A Quick Introduction to Fuzzy Logic Decision Support Modeling

Tim Sheehan
Ecologic Modeler
Conservation Biology Institute

What is it?

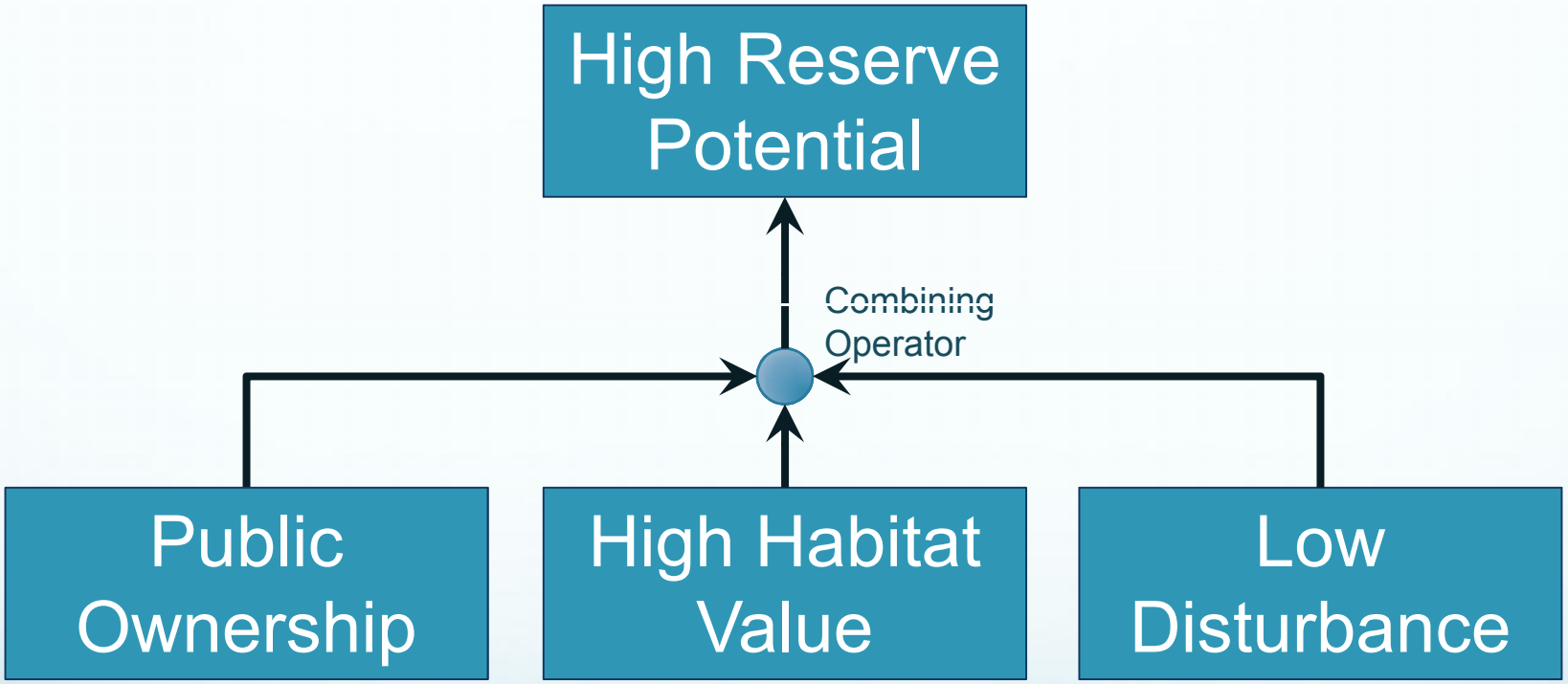
- Tree-based, structured method of evaluating data inputs to produce a single decision-guiding output.

What does it do?

- Combines data of multiple types.
- Produces a single evaluation metric.
- Exposes dominant contributors to the single evaluation metric.

Tree Based Model

Multiple factors combined for a final value



How to Combine Differing Types of Data?

- A common range of values or “space” is needed to combine different types of data.
- e.g. **Low Disturbance** might take into account:
  - Oil wells (point density)
  - Roads (linear density)
  - Invasive species extent (percent coverage)
- If only we had a way to do this!

