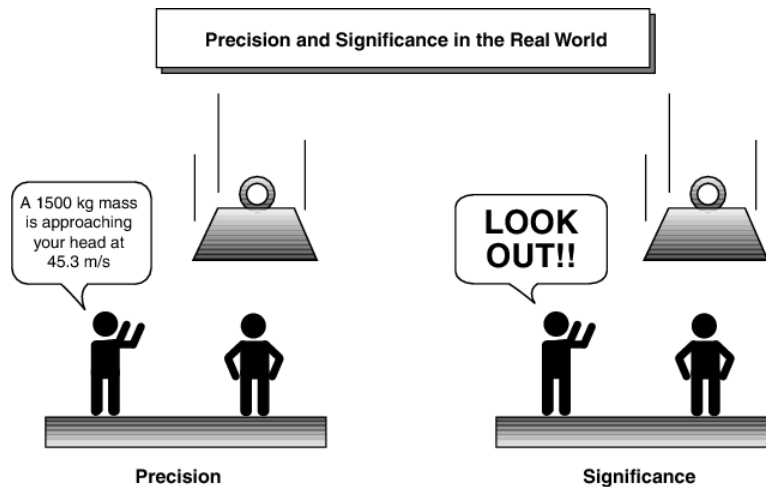


FUZZY INFERENCE SYSTEMS



WATS 4931/6921: OPTIONAL SESSION

April 10, 2014



FIS WORKSHOP PLAN



A. Some Terminology & Definitions



B. Building your own Inference System



C. Some Example FIS Applications



D. Building an FIS



E. Applying FIS in Matlab



F. Applying FIS spatially



G. Building Your Own FIS

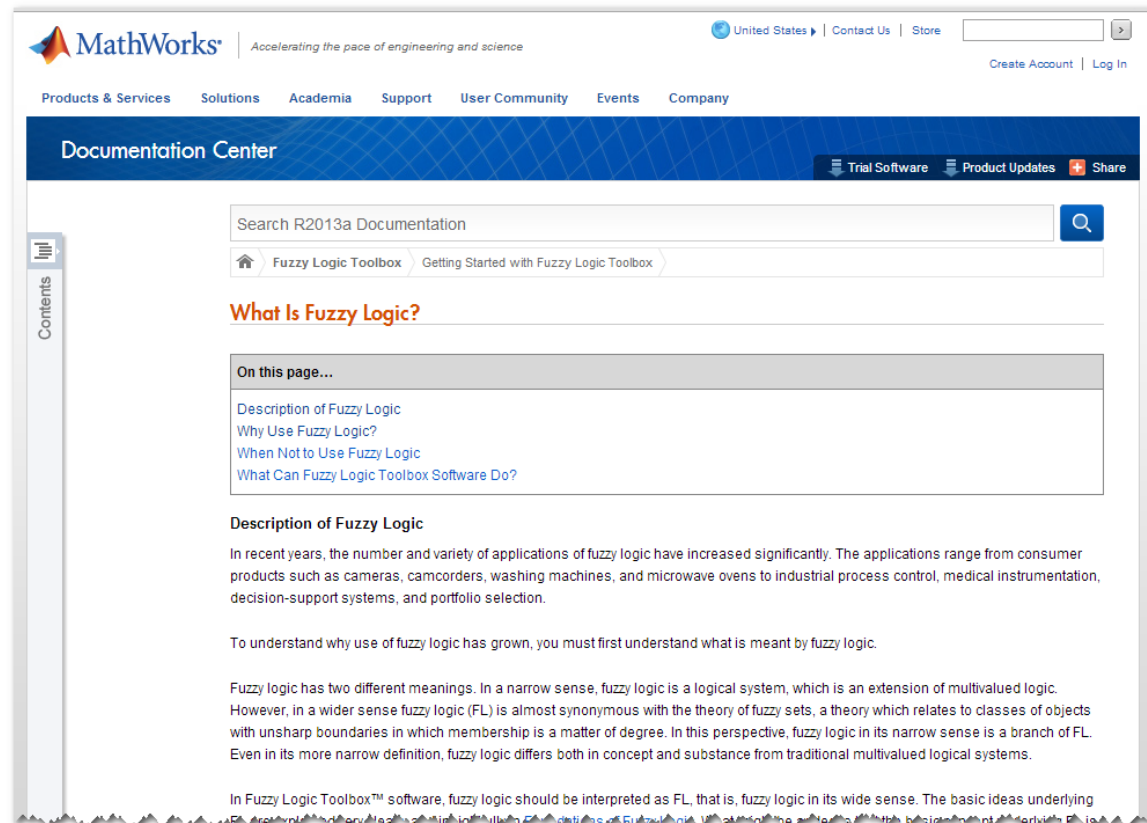


H. Summary of Key Concepts



SOME TERMS...

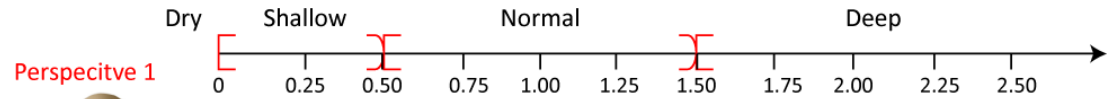
- Fuzzy Sets vs. Crisp Sets
- Fuzzy Logic
- Fuzzy Inference



The screenshot shows the MathWorks Documentation Center interface. At the top, the MathWorks logo and tagline 'Accelerating the pace of engineering and science' are visible. Navigation links for 'Products & Services', 'Solutions', 'Academia', 'Support', 'User Community', 'Events', and 'Company' are present. The 'Documentation Center' header is prominent. A search bar is located below the header. The main content area is titled 'What Is Fuzzy Logic?' and includes a section 'On this page...' with links to 'Description of Fuzzy Logic', 'Why Use Fuzzy Logic?', 'When Not to Use Fuzzy Logic', and 'What Can Fuzzy Logic Toolbox Software Do?'. The 'Description of Fuzzy Logic' section explains that in recent years, the number and variety of applications of fuzzy logic have increased significantly, ranging from consumer products to industrial process control. It also states that to understand why use of fuzzy logic has grown, one must first understand what is meant by fuzzy logic. The text further clarifies that fuzzy logic has two different meanings: a narrow sense (a logical system) and a wider sense (synonymous with the theory of fuzzy sets). The page concludes by stating that in Fuzzy Logic Toolbox™ software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense.

CRISP VS. FUZZY SETS

CRISP CATEGORIZATION OF CONTINUOUS VARIABLE

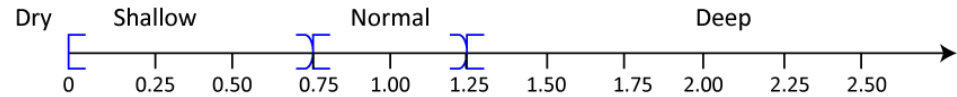


Perspective 1

“Dry” is Water Depth < 0 :
 “Shallow” is Water Depth from 0 to 0.5
 “Normal” is Water Depth from 0.5 to 1.50
 “Deep” is Water Depth > 1.50

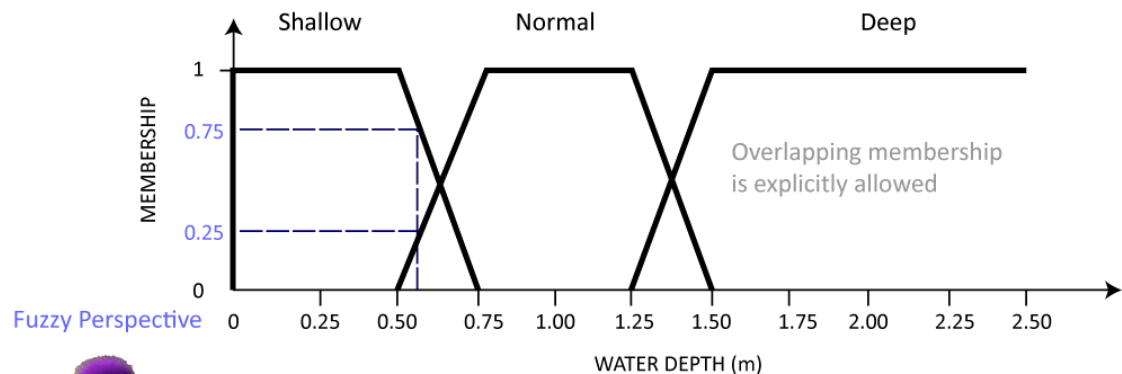
**CATEGORICAL AMBIGUITY
BETWEEN PERSPECTIVES**

Perspective 2



“Dry” is Water Depth < 0
 “Shallow” is Water Depth from 0 to 0.75
 “Normal” is Water Depth from 0.75 to 1.25
 “Deep” is Water Depth > 1.25

FUZZY MEMBERSHIP IN CATEGORIES BASED ON AMBIGUITY/ UNCERTAINTY



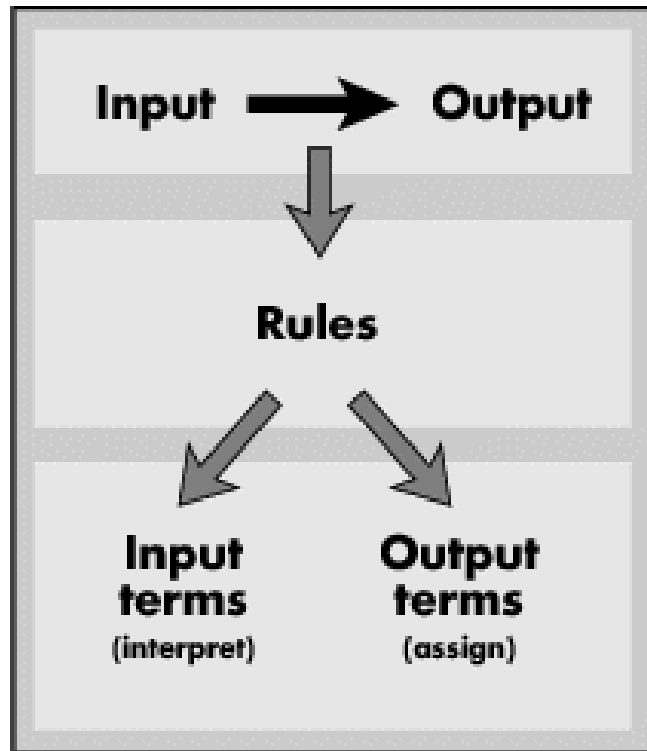
Fuzzy Perspective



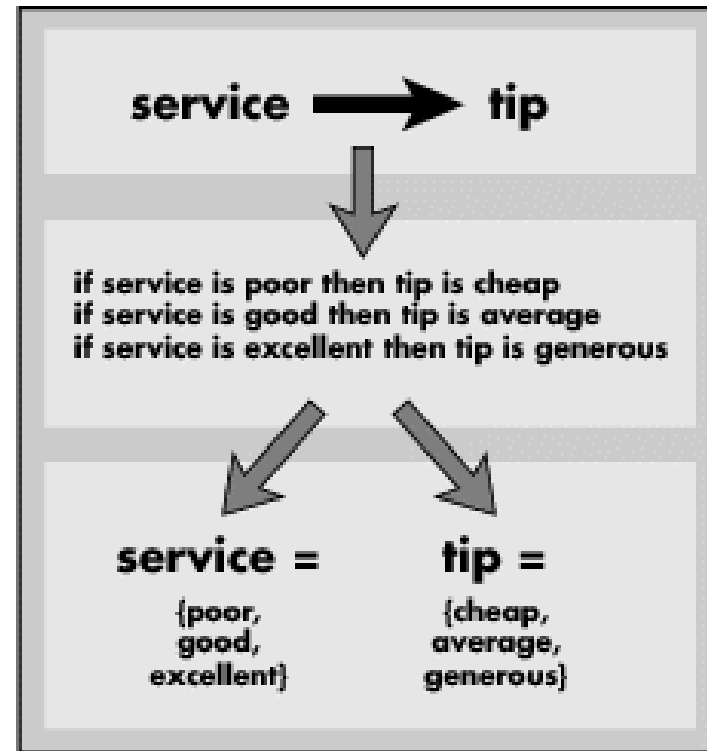
A water depth of 0.60 m has a 75% membership in the “Shallow” category and a 25% membership in the “Normal” Category

AN INFERENCE SYSTEM – RULE BASED

The General Case...

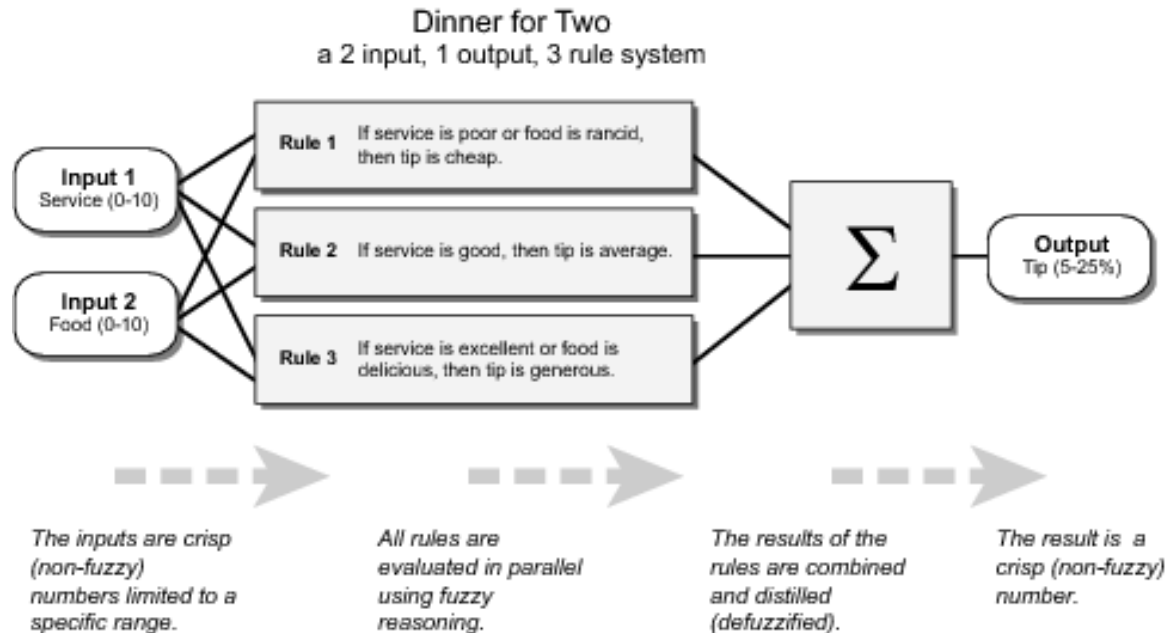


A Specific Example...



FUZZY INFERENCE PROCESS

Process of **formulating mapping** from a given input to an output using fuzzy logic.



- Parallel nature of rules essential
- Instead of sharp switching, logic flows smoothly from regions where behavior is dominated by either one rule or another

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H. Summary of Key Concepts



WHAT IS AN INFERENCE SYSTEM

- AKA:
 - Rule table
 - Look up Table
- Given inputs $a, b, \dots, N \rightarrow$ output is?



AN INFERENCE SYSTEM OR RULE TABLE

- All Words...
 - E.g. Rule 1: 'If suitability of streamside vegetation is *unsuitable* **and** suitability of riparian/upland vegetation is *unsuitable*, then the dam density capacity is NONE
- How many inputs?
- How many categories for each input?
- How many output categories?
- Why 25 rules?

	INPUTS				OUTPUT
	IF	Suitability of Streamside Vegetation	Suitability of Riparian/Upland Vegetation		Dam Density Capacity
RULES	1	Unsuitable	& Unsuitable	, then	None
	2	Barely Suitable	& Unsuitable	, then	Occasional
	3	Moderately Suitable	& Unsuitable	, then	Occasional
	4	Suitable	& Unsuitable	, then	Occasional
	5	Preferred	& Unsuitable	, then	Frequent
	6	Unsuitable	& Barely Suitable	, then	Occasional
	7	Barely Suitable	& Barely Suitable	, then	Occasional
	8	Moderately Suitable	& Barely Suitable	, then	Occasional
	9	Suitable	& Barely Suitable	, then	Frequent
	10	Preferred	& Barely Suitable	, then	Frequent
	11	Unsuitable	& Moderately Suitable	, then	Occasional
	12	Barely Suitable	& Moderately Suitable	, then	Occasional
	13	Moderately Suitable	& Moderately Suitable	, then	Frequent
	14	Suitable	& Moderately Suitable	, then	Frequent
	15	Preferred	& Moderately Suitable	, then	Frequent
	16	Unsuitable	& Suitable	, then	Occasional
	17	Barely Suitable	& Suitable	, then	Occasional
	18	Moderately Suitable	& Suitable	, then	Frequent
	19	Suitable	& Suitable	, then	Frequent
	20	Preferred	& Suitable	, then	Frequent
	21	Unsuitable	& Preferred	, then	Occasional
	22	Barely Suitable	& Preferred	, then	Frequent
	23	Moderately Suitable	& Preferred	, then	Frequent
	24	Suitable	& Preferred	, then	Pervasive
	25	Preferred	& Preferred	, then	Pervasive



HOW WOULD I WRITE PSEUDO CODE FOR AN INFERENCE SYSTEM?

- Let's write it out...



