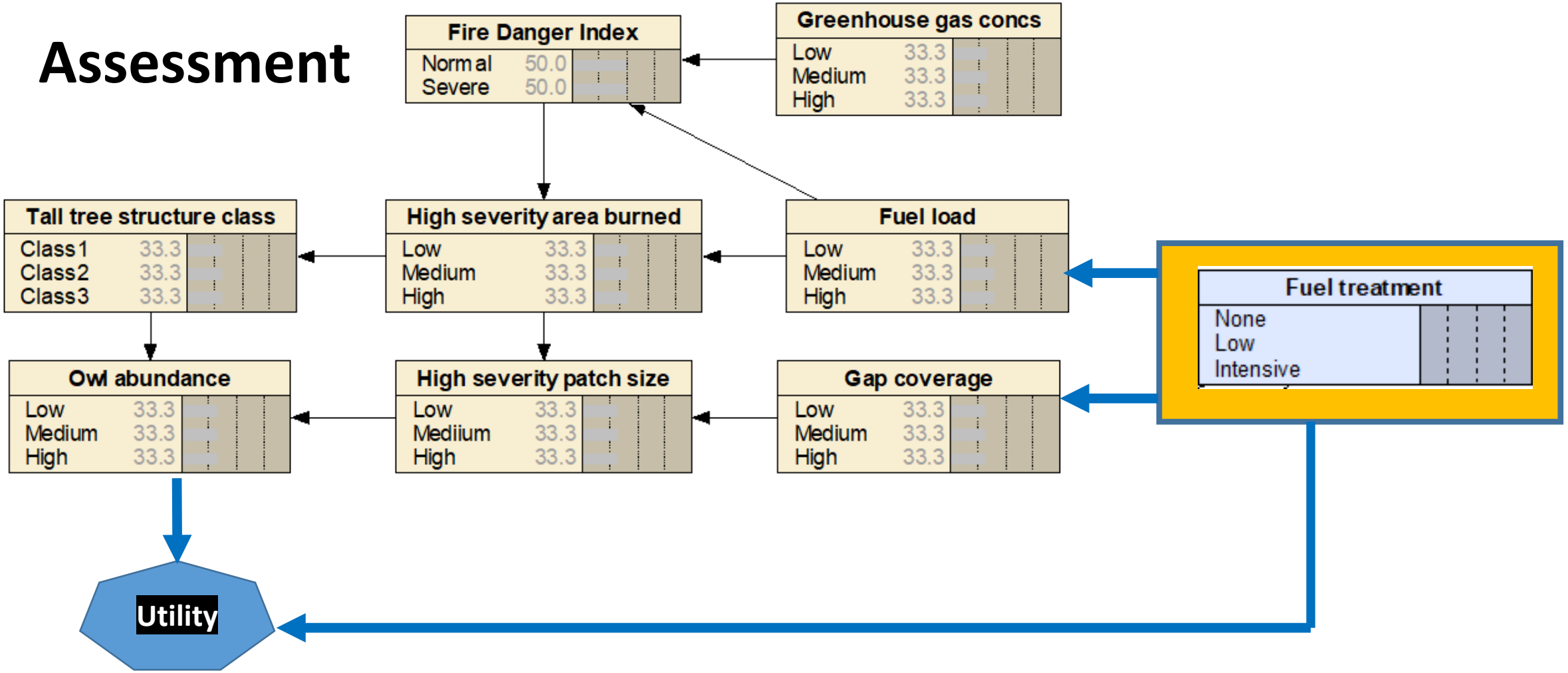
Spotted Owl Habitat Protection

Risk Assessment



Spotted Owl Habitat Protection

Assessment



Decision Analysis

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Utility of BNs in Wildfire Ecological Risk Assessment and Management

Causal diagrams provide tools for supporting assessment and decision making

Bayesian networks provide the calculus necessary for including uncertainties in causal relationships

Establishing a causal hierarchy for assessment and decision making models for environmental applications will benefit future environmental assessment and management endeavors

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Questions?

Images: USFS