Fuzzy Logic Modeling to the Rescue

- Provides a way of normalizing different types of data into a common range of values (“fuzzy space”).
- Provides a set of operators for combining values in different ways to reflect desired results.
- It’s not hard.

Converting Values into “Fuzzy Space”

- Consider this common polling technique based on propositions:

Mark the answer that most strongly reflects your feeling about each statement:

Fuzzy Logic Modeling is exciting.

1	2	3	4	5
StronglyDisagree	Disagree	Neutral	Agree	Strongly Agree

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For Fuzzy Logic

- Change the endpoint definitions to FALSE and TRUE.
- Change the associated values to a continuum ranging from -1 to +1.

What value reflects the **Trueness** *or* **Falseness** *of the proposition:*

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-1	0	+1
Completely False	Neither True nor False	Completely True

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From Real (or Raw) Values to Fuzzy Space

- Most common method:

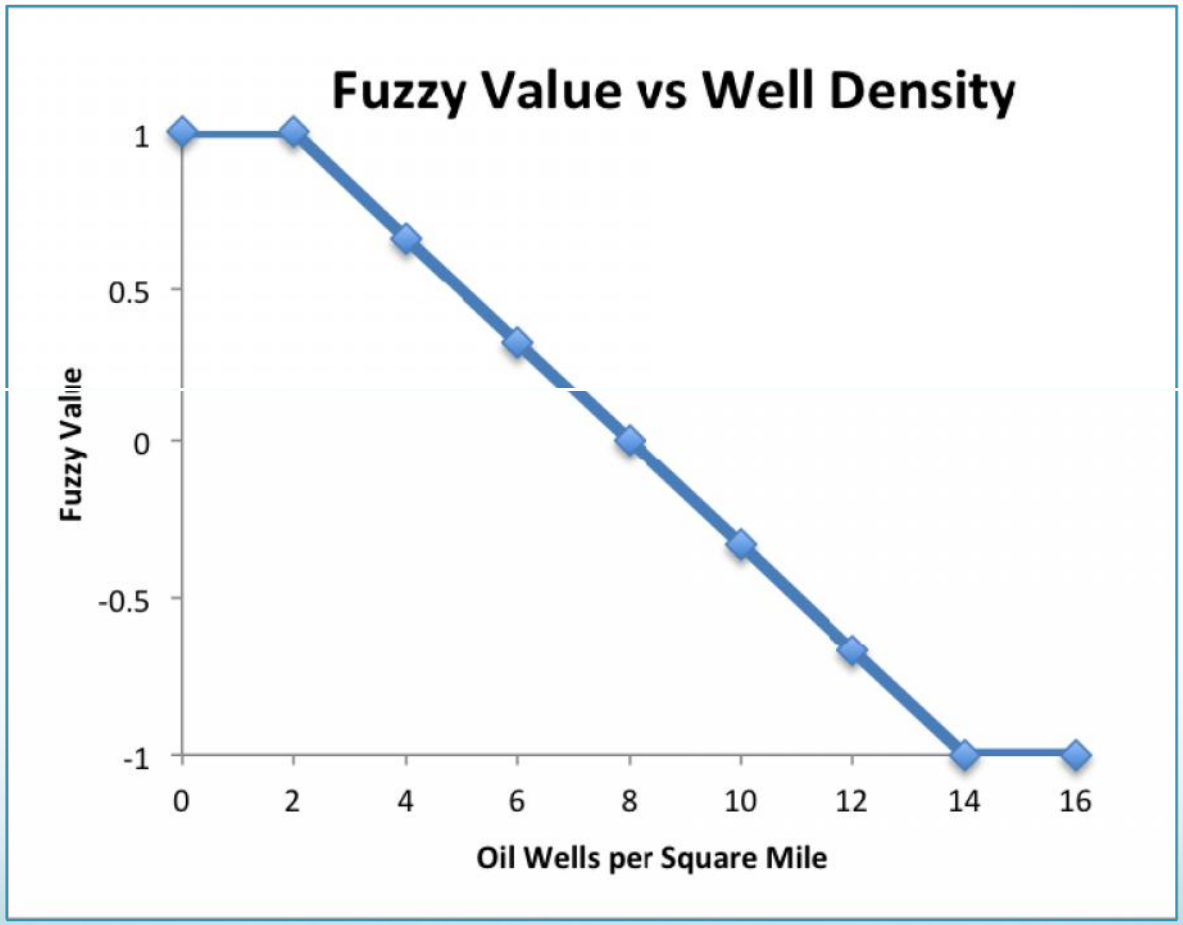
1. Pick a FALSE threshold, and a TRUE threshold
2. Values beyond thresholds convert to FULLY FALSE (-1) or FULLY TRUE (+1)
3. Values between FULLY FALSE and FULLY TRUE are determined using linear interpolation