PROs & CONs of INFERENCE SYSTEM

Pros

- Easy to apply and transparent
- Flexibility in number of inputs and categories

Cons

- Potentially subjective expert judgment
- Number of rules can grow... substantially



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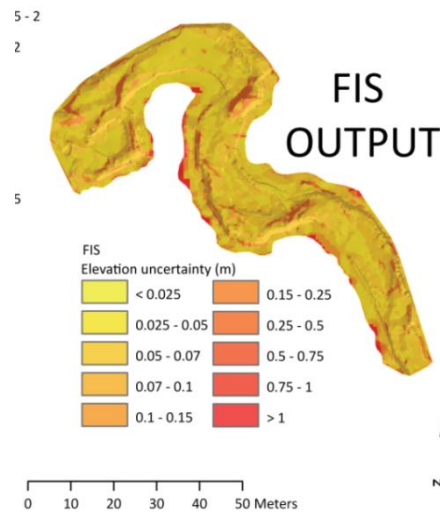


H. Summary of Key Concepts

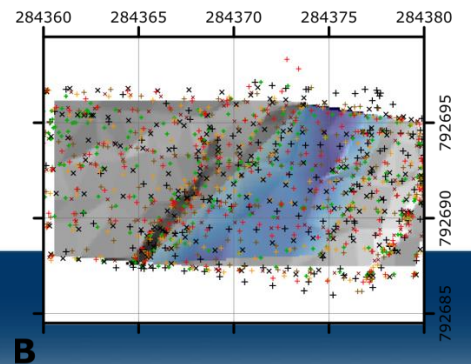


ELEVATION UNCERTAINTY

- Given a point cloud
- Relationship between topographic complexity (slope) and sampling (point density)

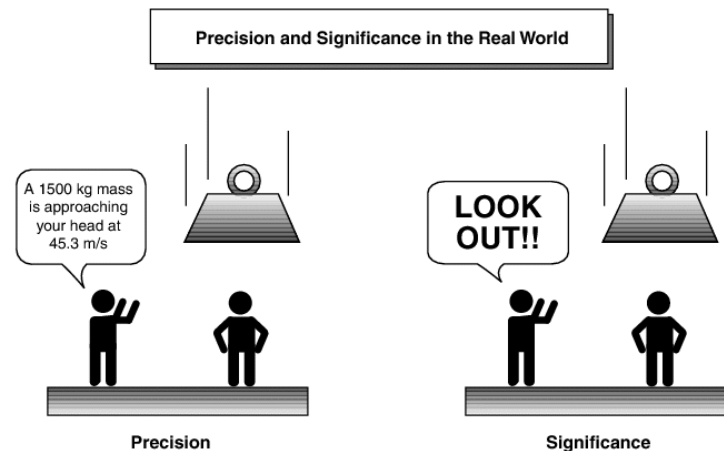
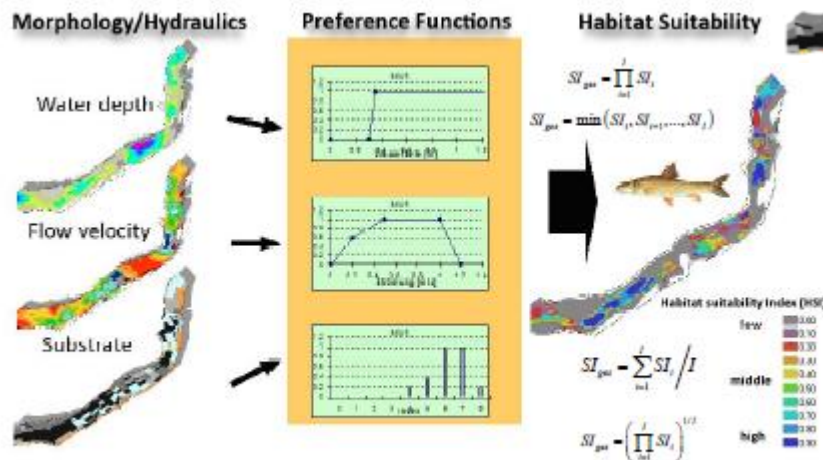
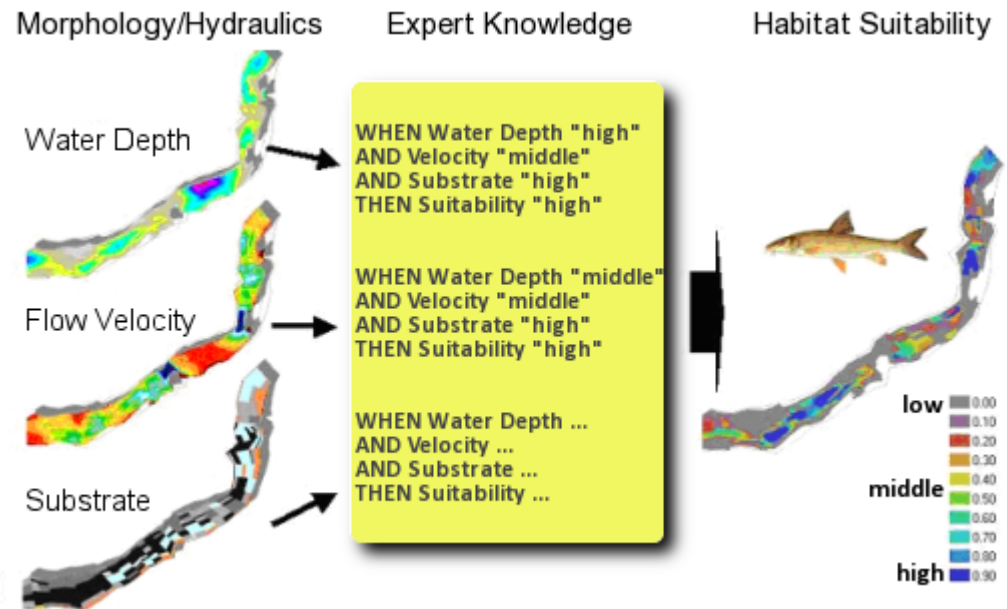


Rule:	Inputs		Output
	Slope %	Pt. ρ m/pts ²	$\delta(z)$ m
1	Low	Low	Average
2	Low	Medium	Low
3	Low	High	Low
4	Medium	Low	High
5	Medium	Medium	High
6	Medium	High	Average
7	High	Low	Extreme
8	High	Medium	High
9	High	High	High



FISH... OR FROG HABITAT

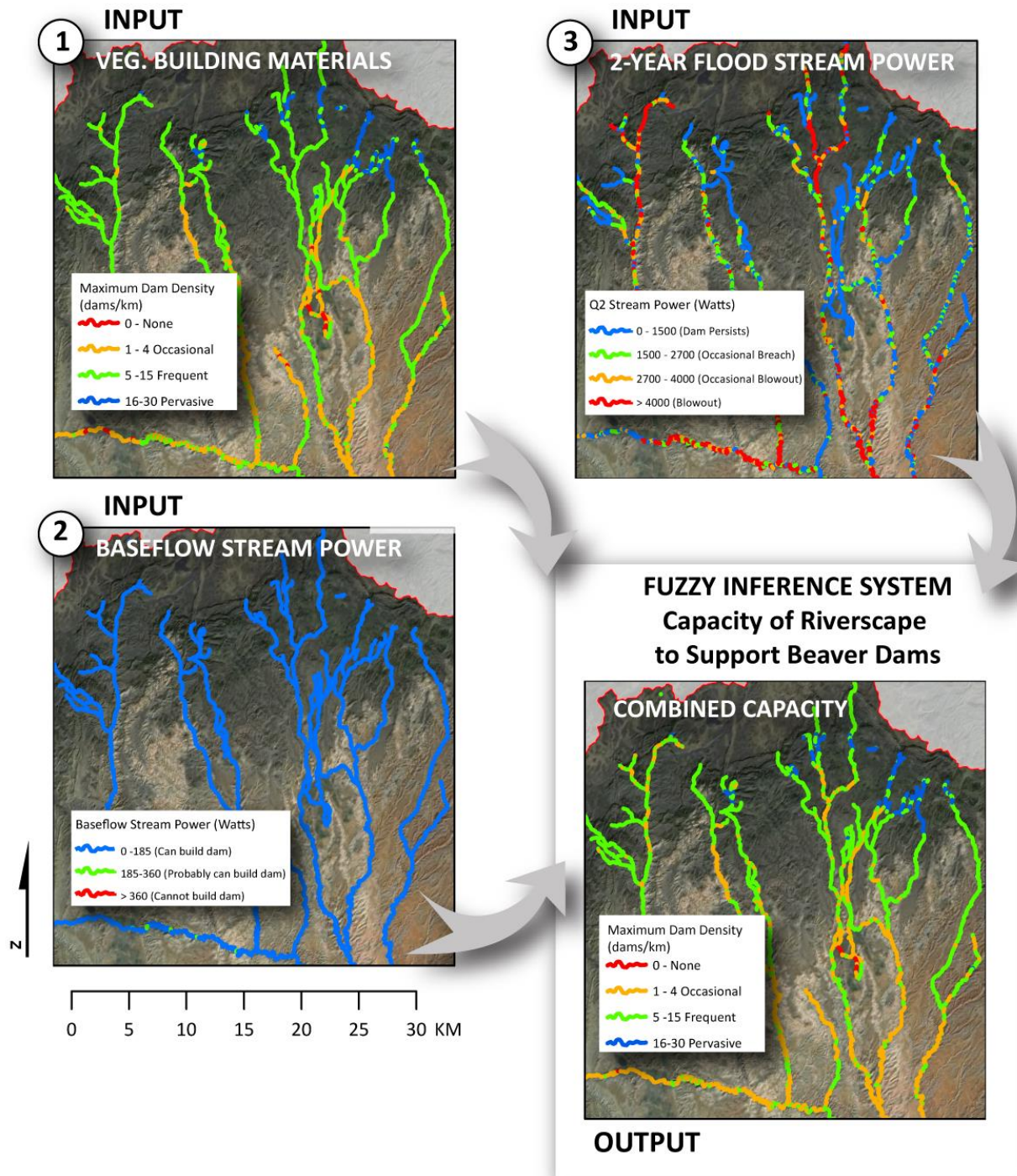
- In contrast to HSI based approach, here we use expert knowledge...



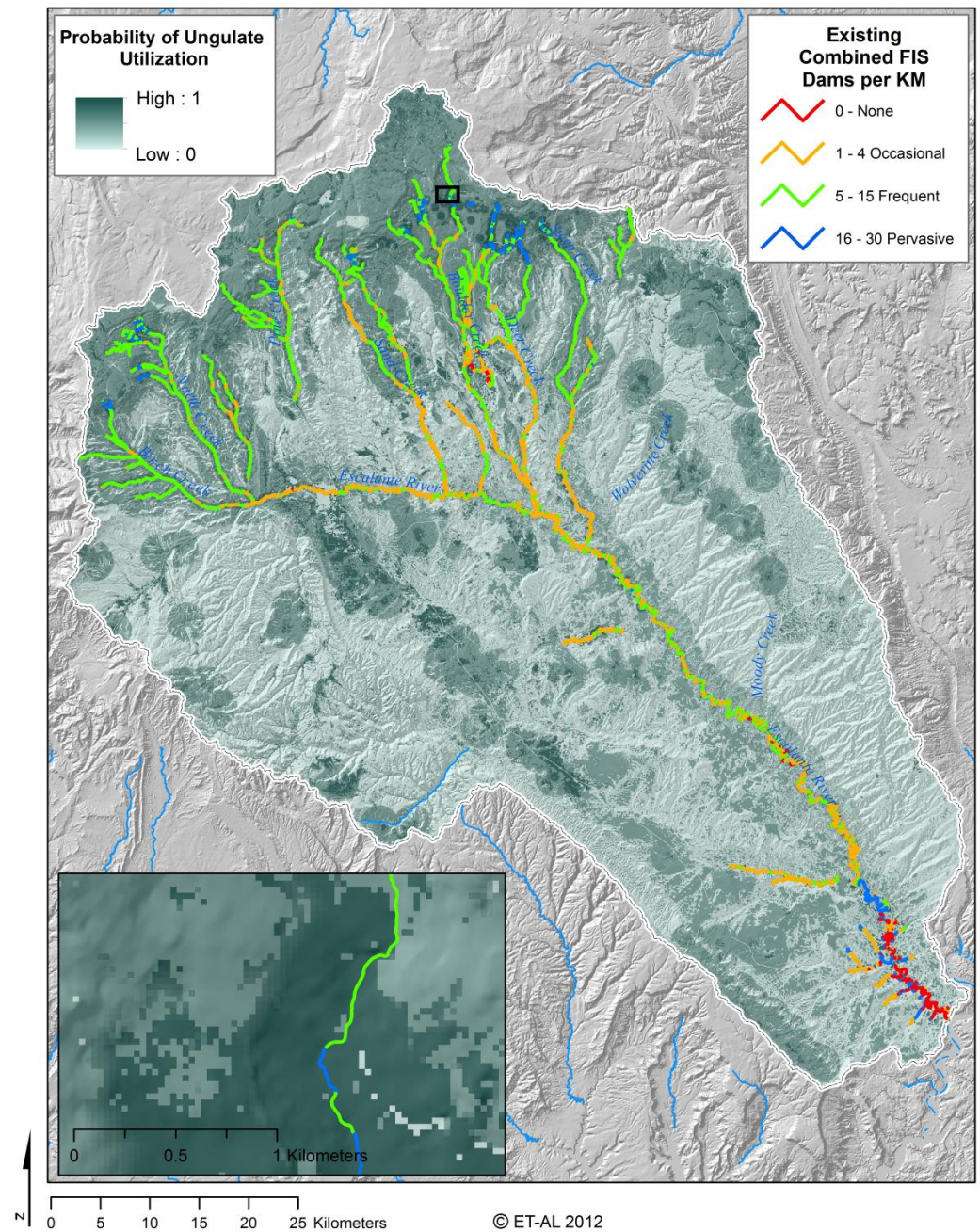
BEAVER

1. Veg FIS
2. Baseflow (can they build a dam?)
3. 2 Year Flood (does dam blow out)

= Resulting Capacity



COWS & BEAVER



ADVANTAGES OF FIS...

- Knowledge about linkages is **imprecise**
- Fuzzy logic calculations consider **multivariate effects** (no assumption of independence)
- **New parameters** incorporated easily
- **Few observations** needed
- Calculation is **understandable** (no black box effect)
- High **flexibility** and adaptability



SOME LIMITATIONS

- FIS inputs need to be represented as continuous variables*
- FIS output must be a continuous variable
- Many scientists are unfamiliar with fuzzy logic



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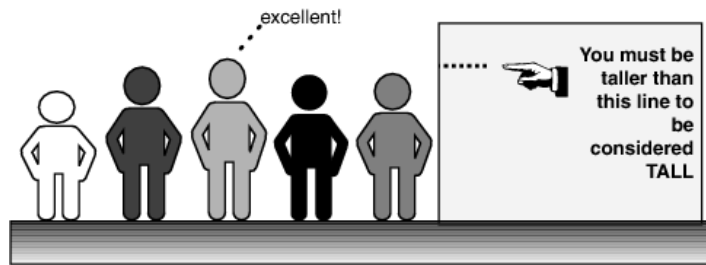
G. Building Your Own FIS



H. Summary of Key Concepts

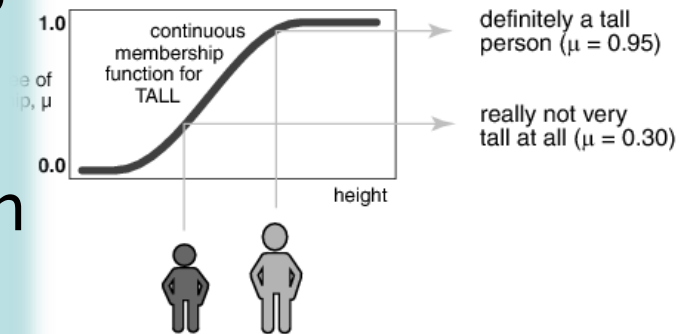
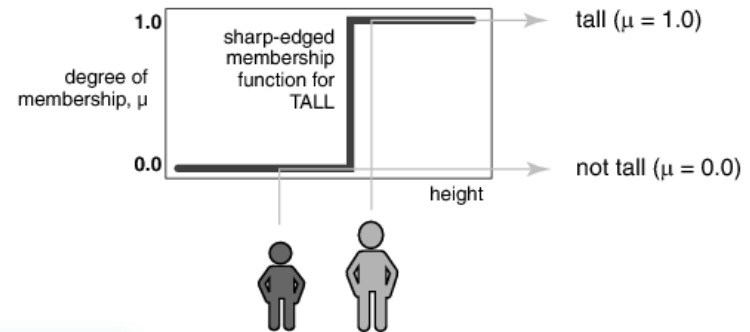


MEMBERSHIP FUNCTIONS — e.g. SEASONS & TALL



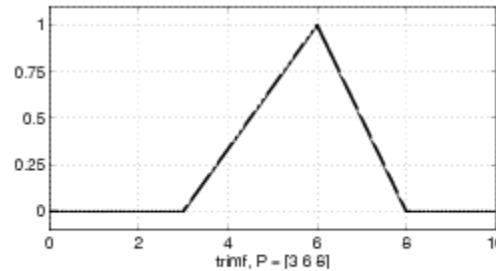
- Fuzzy set theory... useful for classifying continuous variables
- “A *fuzzy set* is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership.” —

“A *membership function* (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1.”

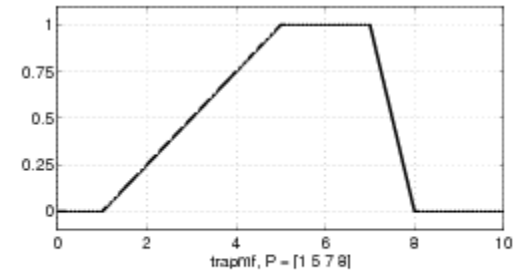


MEMBERSHIP FUNCTIONS CAN HAVE LOTS OF DIFFERENT SHAPES

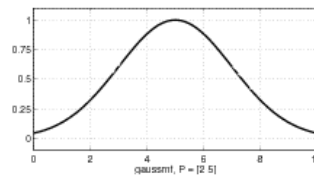
- Triangular
- Trapezoidal
- Gaussian
- Sigmoidal
- Polynomial



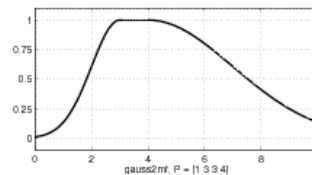
trimf [3 6 8]



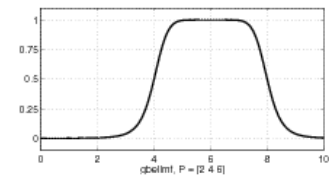
trapmf [1 5 8 9]



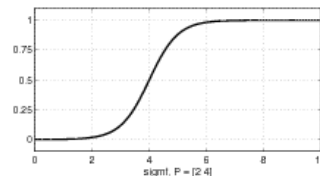
gaussmf



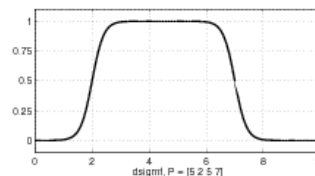
gauss2mf



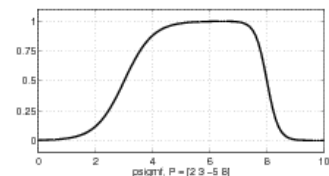
gbellmf



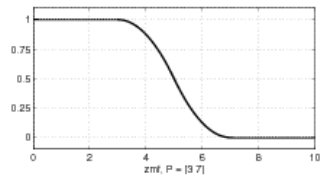
sigmf



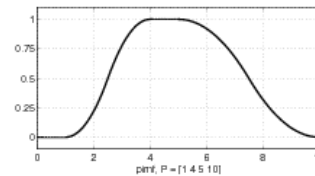
dsigmf



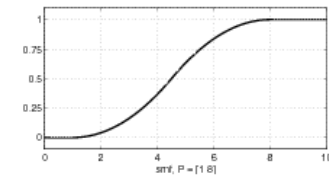
psigmf



zmf



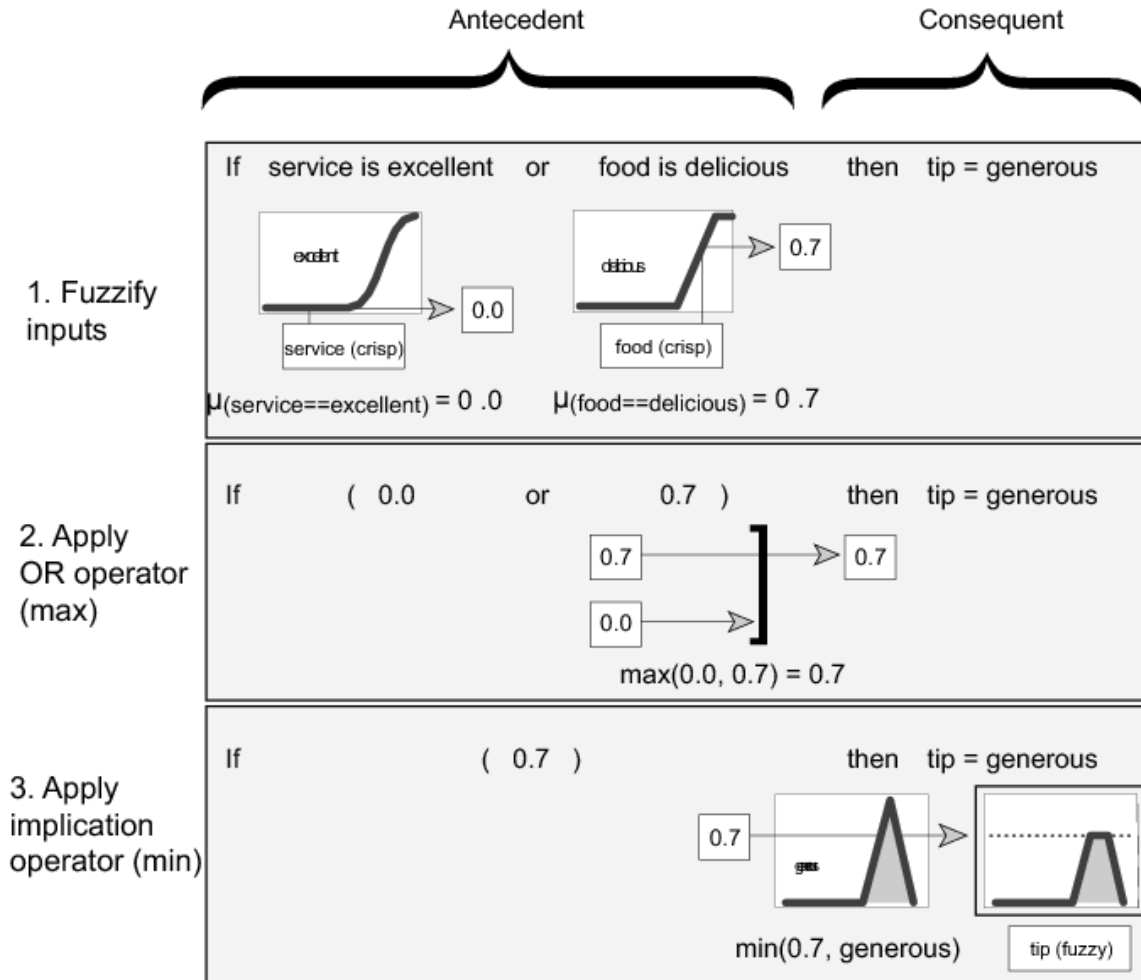
pimf



smf

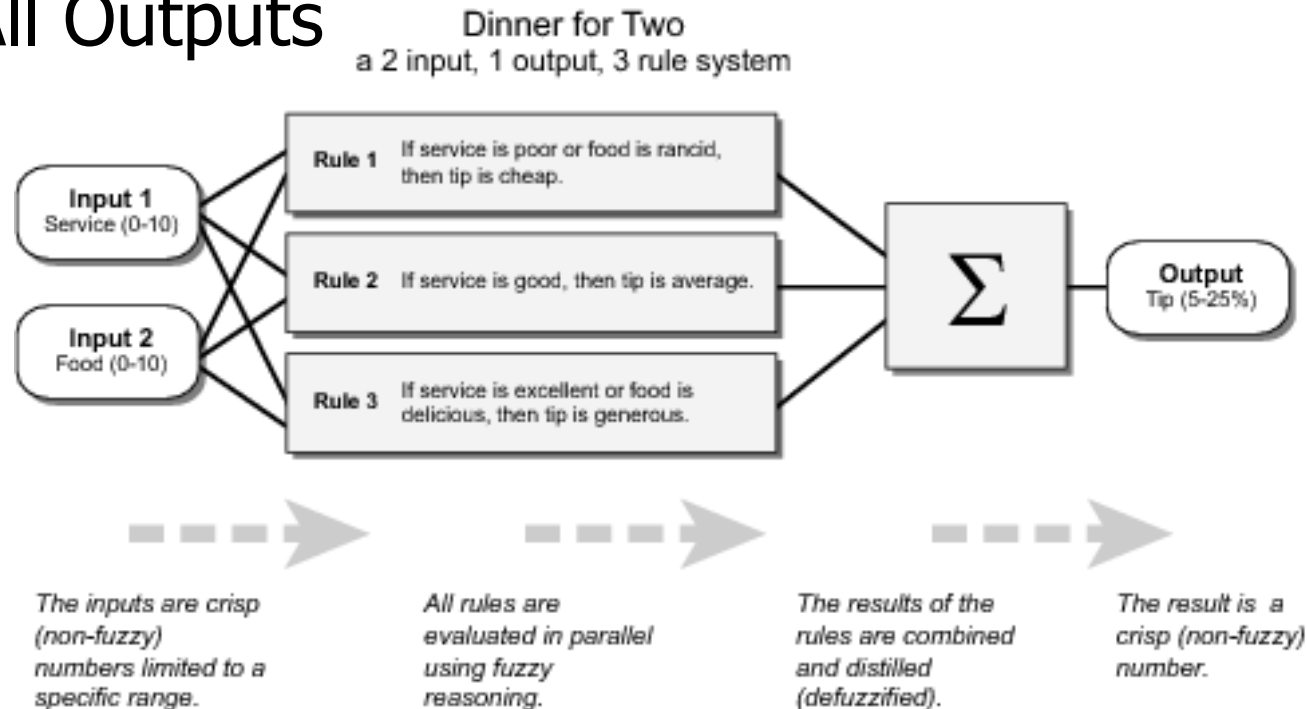


FUZZY INFERENCE SYSTEMS: USES IF, THEN RULES



STEPS IN RUNNING AN FIS (UNDER THE HOOD)

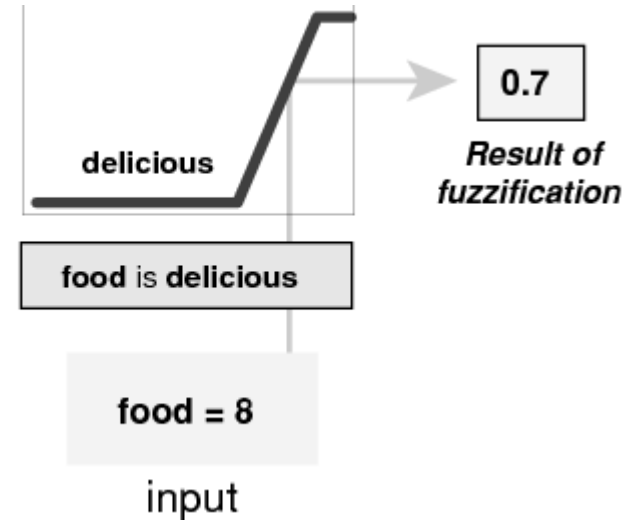
1. Fuzzify Inputs
2. Apply Fuzzy Operator
3. Apply Implication Method
4. Aggregate All Outputs
5. Defuzzify



STEP 1: FUZZIFY INPUTS

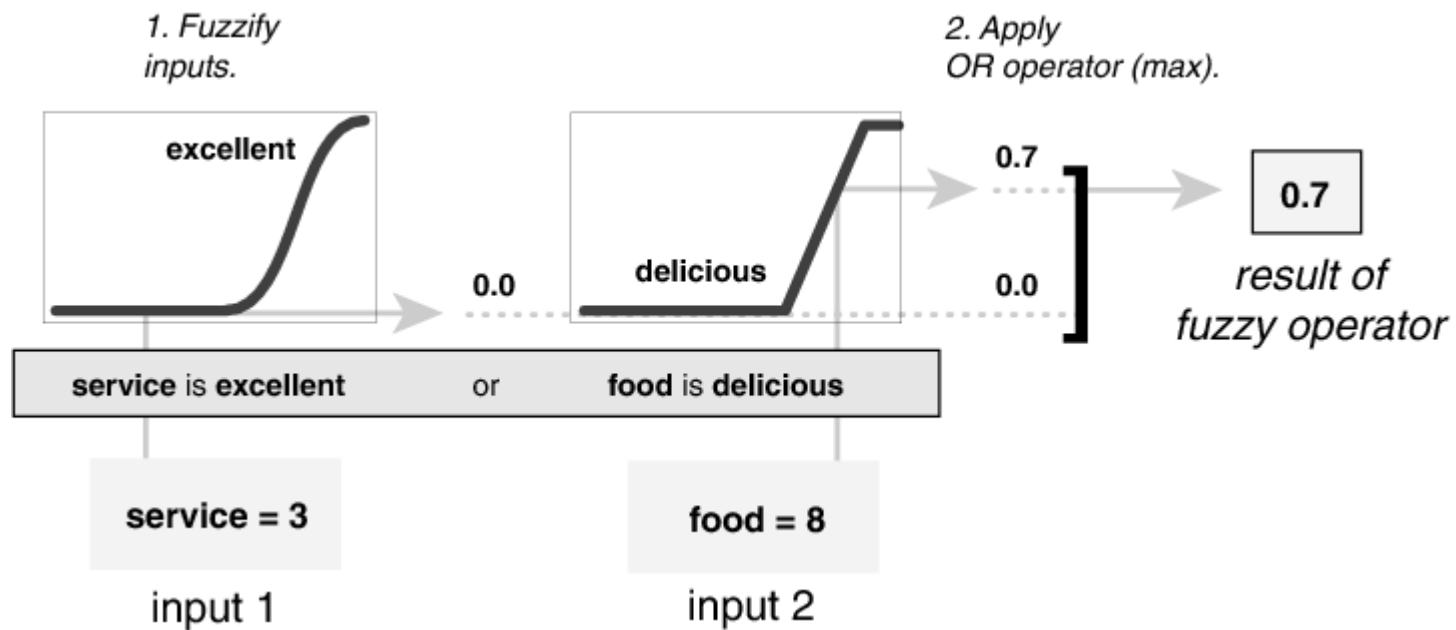
- Go from crisp (continuous) input to fuzzy membership
- Can only be done once input membership functions are defined

1. Fuzzify inputs.



STEP 2: APPLY FUZZY OPERATOR

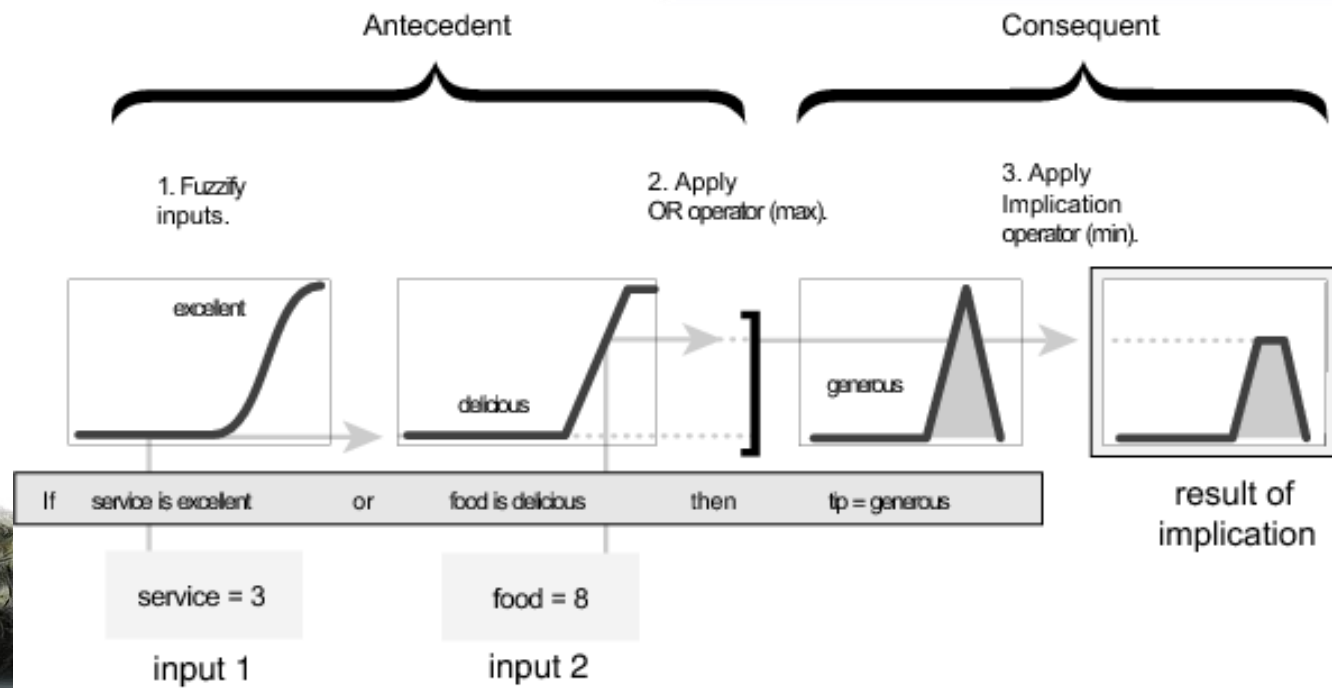
- **AND** methods are supported: *min* (minimum) and *prod* (product).
- **OR** methods are also supported: *max* (maximum), and the probabilistic OR method *probor* (also known as the algebraic sum) is calculated according to the equation: $\text{probor}(a,b) = a + b - ab$



STEP 3: APPLY IMPLICATION METHOD

- A **consequent** is a fuzzy set, which weights appropriately the linguistic characteristics that are attributed to it.
- Reshaped using a function associated with the **antecedent** (a single number).
- Input for **implication** process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule.

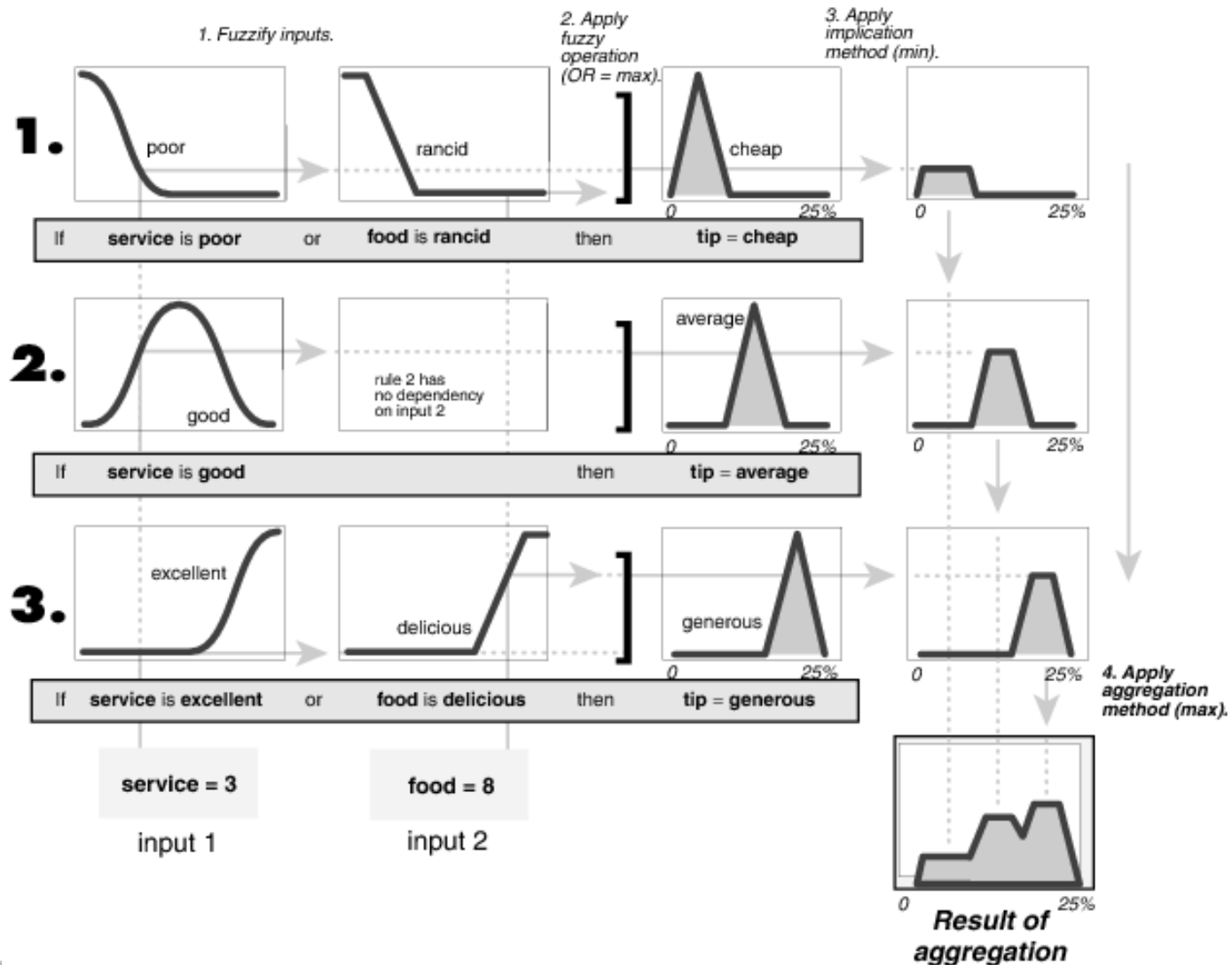
 www.mathworks.com/help/toolbox/fuzzy/fp351dup8.html



STEP 4: AGGREGATE ALL OUTPUTS

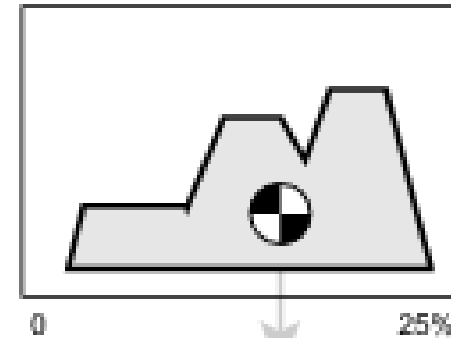
Three built-in methods are supported:

- max (maximum)
- probor (probabilistic OR)
- sum (simply the sum of each rule's output set)



STEP 5: DE-FUZZIFY OUTPUTS

- Five built-in methods supported:
 - Centroid
 - bisector
 - middle of maximum
 - largest of maximum
 - smallest of maximum
- Centroid - most popular defuzzification method - returns the center of area under the curve.