Example: Low Oil Well Density

- Proposition: Mapped polygon has low oil well density
- TRUE threshold: 2 oil wells per mi^2
- FALSE threshold: 14 oil wells per mi^2

Low Oil Well Density

Real space to fuzzy space conversion



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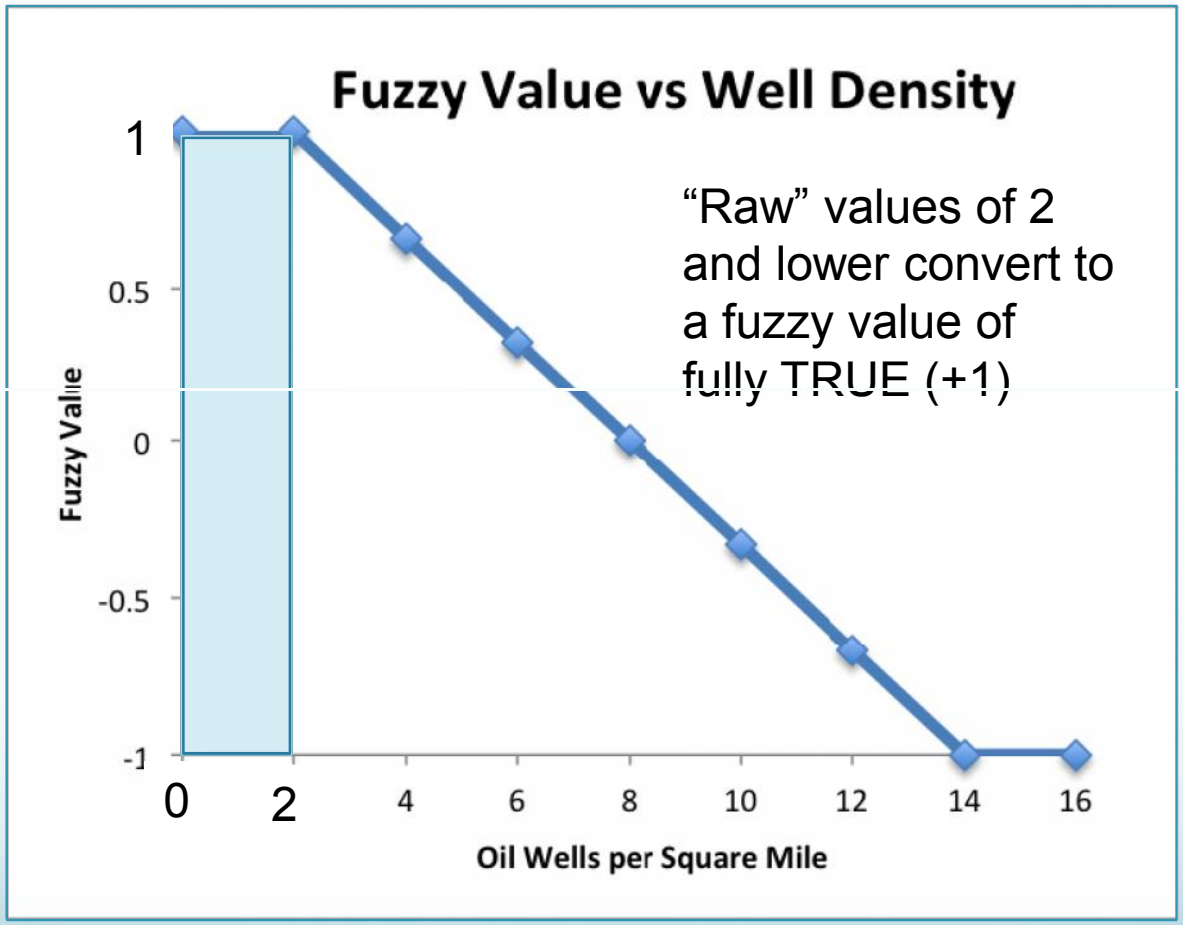