5. Defuzzify the aggregate output (centroid).

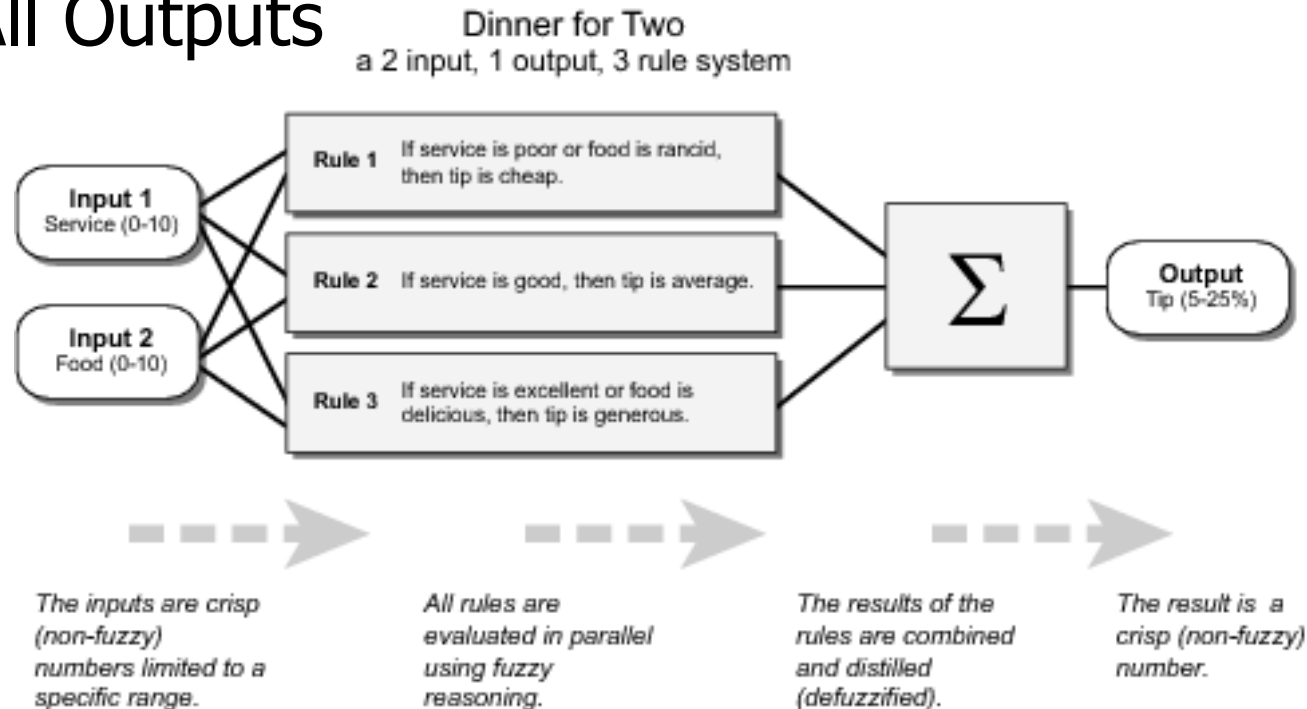
tip = 16.7%

Result of
defuzzification



STEPS IN RUNNING AN FIS (UNDER THE HOOD)

1. Fuzzify Inputs
2. Apply Fuzzy Operator
3. Apply Implication Method
4. Aggregate All Outputs
5. Defuzzify



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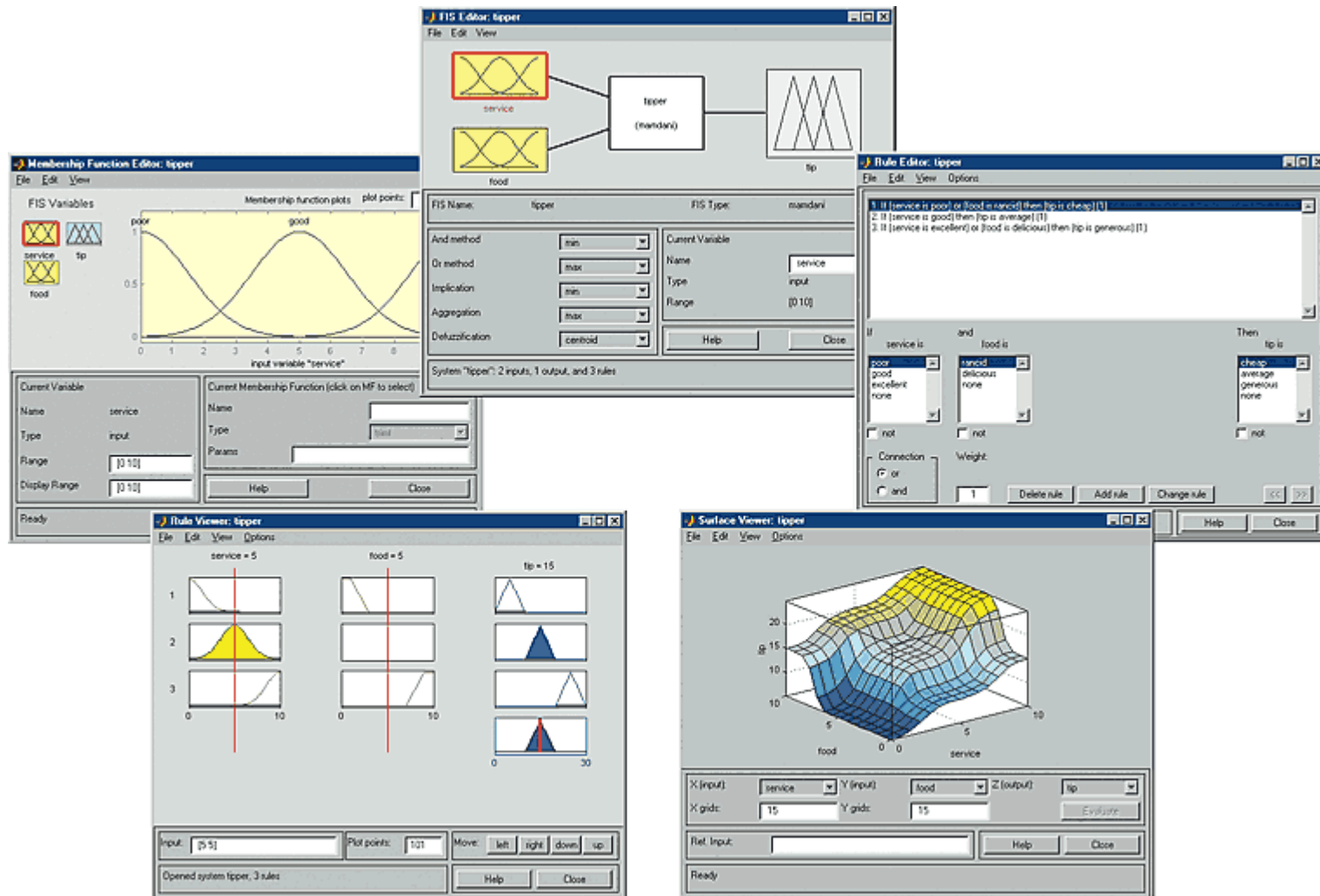
G. Building Your Own FIS



H. Summary of Key Concepts

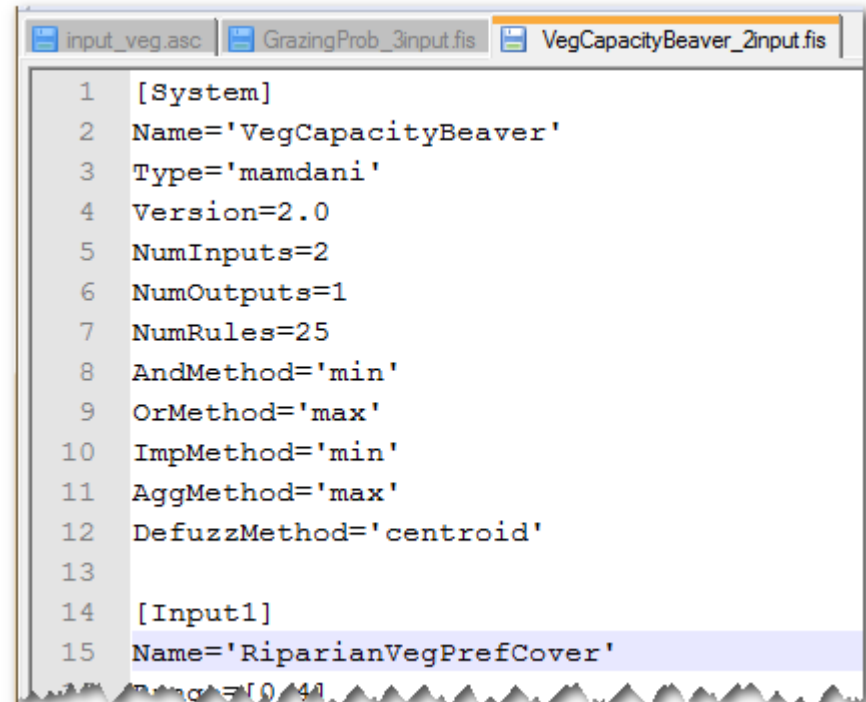


MATLAB FUZZY LOGIC TOOLBOX



THE FIS FILE (*.FIS)

- Simple ascii text file
- Computing w/ words
- Has Header ->
- Section for Inputs
- Section for Outputs
- Rule Table



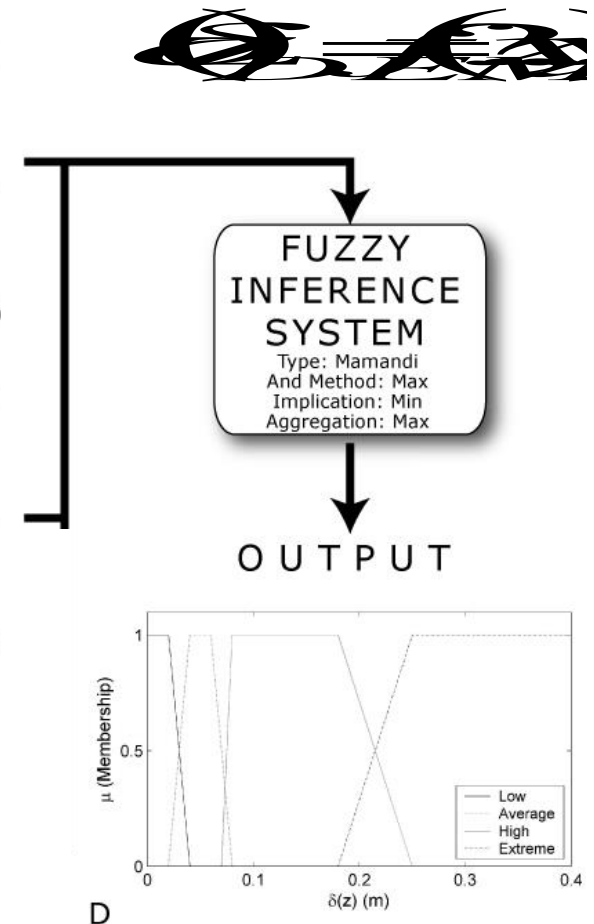
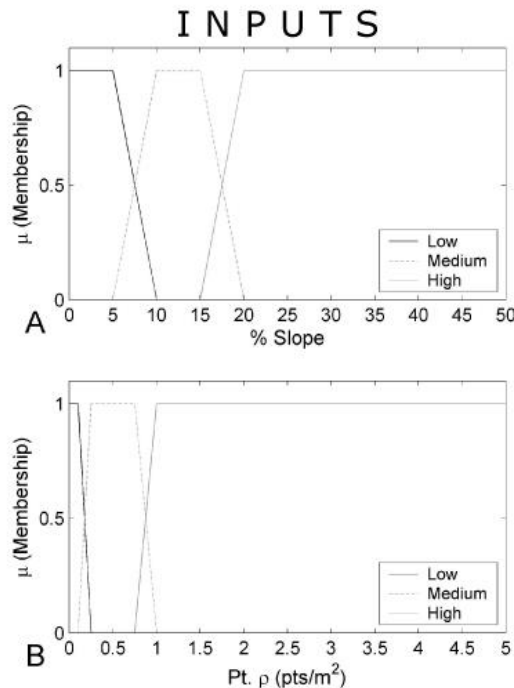
The screenshot shows a text editor window with three tabs: 'input_veg.asc', 'GrazingProb_3input.fis', and 'VegCapacityBeaver_2input.fis'. The active tab is 'VegCapacityBeaver_2input.fis', which displays the following text:

```
1 [System]
2 Name='VegCapacityBeaver'
3 Type='mamdani'
4 Version=2.0
5 NumInputs=2
6 NumOutputs=1
7 NumRules=25
8 AndMethod='min'
9 OrMethod='max'
10 ImpMethod='min'
11 AggMethod='max'
12 DefuzzMethod='centroid'
13
14 [Input1]
15 Name='RiparianVegPrefCover'
```



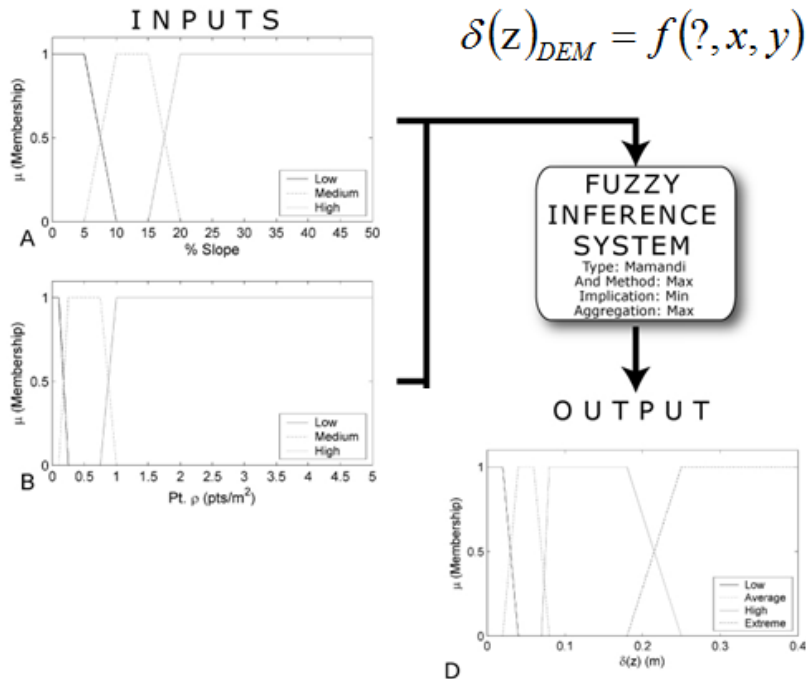
DEFINING MEMBERSHIP FUNCTIONS

- Define Inputs & Output
- Define number of categories in each
- Represent categorical uncertainty (vagueness) with membership functions
- Choose shape (triangular, trapezoidal, sinusoidal)
- Specify each...
- Provide 'words' for categories



DEFINING MEMBERSHIP FUNCTIONS

- * .fis is just a text file:

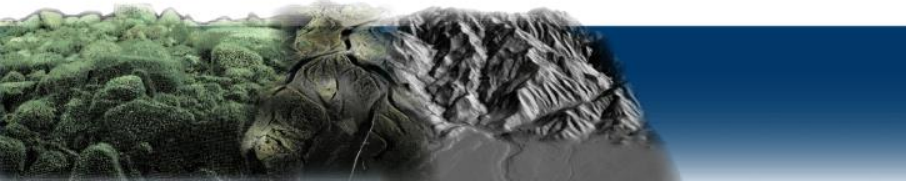


- Edit to specify membership functions...

```

11 AggMethod='max'
12 DefuzzMethod='centroid'
13
14 [Input1]
15 Name='Slope'
16 Range=[0 10000]
17 NumMFs=3
18 MF1='Low':'trapmf',[0 0 5 10]
19 MF2='Medium':'trapmf',[5 10 15 20]
20 MF3='High':'trapmf',[15 20 10000 10000]
21
22 [Input2]
23 Name='PointDensity'
24 Range=[0 100]
25 NumMFs=3
26 MF1='Low':'trapmf',[0 0 0.1 0.25]
27 MF2='Medium':'trapmf',[0.1 0.25 0.75 1]
28 MF3='High':'trapmf',[0.75 1 100 100]
29
30 [Output1]
31 Name='ElevUncertainty'
32 Range=[0 1.5]
33 NumMFs=4
34 MF1='Low':'trapmf',[0 0 0.03 0.06]
35 MF2='Average':'trapmf',[0.03 0.06 0.08 0.10]
36 MF3='High':'trapmf',[0.08 0.10 0.20 0.25]
37 MF4='Extreme':'trapmf',[0.20 0.25 1.5 1.5]
38
39 [Rules]

```



BUILD THE RULE TABLE...

- *.fis is just a text file:

Input 1

Input 2

Output

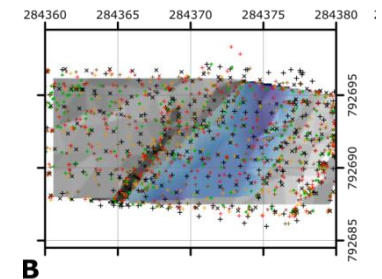
[Rules]

38					
39					
40	1	1,	3	(1)	: 1
41	1	2,	2	(1)	: 1
42	1	3,	1	(1)	: 1
43	2	1,	3	(1)	: 1
44	2	2,	2	(1)	: 1
45	2	3,	1	(1)	: 1
46	3	1,	4	(1)	: 1
47	3	2,	3	(1)	: 1
48	3	3,	2	(1)	: 1
49					

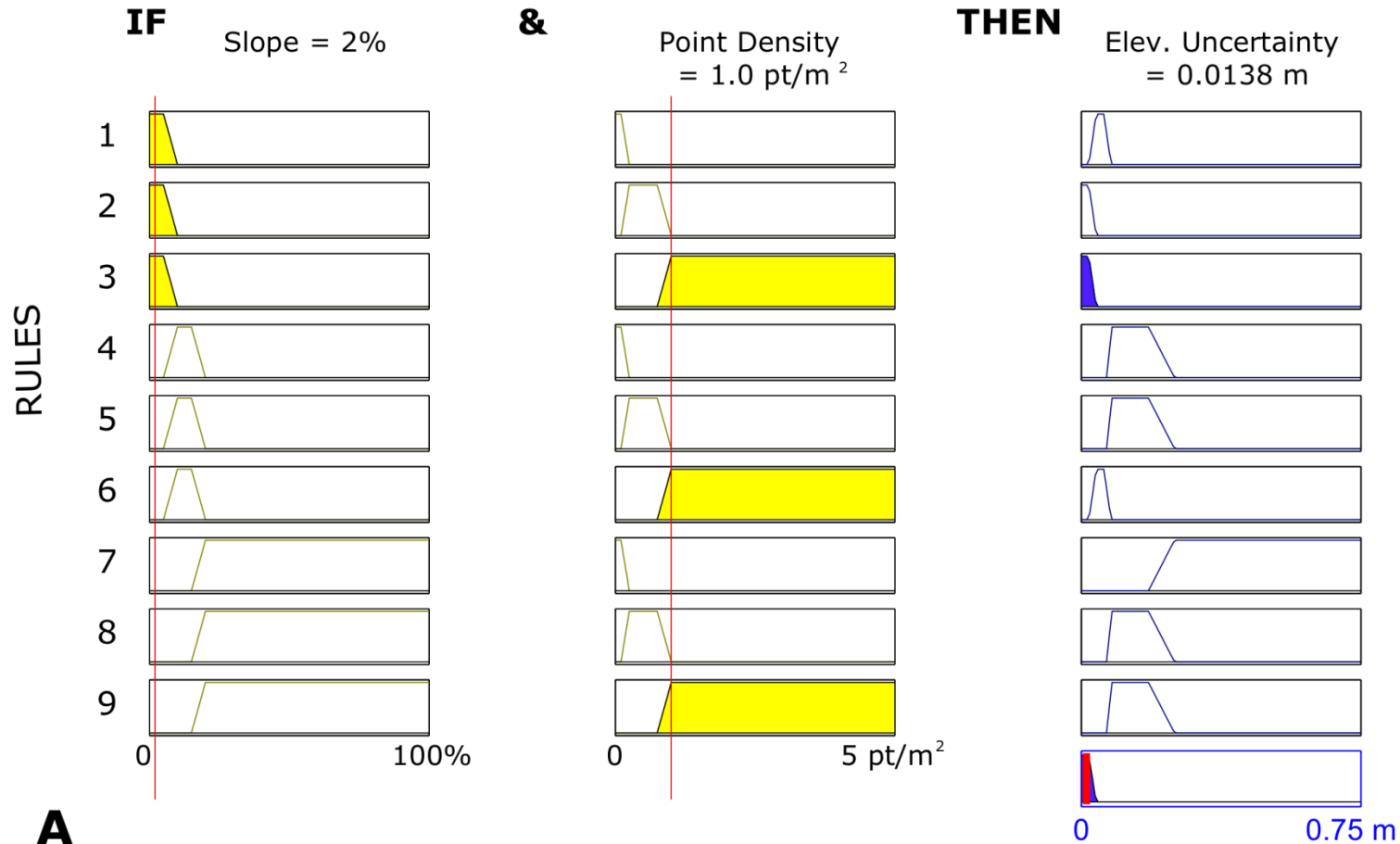
Weight

Operator (1 is **and**; 2 is **or**)

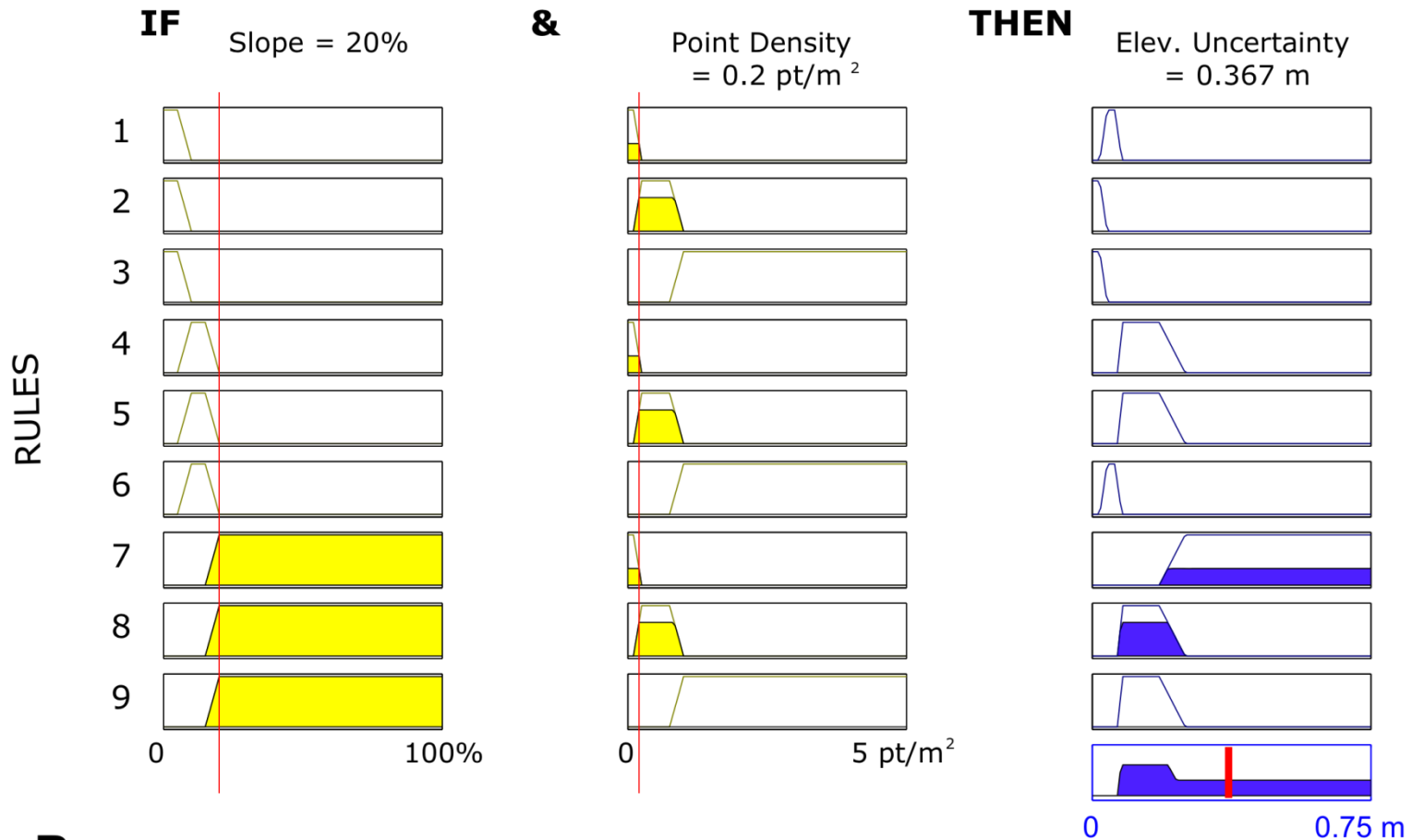
Rule:	Inputs		Output
	Slope %	Pt. ρ m/pts ²	$\delta(z)$ m
1	Low	Low	Average
2	Low	Medium	Low
3	Low	High	Low
4	Medium	Low	High
5	Medium	Medium	High
6	Medium	High	Average
7	High	Low	Extreme
8	High	Medium	High
9	High	High	High



EXAMPLE IMPLEMENTATION (2-RULE)



EXAMPLE IMPLEMENTATION



B



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F. Applying FIS spatially



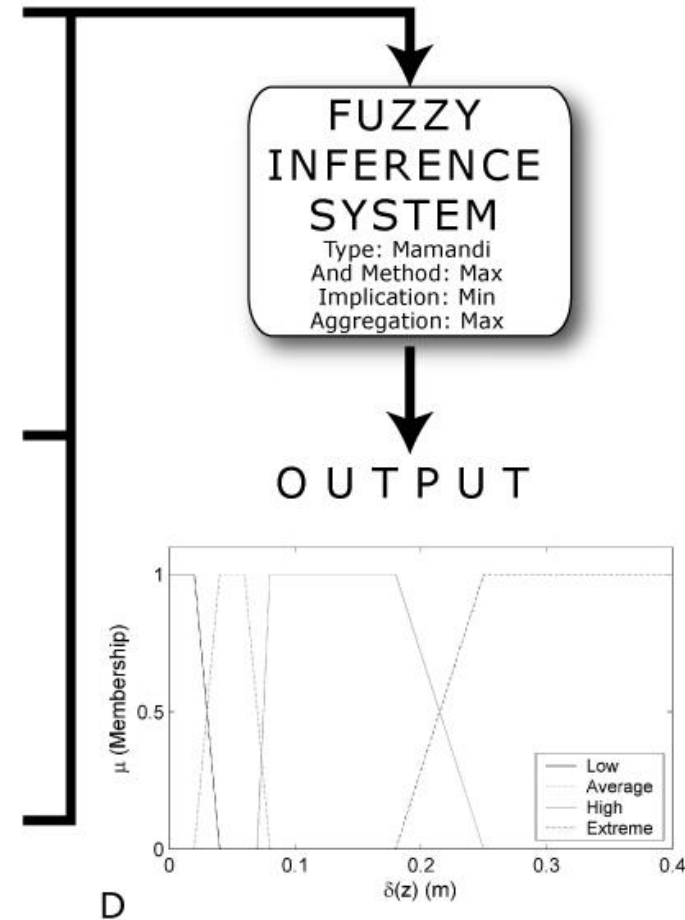
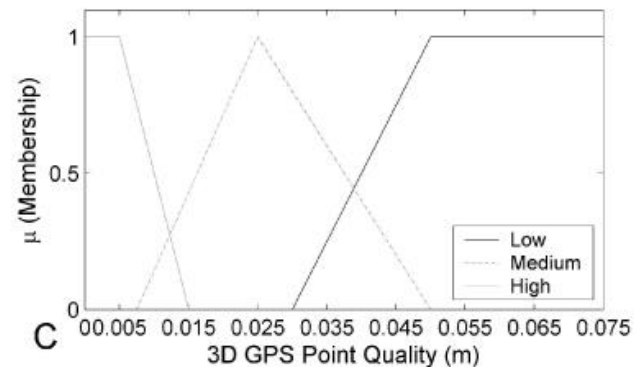
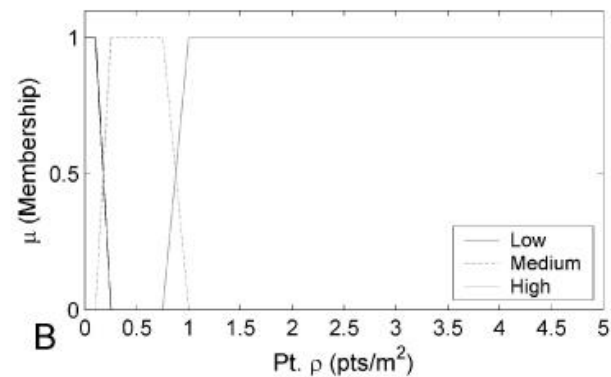
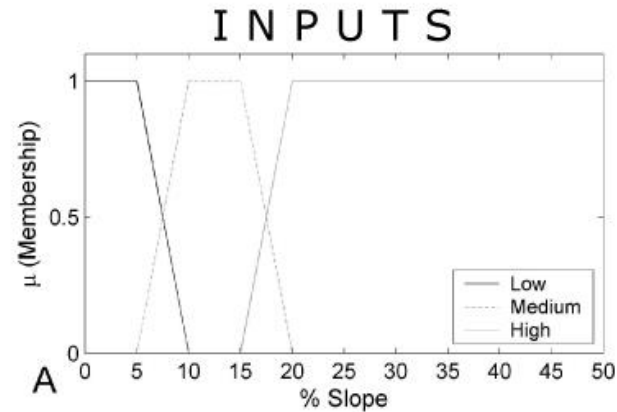
G. Building Your Own FIS



H. Summary of Key Concepts

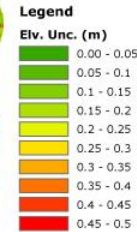
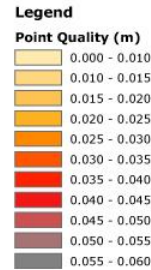
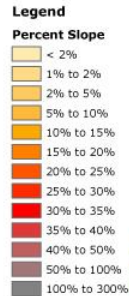
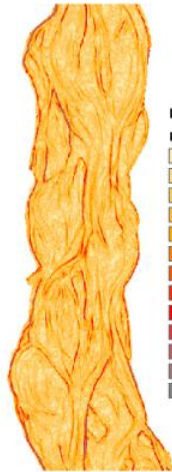
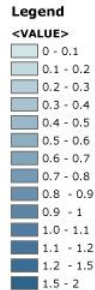
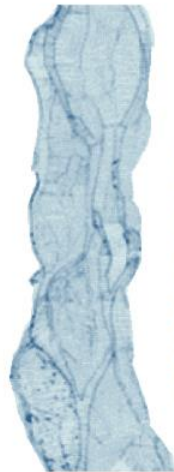


LETS APPLY THIS WITH A REAL EXAMPLE



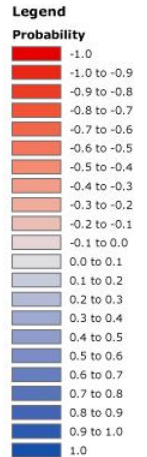
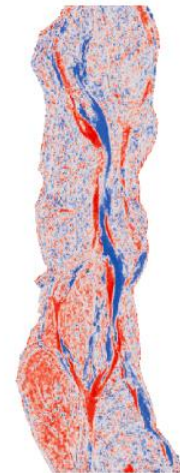
APPLY FIS ON CELL BY CELL BASIS

2006

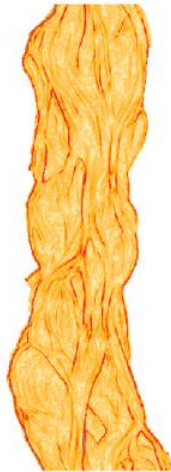
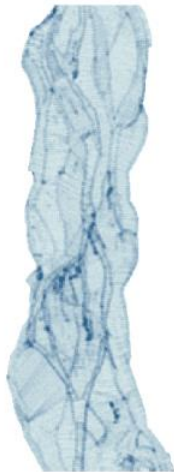


FIS Input 1 (Point Density) + FIS Input 2 (Slope) + FIS Input 3 (GPS Quality) = FIS Surface (El. Unc. (m))

Both FIS Surfaces Combined to DoD Probability

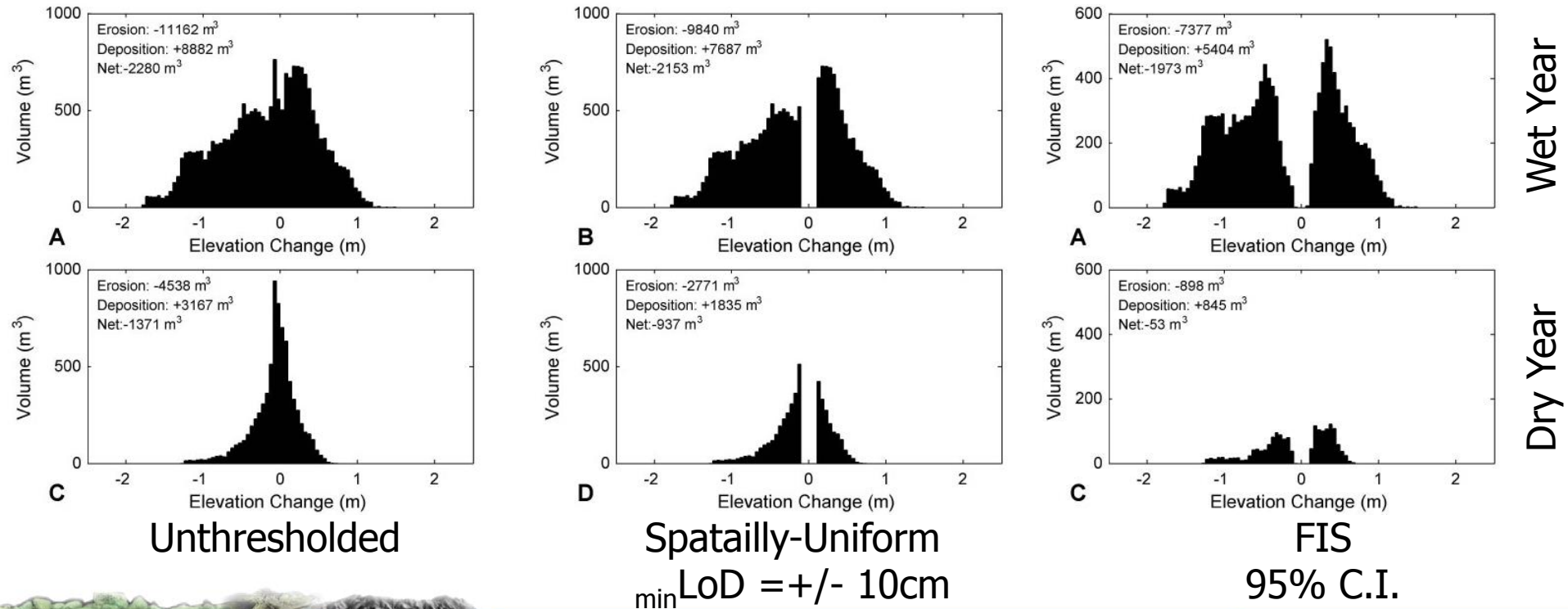


2005



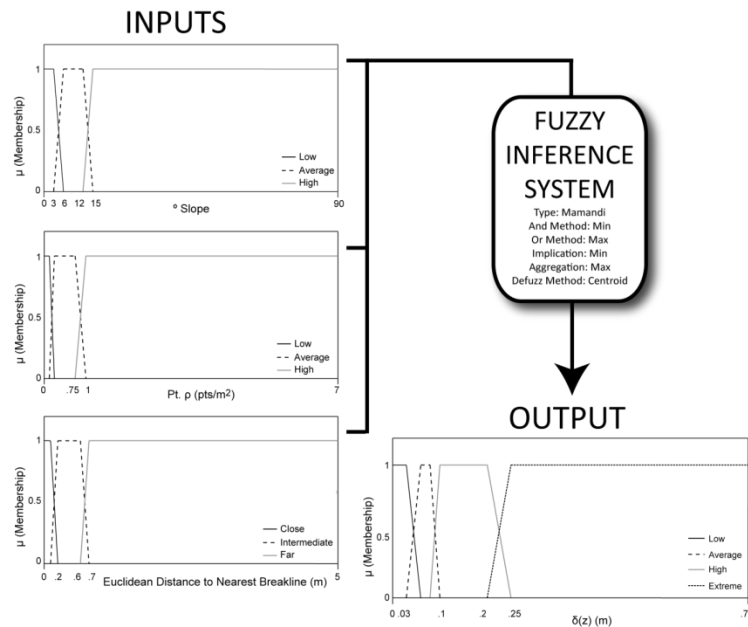
WHAT DOES FIS DO?

- Recovers some low magnitude change & discards some higher magnitude change
- More realistic bimodal distribution...

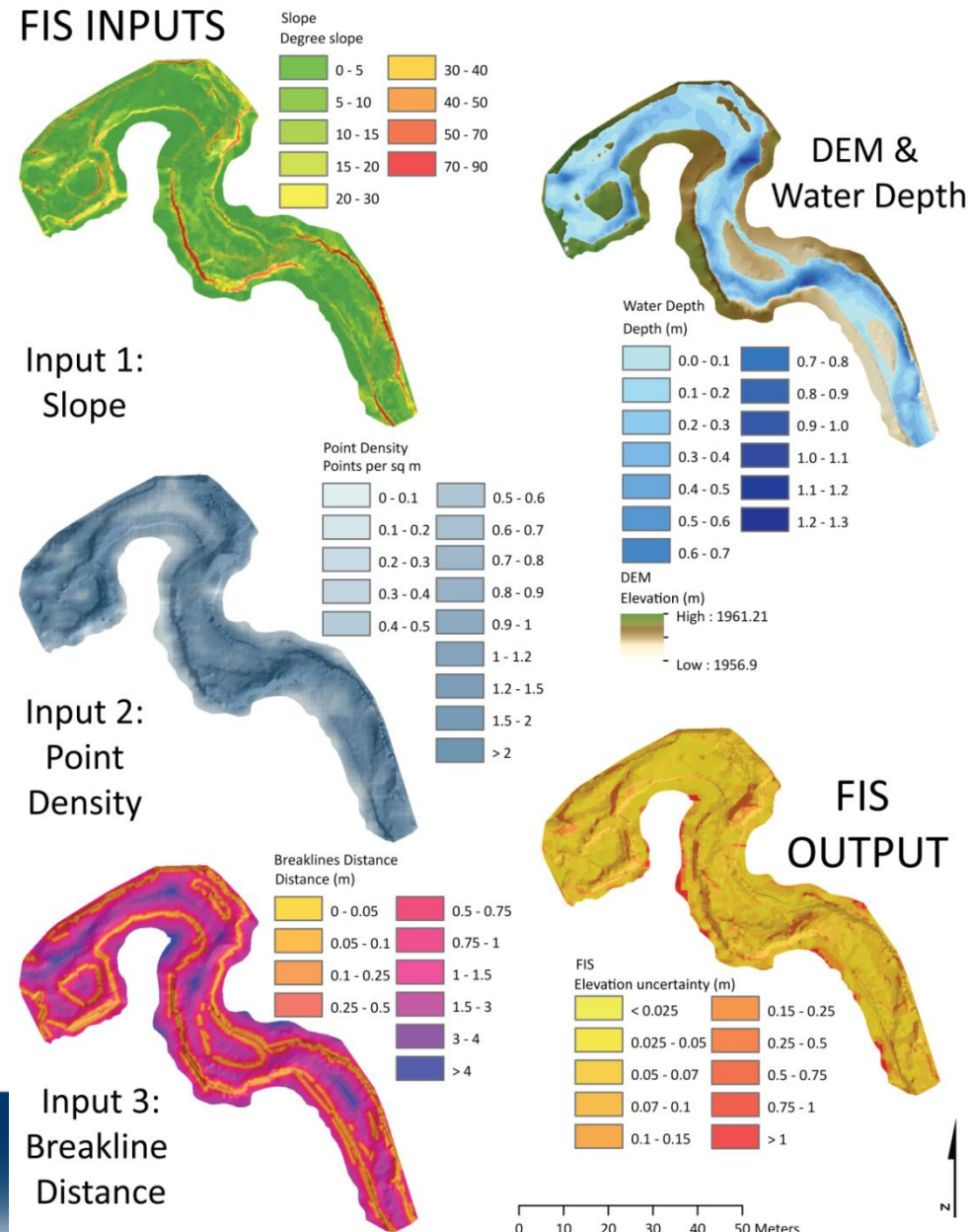


AN FIS USING BREAKLINES...