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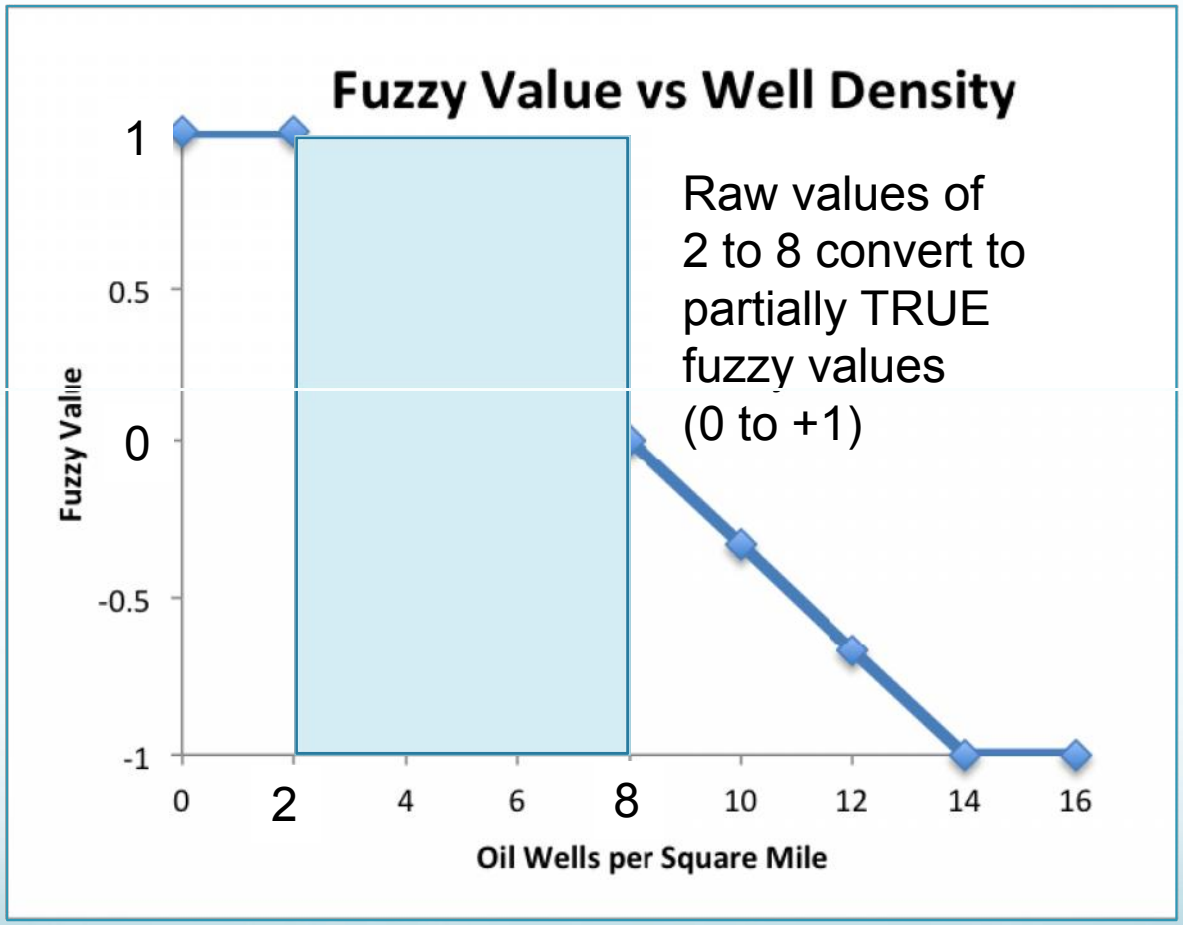