- 3 Inputs
 - Slope
 - Point Density
 - Distance to breakline



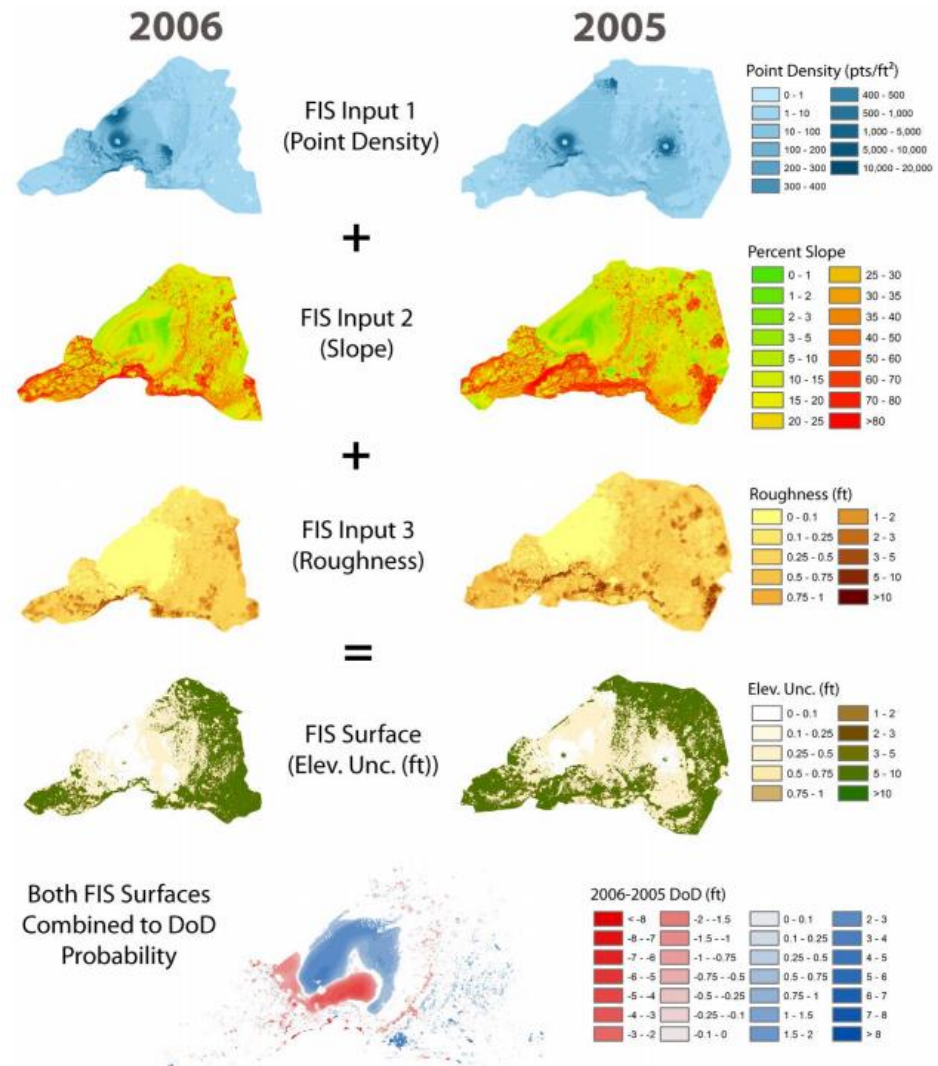
FIS INPUTS



From: Bangen et al. (In Review: Geomorphology)
 & Bangen (2013)

AN FIS FOR TLS DATA

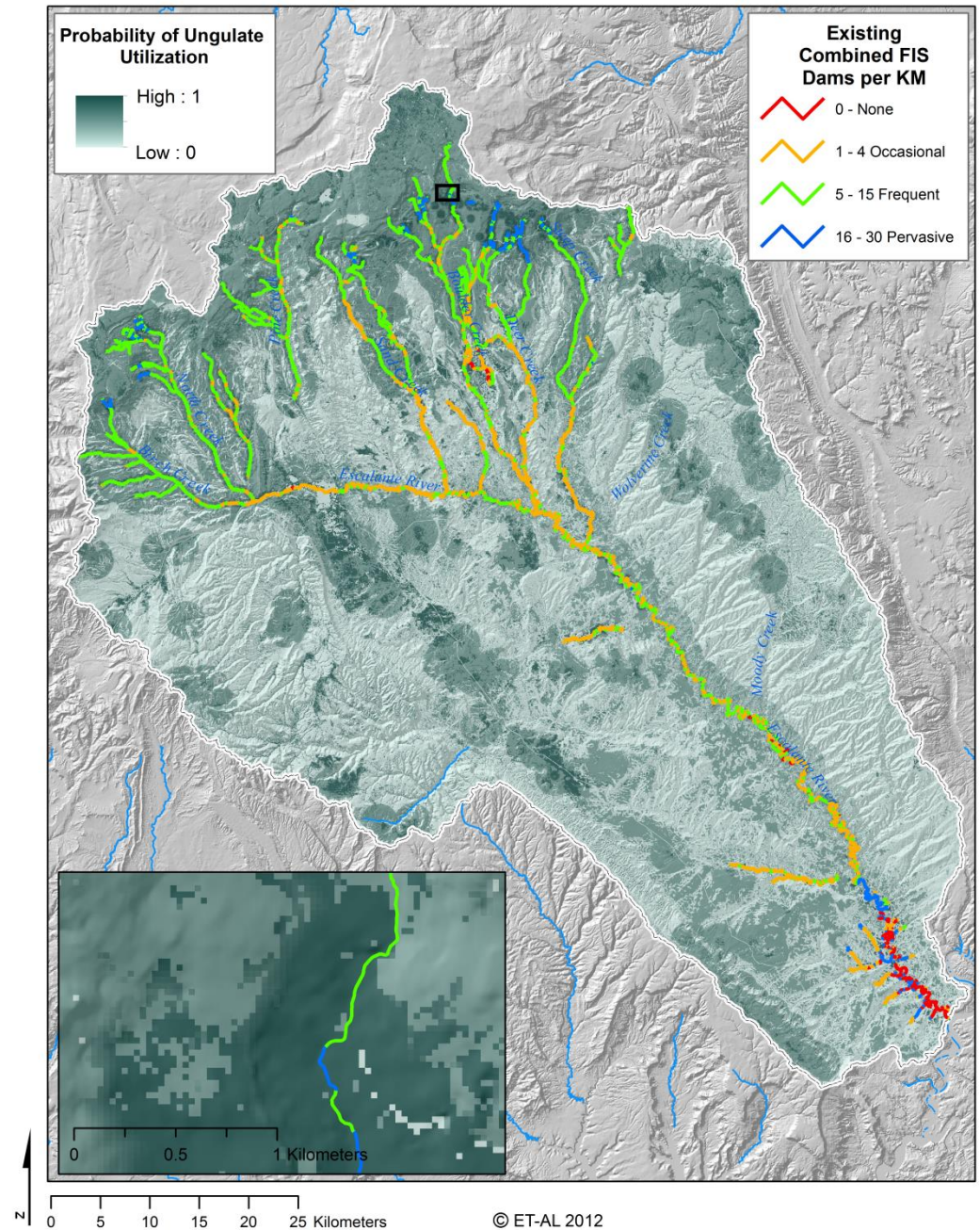
Rule	Inputs→			Output Elevation Uncertainty
	Slope	Point Density	Roughness	
1	Low	Sparse	Smooth (sand)	Average
2	Low	Medium	Smooth (sand)	Average
3	Low	Dense	Smooth (sand)	Low
4	Medium	Sparse	Smooth (sand)	High
5	Medium	Medium	Smooth (sand)	Average
6	Medium	Dense	Smooth (sand)	Low
7	High	Sparse	Smooth (sand)	High
8	High	Medium	Smooth (sand)	Average
9	High	Dense	Smooth (sand)	Average
10	Low	Sparse	Rough (Gravel/Cobble)	High
11	Low	Medium	Rough (Gravel/Cobble)	Average
12	Low	Dense	Rough (Gravel/Cobble)	Average
13	Medium	Sparse	Rough (Gravel/Cobble)	Extreme
14	Medium	Medium	Rough (Gravel/Cobble)	High
15	Medium	Dense	Rough (Gravel/Cobble)	Average
16	High	Sparse	Rough (Gravel/Cobble)	Extreme
17	High	Medium	Rough (Gravel/Cobble)	High
18	High	Dense	Rough (Gravel/Cobble)	Average
19	Low	Sparse	Very Rough (Boulder/Veg)	Extreme
20	Low	Medium	Very Rough (Boulder/Veg)	Extreme
21	Low	Dense	Very Rough (Boulder/Veg)	High
22	Medium	Sparse	Very Rough (Boulder/Veg)	Extreme
23	Medium	Medium	Very Rough (Boulder/Veg)	Extreme
24	Medium	Dense	Very Rough (Boulder/Veg)	High
25	High	Sparse	Very Rough (Boulder/Veg)	Extreme
26	High	Medium	Very Rough (Boulder/Veg)	Extreme
27	High	Dense	Very Rough (Boulder/Veg)	Extreme



From: [Leary et al. \(2012\)](#)

A VECTOR MODEL & A RASTER MODEL

- How do I run a vector model vs. a raster model?



THE KEY....

- Where do you put `evalfis()`?
 - Vector -> Inside a loop going through each row





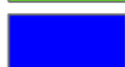
```
175
176 %% BEAVER VEG CAPACITY FIS
177 BeaverVegCap = zeros(length(data),1);
178
179 for b=1:length(data);
180     BeaverVegCap(b)= evalfis([evt30LWM(b) evt100LWM(b)], userVegFIS);
181 end
182
183
184 %% BEAVER COMBINED FIS
```

- Raster -> In nested loop or vectorized matrix operation

```
46 switch numFISinputs
47
48     case 2
49         % Prep Inputs & Get Addresses Dialed
50         FISin1 = inputRasters(1,:,:);
51         noData1 = find(isnan(FISin1) == 1);
52         Data1 = find(isnan(FISin1) == 0);
53         FISin2 = inputRasters(2,:,:);
54
59
60         % FIS calculation
61         GrazeCapacity(DataCells)=evalfis([FISin1(DataCells) FISin2(DataCells)], userFIS);
62         GrazeCapacity(nodatacells)= NaN;
63
```

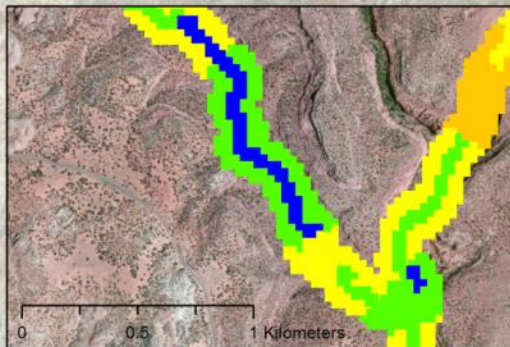
Existing LANDFIRE Land Cover Dam-building Material Classification

Bank (30 m) & Riparian (100 m) Buffers

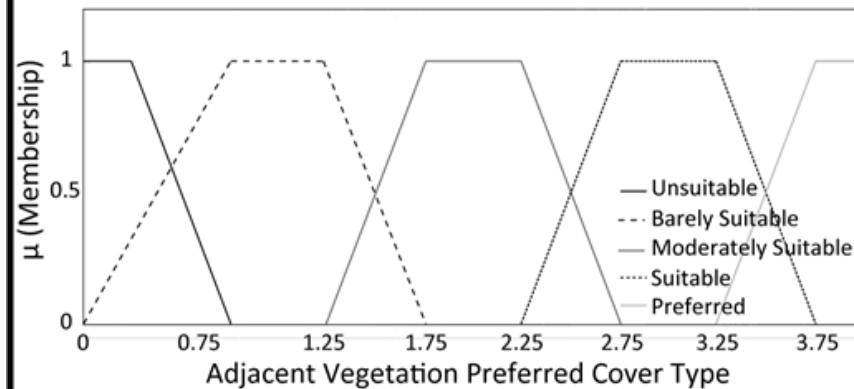
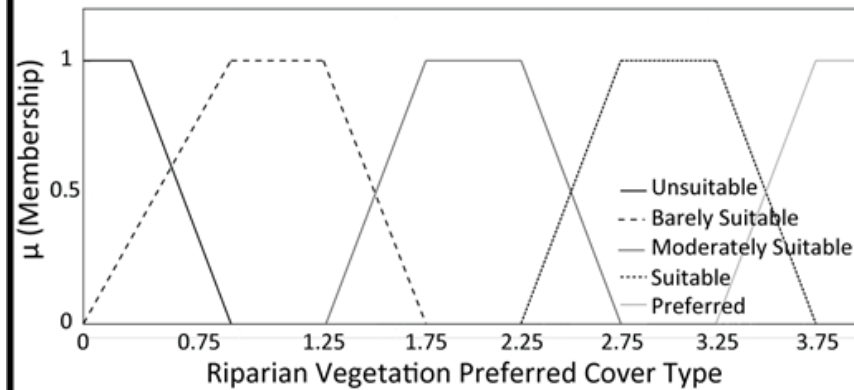
	0 - Unsuitable Material
	1 - Barely Suitable Material
	2 - Moderately Suitable Material
	3 - Suitable Material
	4 - Preferred Material

GIS Vegetation Output

- Evidence of riparian vegetation to support dam building activity
- Evidence of adjacent vegetation to support expanding activity



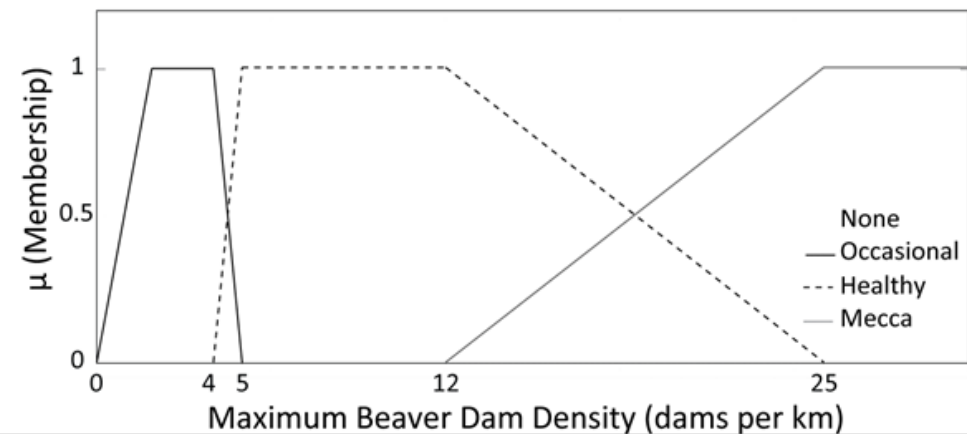
INPUTS



FUZZY INFERENCE SYSTEM

Type: Mamandi
 And Method: Min
 Or Method: Max
 Implication: Min
 Aggregation: Max
 Defuzz Method: Centroid

OUTPUT



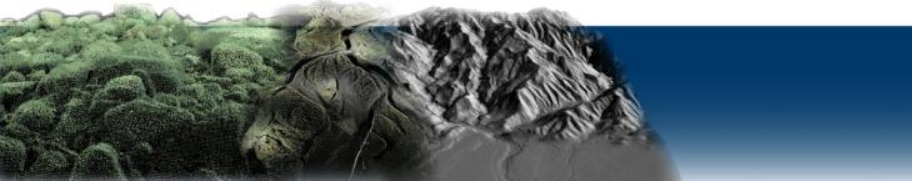
PERENNIAL STREAM & VEGETATION FIS

MEMBERSHIP FUNCTIONS (*.FIS)

- Simple ascii text file
- Computing w/ words

```
input_veg.asc | GrazingProb_3input.fis | VegCapacityBeaver_2input.fis
1 [System]
2 Name='VegCapacityBeaver'
3 Type='mamdani'
4 Version=2.0
5 NumInputs=2
6 NumOutputs=1
7 NumRules=25
8 AndMethod='min'
9 OrMethod='max'
10 ImpMethod='min'
11 AggMethod='max'
12 DefuzzMethod='centroid'
13
14 [Input1]
15 Name='RiparianVegPrefCover'
```

```
14 [Input1]
15 Name='RiparianVegPrefCover'
16 Range=[0 4]
17 NumMFs=5
18 MF1='UnsuitableMaterial':'trimf',[0 0 1]
19 MF2='BarelySuitableMaterial':'trimf',[0 1 2]
20 MF3='ModeratelySuitableMaterial':'trimf',[1 2 3]
21 MF4='SuitableMaterial' : 'trimf' , [2 3 4]
22 MF5='PreferredMaterial' : 'trimf' , [3 4 4]
23
24 [Input2]
25 Name='AdjacentVegPrefCover'
26 Range=[0 4]
27 NumMFs=5
28 MF1='UnsuitableMaterial':'trimf',[0 0 1]
29 MF2='BarelySuitableMaterial':'trimf',[0 1 2]
30 MF3='ModeratelySuitableMaterial':'trimf',[1 2 3]
31 MF4='SuitableMaterial' : 'trimf' , [2 3 4]
32 MF5='PreferredMaterial' : 'trimf' , [3 4 4]
33
34 [Output1]
35 Name='BeaverDamsVegCanSupport'
36 Range=[0 45]
37 NumMFs=4
38 MF1='None':'trimf',[0 0 1]
39 MF2='Occasional':'trapmf',[0 1 4 5]
40 MF3='Moderate':'trapmf',[4 5 12 20]
41 MF4='Mecca':'trapmf',[12 20 45 45]
42
```



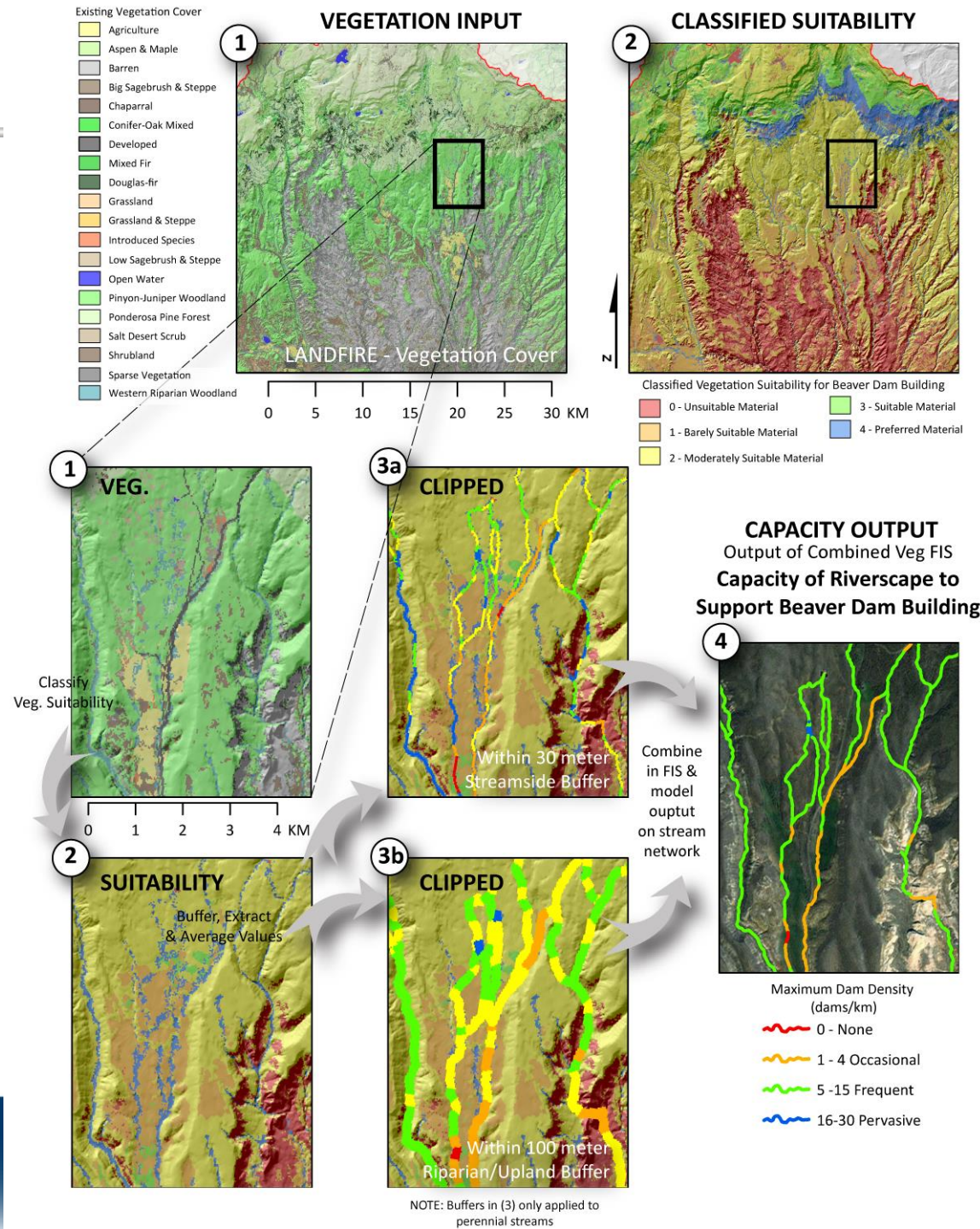
THE RULE TABLE...

43	[rules]
44	1 1, 1 (1) : 1
45	2 1, 2 (1) : 1
46	3 1, 2 (1) : 1
47	4 1, 2 (1) : 1
48	5 1, 3 (1) : 1
49	1 2, 2 (1) : 1
50	2 2, 2 (1) : 1
51	3 2, 2 (1) : 1
52	4 2, 3 (1) : 1
53	5 2, 3 (1) : 1
54	1 3, 2 (1) : 1
55	2 3, 2 (1) : 1
56	3 3, 3 (1) : 1
57	4 3, 3 (1) : 1
58	5 3, 3 (1) : 1
59	1 4, 2 (1) : 1
60	2 4, 2 (1) : 1
61	3 4, 3 (1) : 1
62	4 4, 3 (1) : 1
63	5 4, 3 (1) : 1
64	1 5, 2 (1) : 1
65	2 5, 3 (1) : 1
66	3 5, 3 (1) : 1
67	4 5, 4 (1) : 1
68	5 5, 4 (1) : 1

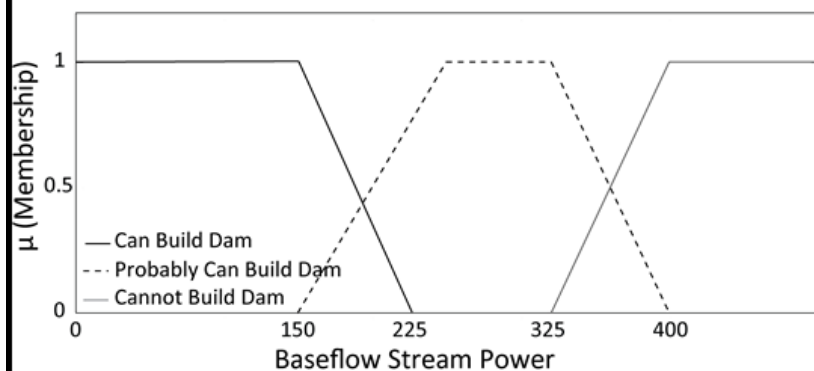
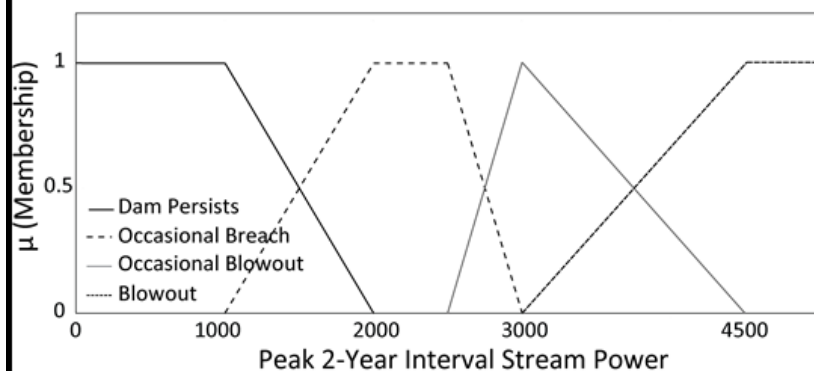
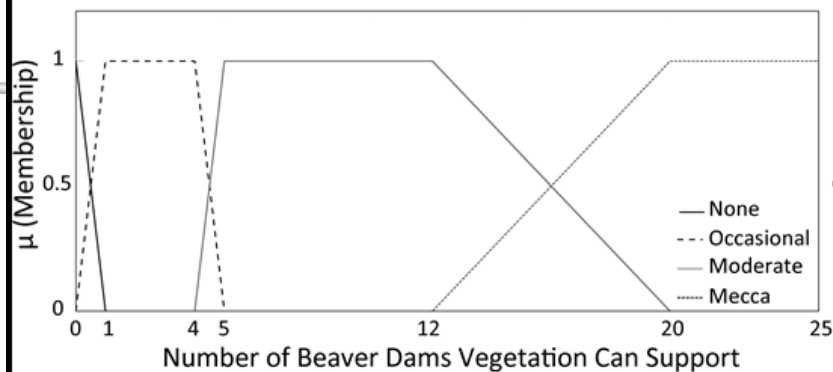
INPUTS					OUTPUT
IF	Suitability of Streamside Vegetation		Suitability of Riparian/Upland Vegetation		Dam Density Capacity
RULES	1 Unsuitable	&	Unsuitable	, then	None
	2 Barely Suitable	&	Unsuitable	, then	Occasional
	3 Moderately Suitable	&	Unsuitable	, then	Occasional
	4 Suitable	&	Unsuitable	, then	Occasional
	5 Preferred	&	Unsuitable	, then	Frequent
	6 Unsuitable	&	Barely Suitable	, then	Occasional
	7 Barely Suitable	&	Barely Suitable	, then	Occasional
	8 Moderately Suitable	&	Barely Suitable	, then	Occasional
	9 Suitable	&	Barely Suitable	, then	Frequent
	10 Preferred	&	Barely Suitable	, then	Frequent
	11 Unsuitable	&	Moderately Suitable	, then	Occasional
	12 Barely Suitable	&	Moderately Suitable	, then	Occasional
	13 Moderately Suitable	&	Moderately Suitable	, then	Frequent
	14 Suitable	&	Moderately Suitable	, then	Frequent
	15 Preferred	&	Moderately Suitable	, then	Frequent
	16 Unsuitable	&	Suitable	, then	Occasional
	17 Barely Suitable	&	Suitable	, then	Occasional
	18 Moderately Suitable	&	Suitable	, then	Frequent
	19 Suitable	&	Suitable	, then	Frequent
	20 Preferred	&	Suitable	, then	Frequent
	21 Unsuitable	&	Preferred	, then	Occasional
	22 Barely Suitable	&	Preferred	, then	Frequent
	23 Moderately Suitable	&	Preferred	, then	Frequent
	24 Suitable	&	Preferred	, then	Pervasive
	25 Preferred	&	Preferred	, then	Pervasive

VEG MODEL...

1. LANDFIRE Vegetation
2. Classify in terms of suitability for dam building
3. Clip down to 30 m and 100 m stream buffers
4. Run FIS Model to transfer raster to vector...



INPUTS

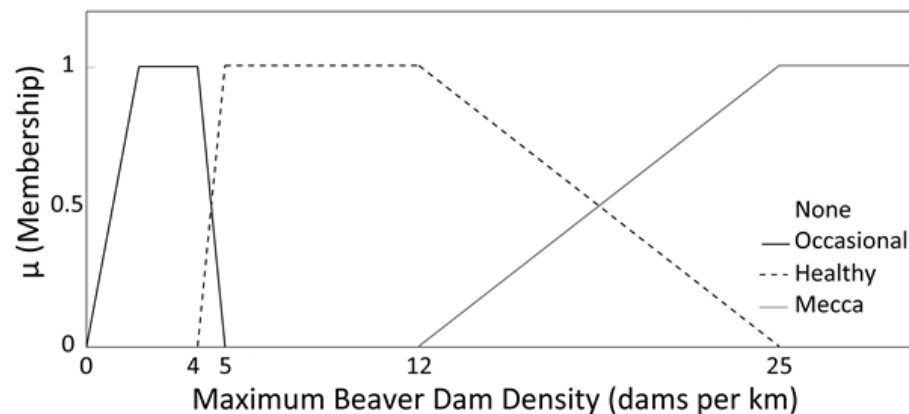


PERENNIAL STREAM VEGETATION & STREAM POWER FIS

FUZZY INFERENCE SYSTEM

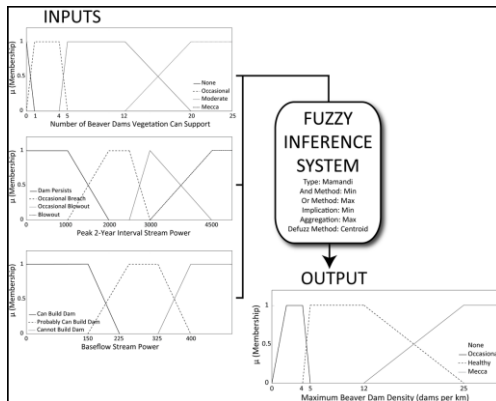
Type: Mamandi
And Method: Min
Or Method: Max
Implication: Min
Aggregation: Max
Defuzz Method: Centroid

OUTPUT



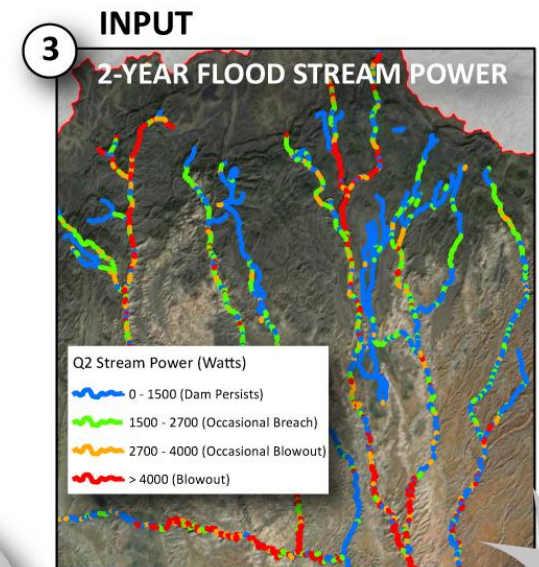
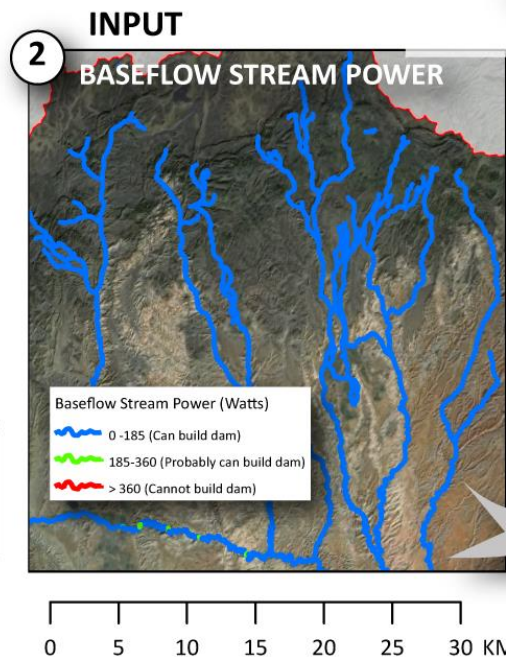
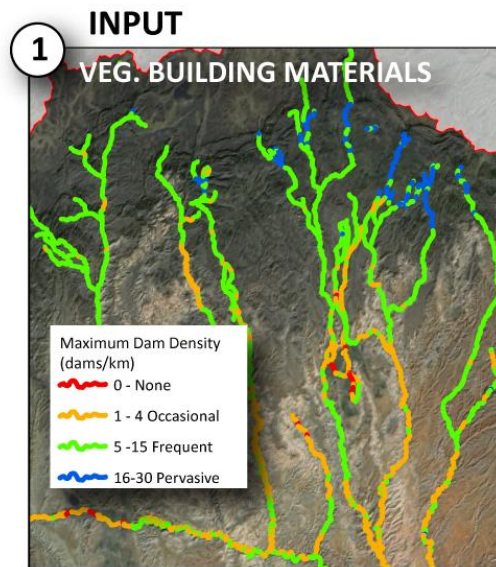
RULE TABLE...

	INPUTS				OUTPUT	
	IF	Vegetative Dam Density Capacity (FIS)	Baseflow Stream Power	2 Year Flood Stream Power		Dam Density Capacity
RULES	1	None	& -	& -	, then	None
	2	-	& Cannot Build Dam	& -	, then	None
	3	Occasional	& Can Build Dam	& Dam Persists	, then	Occasional
	4	Frequent	& Can Build Dam	& Dam Persists	, then	Frequent
	5	Pervasive	& Can Build Dam	& Dam Persists	, then	Pervasive
	6	Occasional	& Can Build Dam	& Occasional Breach	, then	Occasional
	7	Frequent	& Can Build Dam	& Occasional Breach	, then	Frequent
	8	Pervasive	& Can Build Dam	& Occasional Breach	, then	Frequent
	9	Occasional	& Can Build Dam	& Occasional Blowout	, then	Occasional
	10	Frequent	& Can Build Dam	& Occasional Blowout	, then	Occasional
	11	Pervasive	& Can Build Dam	& Occasional Blowout	, then	Frequent
	12	Occasional	& Can Build Dam	& Blowout	, then	Occasional
	13	Frequent	& Can Build Dam	& Blowout	, then	Occasional
	14	Pervasive	& Can Build Dam	& Blowout	, then	Occasional
	15	Occasional	& Can Probably Build Dam	& Occasional Breach	, then	Occasional
	16	Frequent	& Can Probably Build Dam	& Occasional Breach	, then	Frequent
	17	Pervasive	& Can Probably Build Dam	& Occasional Breach	, then	Frequent
	18	Occasional	& Can Probably Build Dam	& Occasional Blowout	, then	Occasional
	19	Frequent	& Can Probably Build Dam	& Occasional Blowout	, then	Occasional
	20	Pervasive	& Can Probably Build Dam	& Occasional Blowout	, then	Frequent
	21	Occasional	& Can Probably Build Dam	& Blowout	, then	Occasional
	22	Frequent	& Can Probably Build Dam	& Blowout	, then	Occasional
	23	Pervasive	& Can Probably Build Dam	& Blowout	, then	Occasional

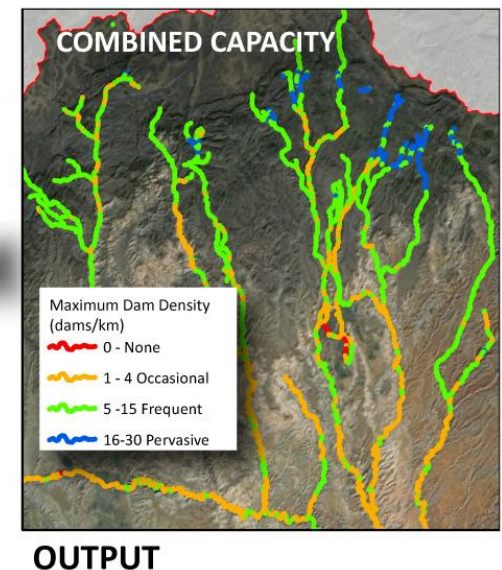


COMBINED

1. Veg FIS
 2. Baseflow (can they build a dam?)
 3. 2 Year Flood (does dam blow out)
- = Resulting Capacity



FUZZY INFERENCE SYSTEM Capacity of Riverscape to Support Beaver Dams



FIS WORKSHOP PLAN



A. Some Terminology & Definitions



B. Building your own Inference System



C. Some Example FIS Applications



D. Building an FIS



E. Applying FIS in Matlab



F. Applying FIS spatially



G. Building Your Own FIS

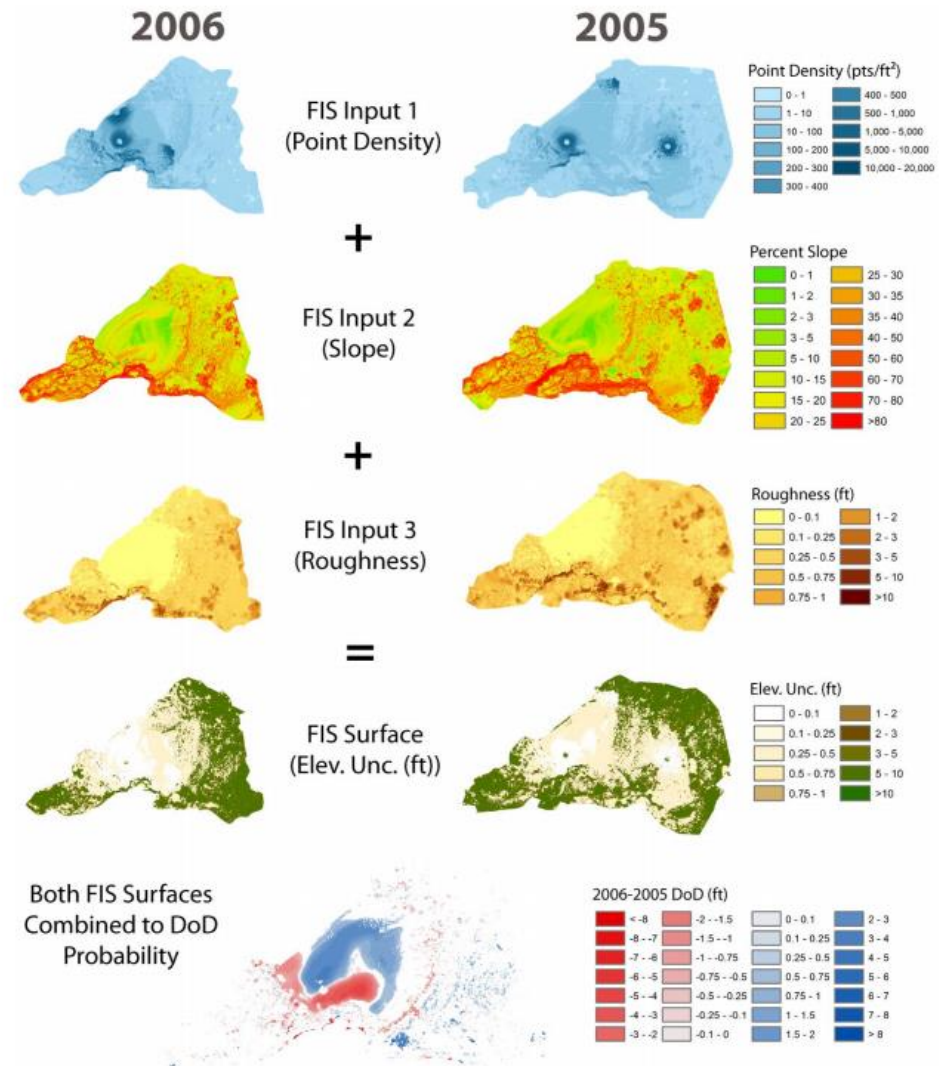


H. Summary of Key Concepts



TAKE A 2 INPUT FIS FILE... MAKE IT 3

- Adjust header
- Add one input
- Adjust rule table
- Visualize in Matlab to see if it works like you thought it should