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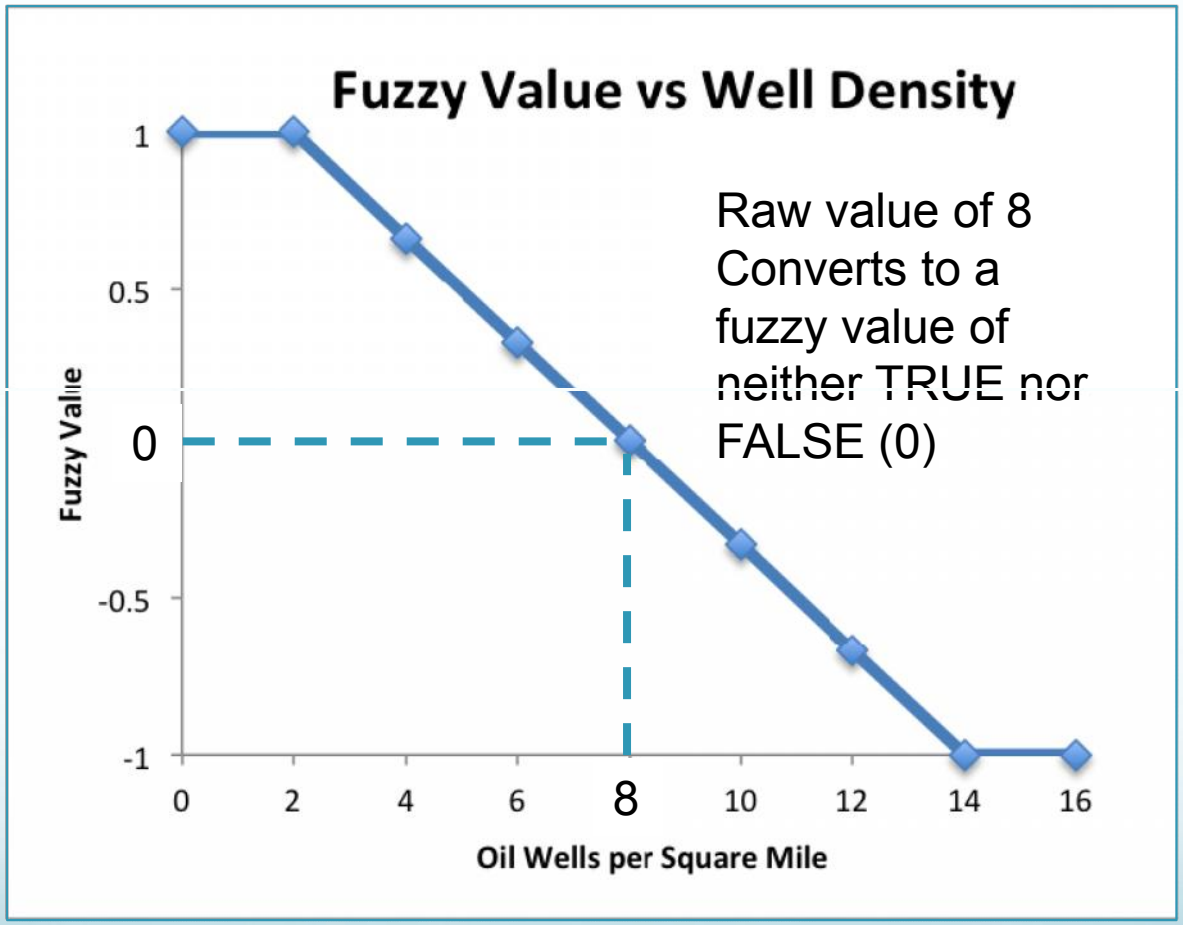