FIS WORKSHOP PLAN



A. Some Terminology & Definitions



B. Building your own Inference System



C. Some Example FIS Applications



D. Building an FIS



E. Applying FIS in Matlab



F. Applying FIS spatially



G. Building Your Own FIS



H. Summary of Key Concepts



SUMMARY

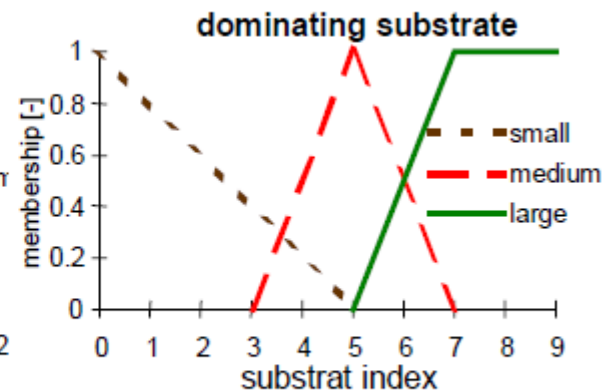
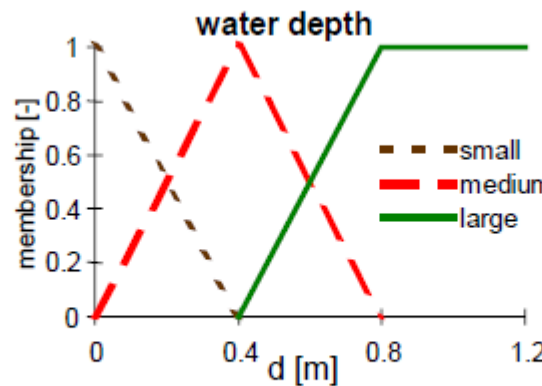
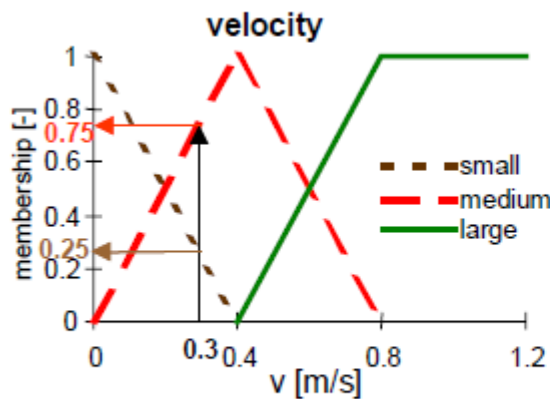
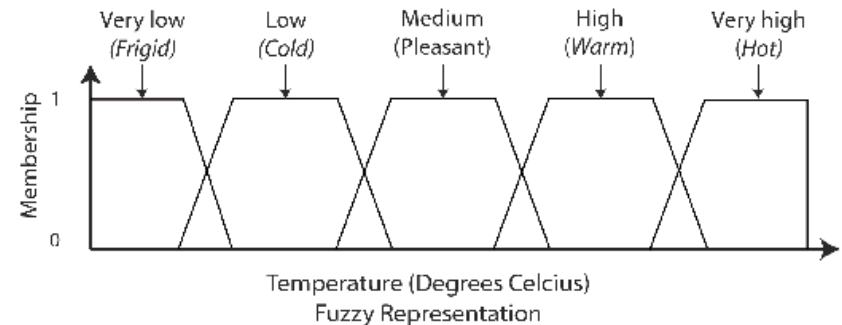
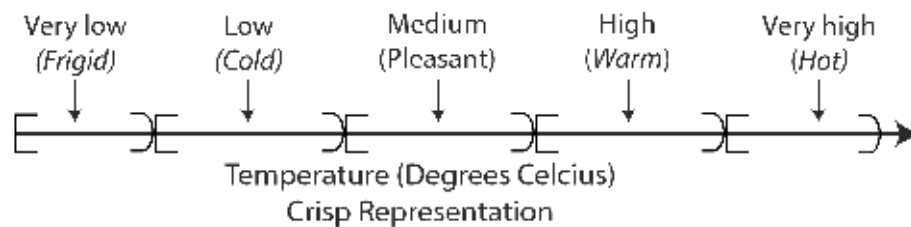
- FIS is computing with words – flexible framework for combining imprecise information and inputs you have to get the output you want
- FIS is an excellent way of explicitly accounting for categorical uncertainty (i.e. ambiguity) associated with rules
- FIS requires some continuous input & produces continuous outputs
- Output explicitly represents uncertainty
- Sensitivity to MF shape and individual rules low
- Sensitivity to output range and MF types high



EXTRA SLIDES



CRISP VS. FUZZY SETS...

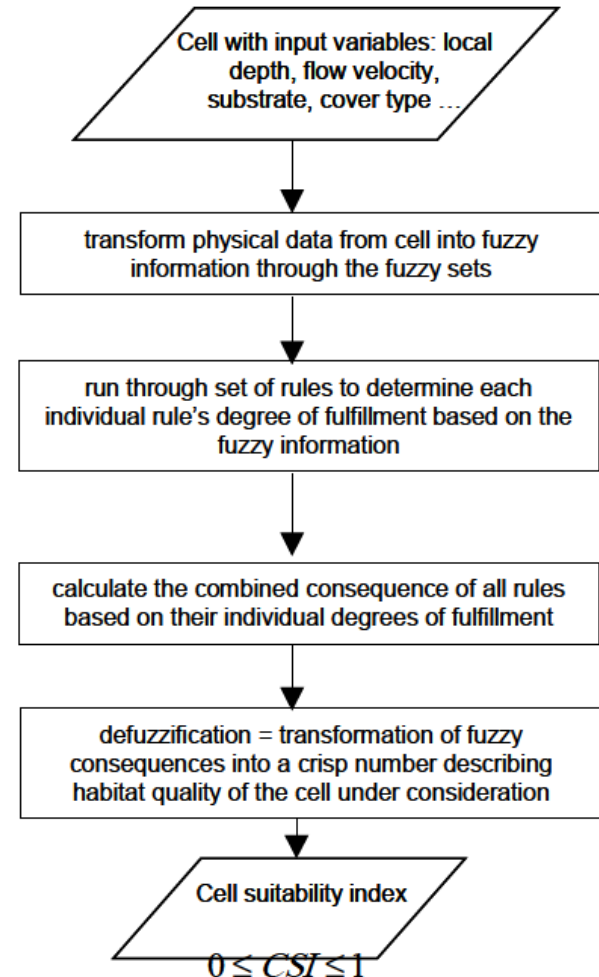


Fuzzy set theory... useful for classifying continuous variables

STEPS IN A FUZZY INFERENCE SYSTEM

1. Define output categories and membership functions
2. Decide inputs
 1. Define categories and membership functions for each input
3. Build rule table (weight rules if desired)
4. Apply each relevant rule
5. Method for combining rules to
6. Method for defuzzifying output (back to crisp value)

Schneider M and Jorde K. 2003. Fuzzy-Rule Based Models for the Evaluation of Fish Habitat Quality and Instream Flow Assessment, Proc. International IFIM Users Workshop: Fort Collins, CO, 22 pp.



CASiMiR

- There is an English version...



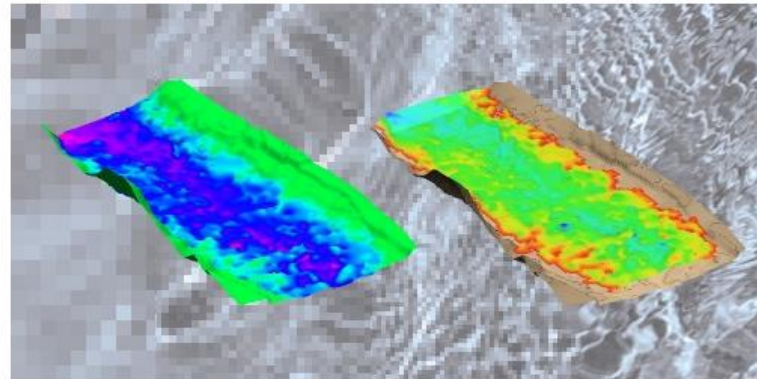
Universität Stuttgart
Institut für Wasserbau



Schneider & Jorde
Ecological Engineering GmbH

Computer Aided Simulation Model for Instream Flow Requirements 

Home	Workshops	Anwendungen	Download	Publikationen	Kontakt
------	-----------	-------------	----------	---------------	---------



Über CASiMiR

Informieren Sie sich über diese einzigartige Fuzzy-Logik Software. [Hier](#) finden Sie alle Infos zu den Funktionen und Anwendungen der Software.

Software downloaden

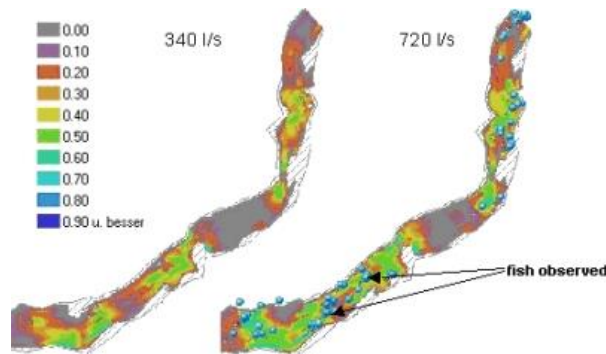
[Hier](#) finden Sie die neuesten Versionen des CASiMiR Programmes.

Willkommen

Auf der Homepage zu CASiMiR - dem Simulationssystem zur Untersuchung von Gewässerhabitaten. Wir freuen uns, dass Sie sich für unsere CASiMiR Software interessieren. Diese Internetseite stellt Ihnen einige [Anwendungsmöglichkeiten](#) für die Software vor. Im [Downloadbereich](#) stellen wir Ihnen einzelne Module von CASiMiR zur freien Nutzung zur Verfügung. Mit Hilfe einzelner Fallbeispiele können Sie selbst erste Modellierungen durchführen. Wenn Sie weitere Fragen haben und Informationen möchten, wenden Sie sich an [Kontakt](#). Außer Informationen zum Modell haben wir auch eine Liste von [Publikationen](#) mit Bezug zu CASiMiR bereit gestellt.

Kontakt aufnehmen

Wir freuen uns von Ihnen Rückmeldungen zu bekommen. Für Fragen können Sie uns per [Email](#) erreichen an der [Universität Stuttgart](#) oder bei der [sje GmbH](#)



UtahStateUniversity
ECOGEOGRAPHY & TOPOGRAPHIC
ANALYSIS LABORATORY

FIS WORKSHOP PLAN



A. Some Terminology & Definitions



B. Some Example FIS Applications



C. Building an FIS



D. Applying FIS in Matlab



E. Applying FIS spatially



F. Building Your Own FIS



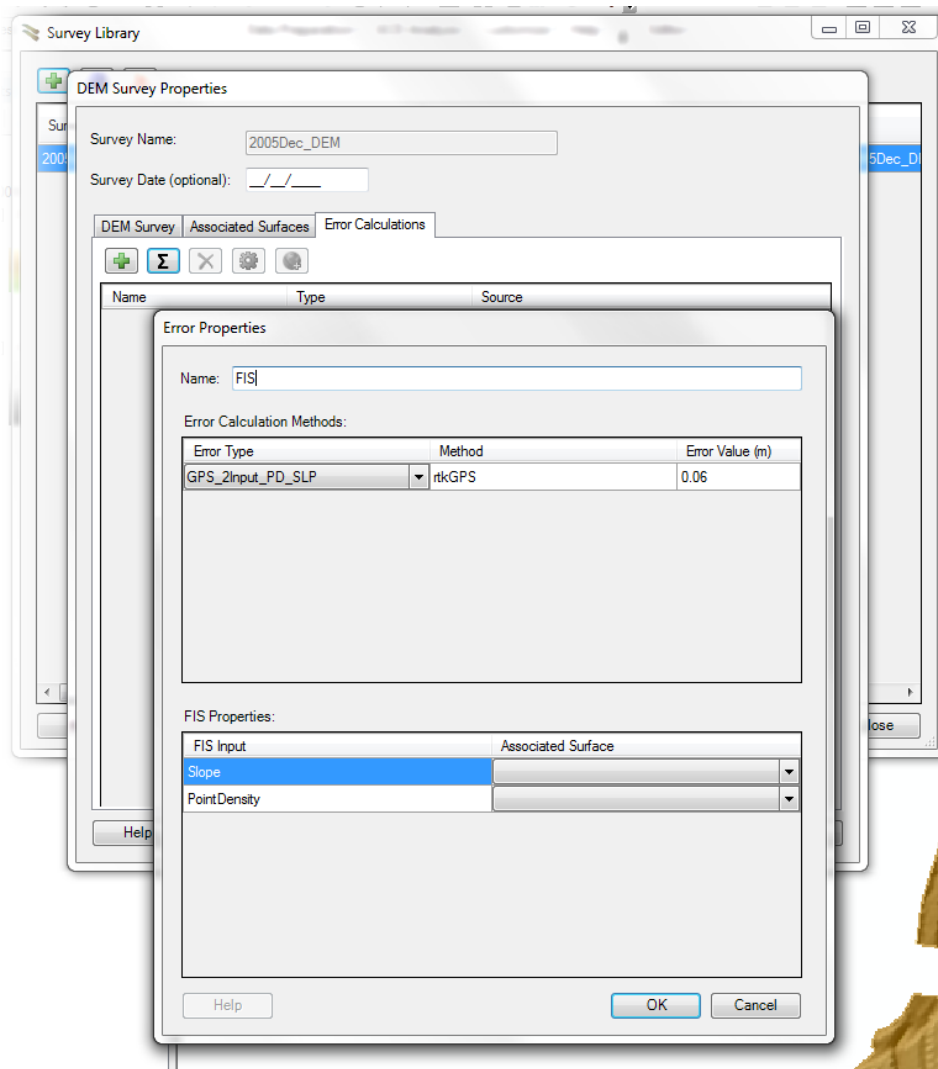
G. FIS within GCD 5



H. Summary of Key Concepts

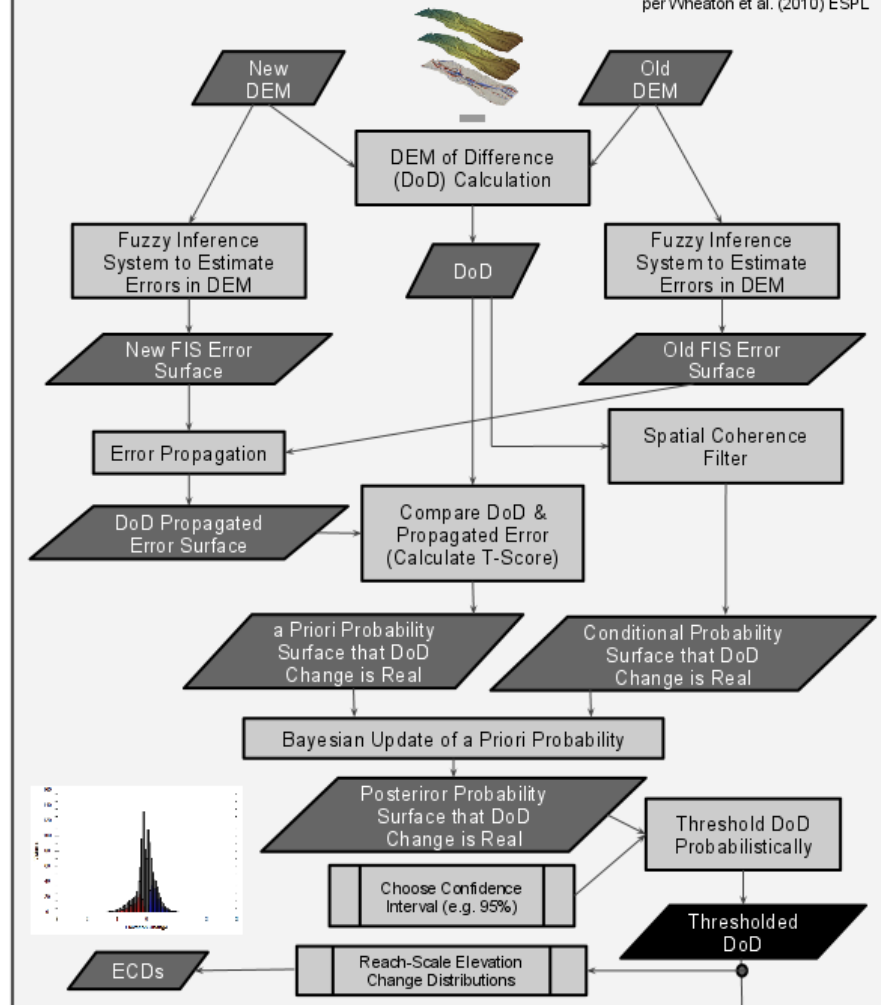


USING THE GCD SOFTWARE... FIS



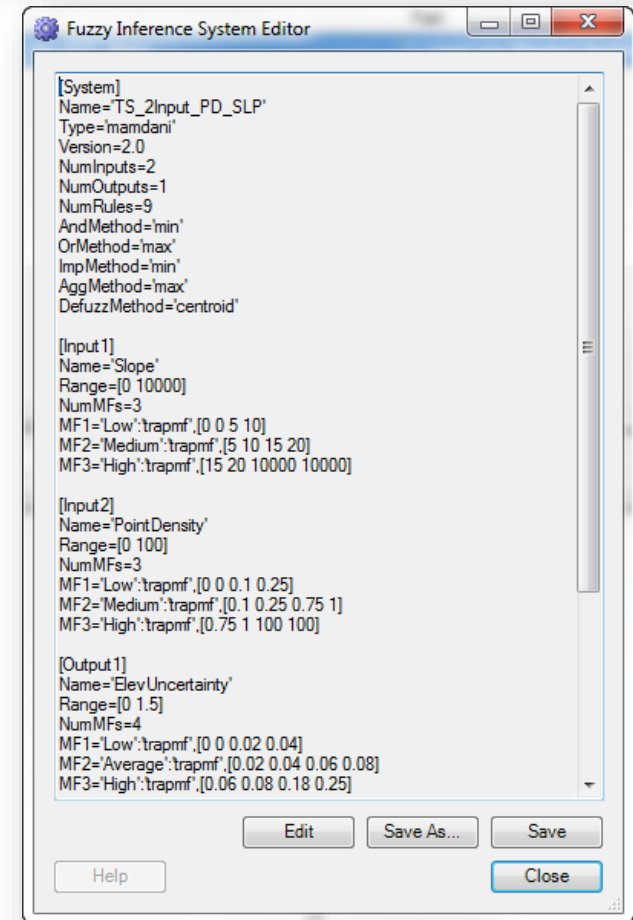
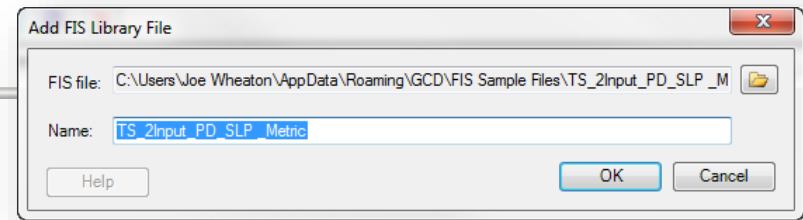
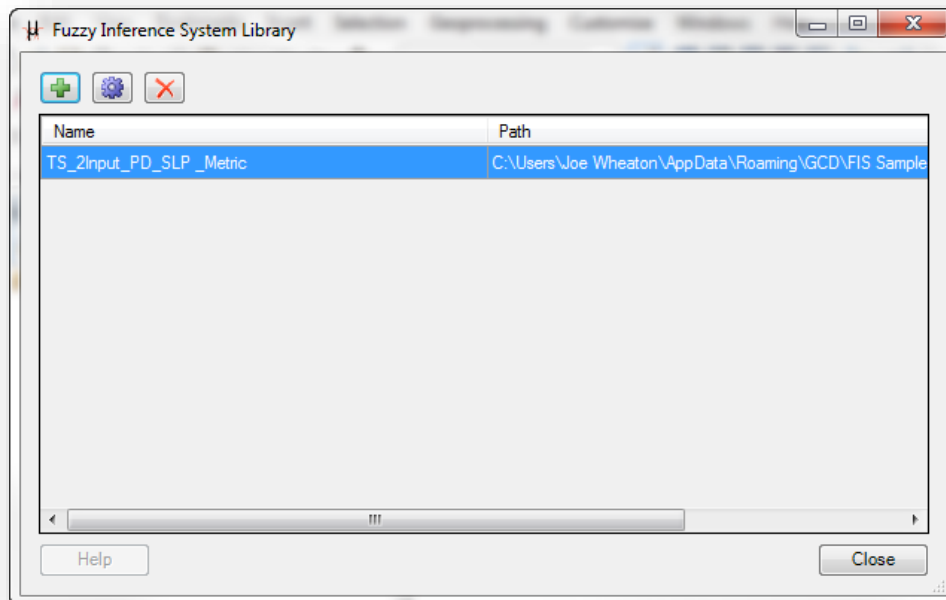
GCD Standard Workflow

Using Fuzzy Inference System, Spatial Coherence Filter & Bayesian Updating as per Wheaton et al. (2010) ESPL



FIS LIBRARY

- You can add as many FIS to library as you want



YOU RUN FIS IN ERROR SURFACES TAB

- Error surfaces created in Survey Library
- Inputs to FIS loaded in Associated Surfaces Tab