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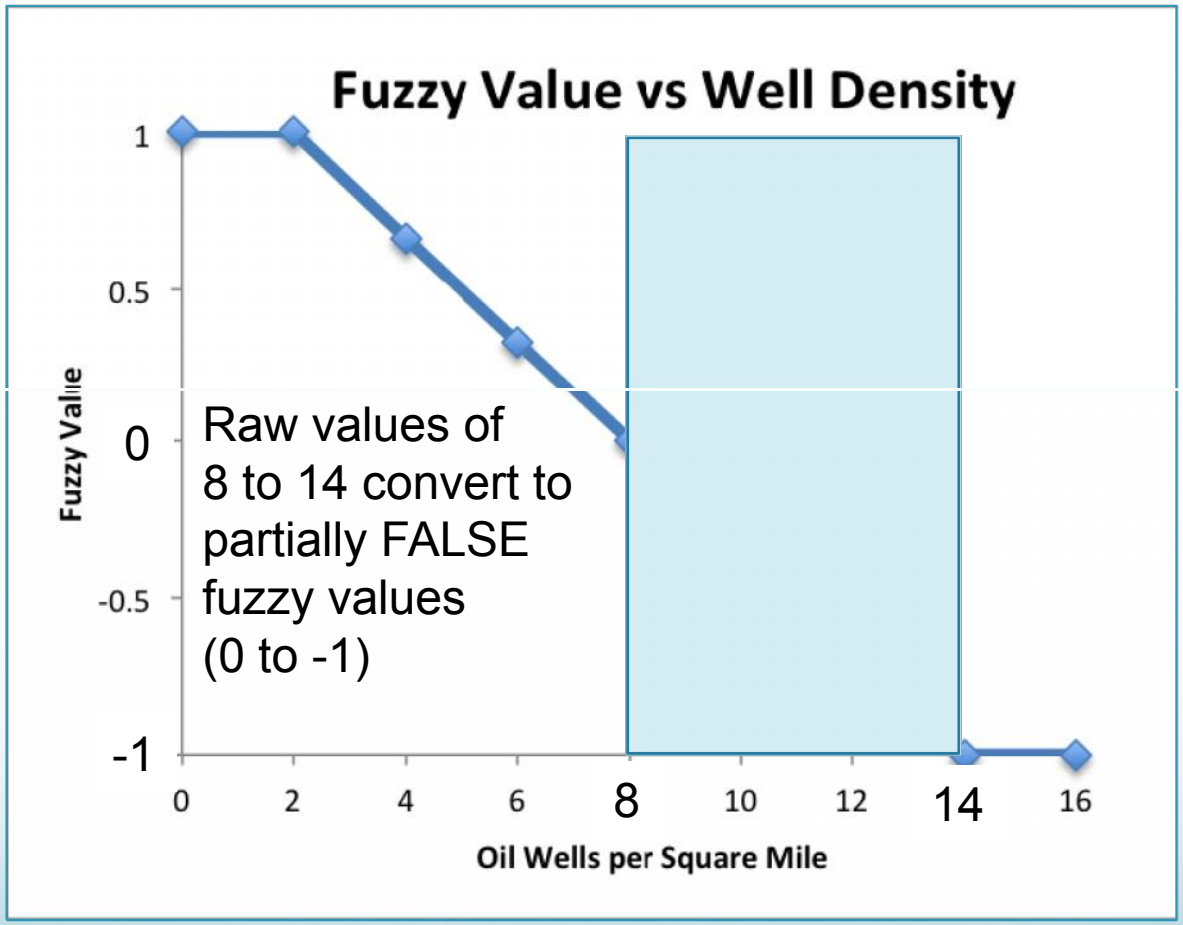

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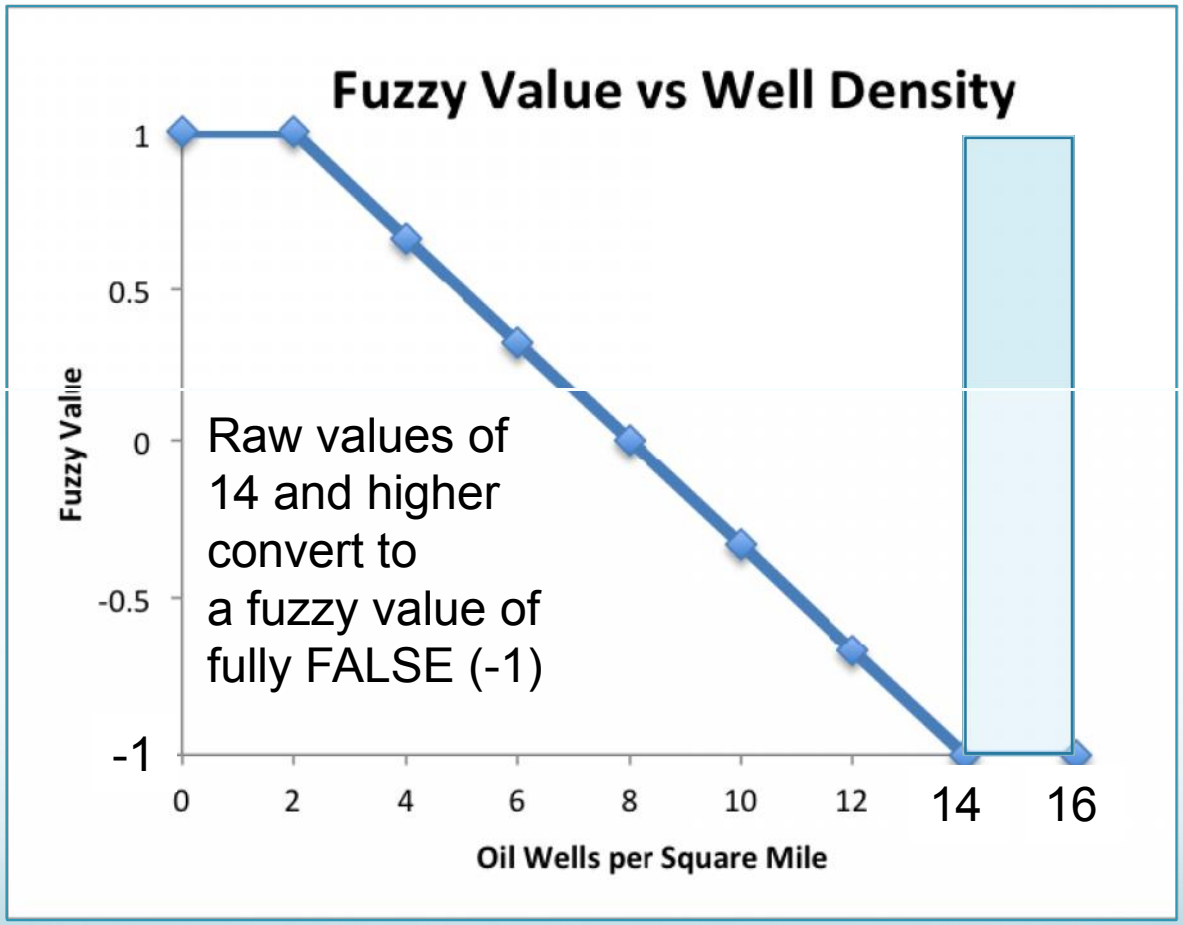

Fuzzy Logic Operators

- Take fuzzy value(s) as input
- Produce a single fuzzy value as output
- Provide flexibility in how variables are combined

NOT Operator

- Single input.
- Returns the negative of the current value.
- TRUEness and FALSEness are swapped.
- Useful for working with the opposite of the original proposition.
- e.g. “Has high vegetation coverage” to “Has low vegetation coverage.”

UNION Operator

- Two or more inputs.
- Returns the mean of the inputs.
- Useful for spatially overlapping conditions in which all contribute further to a result.
- e.g. “High agricultural development” and “High oil and gas development” contributing to “High non-residential development.”

WEIGHTED UNION Operator

- Two or more inputs.
- Returns the weighted mean of the inputs.
- Useful for spatially overlapping conditions in which conditions contribute differentially to a result.
- e.g. “Low agricultural development” and “Low abandoned mineral development” contributing to “High restoration potential.”

OR Operator

- Two or more inputs.
- Returns the TRUEest of the inputs.
- Useful when one of the input conditions is sufficient for the output condition.
- E.g. “High in desert tortoise habitat” and “High in California condor habitat” contributing to “High in endangered species habitat.”

ORNEG (negative OR) Operator

- Two or more inputs.
- Returns the FALSEest of the inputs values.
- Useful when all of the input conditions are necessary for the output condition.
- e.g. “Low annual precipitation” and “High distance from roads” contributing to “Highly suitable western diamondback rattlesnake habitat.”

AND operator

- Two or more operators
- In some fuzzy logic systems, equivalent to ORNEG, in others (e.g. EMDS), returns a value weighted strongly towards the FALSEST of the input values.
- Useful when all of the input conditions are necessary for the output condition.
- e.g. “Low annual precipitation” and “High distance from roads” contributing to “Highly suitable diamondback rattlesnake habitat.”

SELECTED UNION

- Three or more inputs.
- A hybrid of the AND and OR operators.
- User specifies:
  - How many of the inputs to consider.
  - Whether the considered inputs are TRUEest or FALSEest
- Operator takes the mean (UNION) of the selected inputs.

SELECTED UNION (cont'd)

- Useful when a limited number of many input conditions contribute to the output condition.
- e.g. "Low agricultural development," "Low road density," "Low mining density," and "Low urban development," and "Low logging density" contributing to "High runoff water quality."