

Towards a water quality index (WQI) for Andean micro-watersheds using pressure-state-response indicators and fuzzy logic system

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Water quality

- Accessible and high quality freshwater is a limited and highly variable resource
- Projections show that 40% of the world's population currently lives in water-stressed river basins, and that will rise the water demand by 55% in 2050
- In 2050, 240 million people are expected to remain without access to clean water, and 1.4 billion without access to basic sanitation (OECD, 2015)



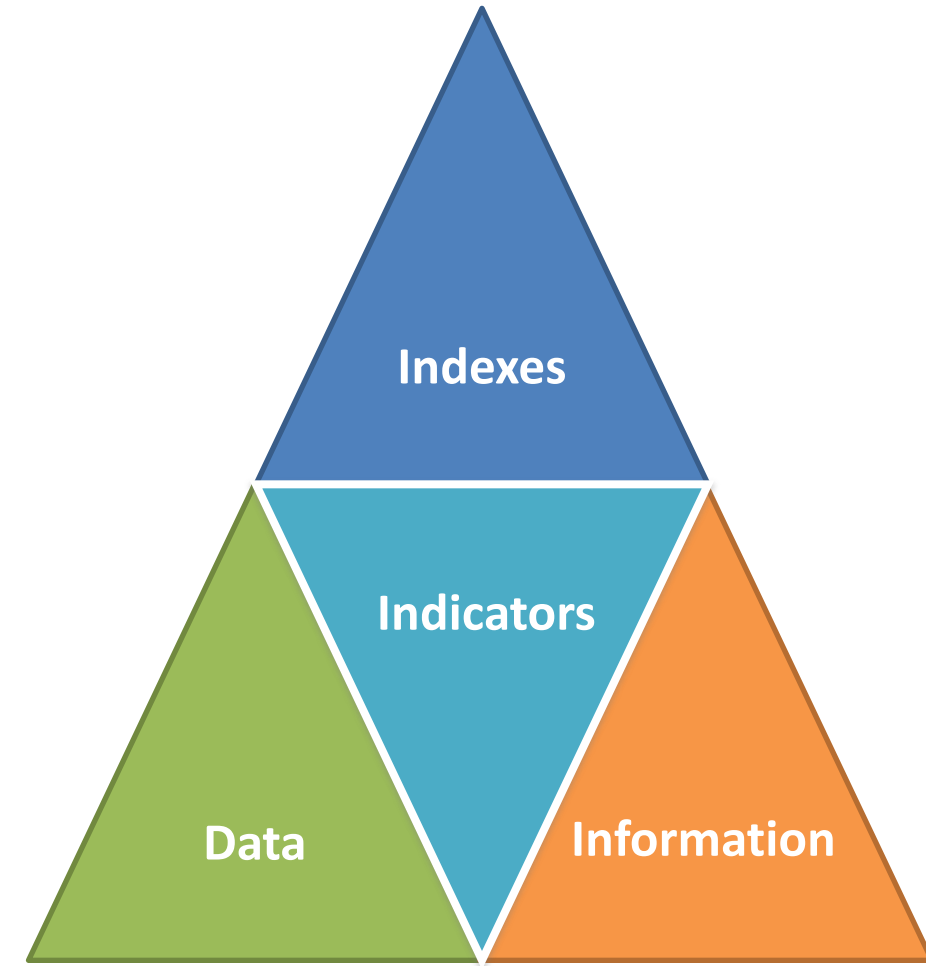
Cauca River-Colombia



Dagua River-Colombia

Water quality and indices

- Water quality index is an effective tool to investigate, describe and predict the ecological state of an aquatic ecosystem
- Various environmental variables may simultaneously affect water quality
- Appropriate selection of a limited number of key indicators facilitates cost-effective management of water resources



Some WQI

A huge number of WQI:

- Weight Arithmetic Water Quality Index (WAWQI)
- National Sanitation Foundation Water Quality Index (NSFWQI)
- Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI)
- Oregon Water Quality Index (OWQI)

$$WQI = \sum_{i=1}^n Q_i W_i$$

$$WQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

$$WQI = \sqrt{\frac{n}{\sum_{i=1}^n \frac{1}{SI_i^2}}}$$

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates and total solids

Micro-watershed in Andean Region

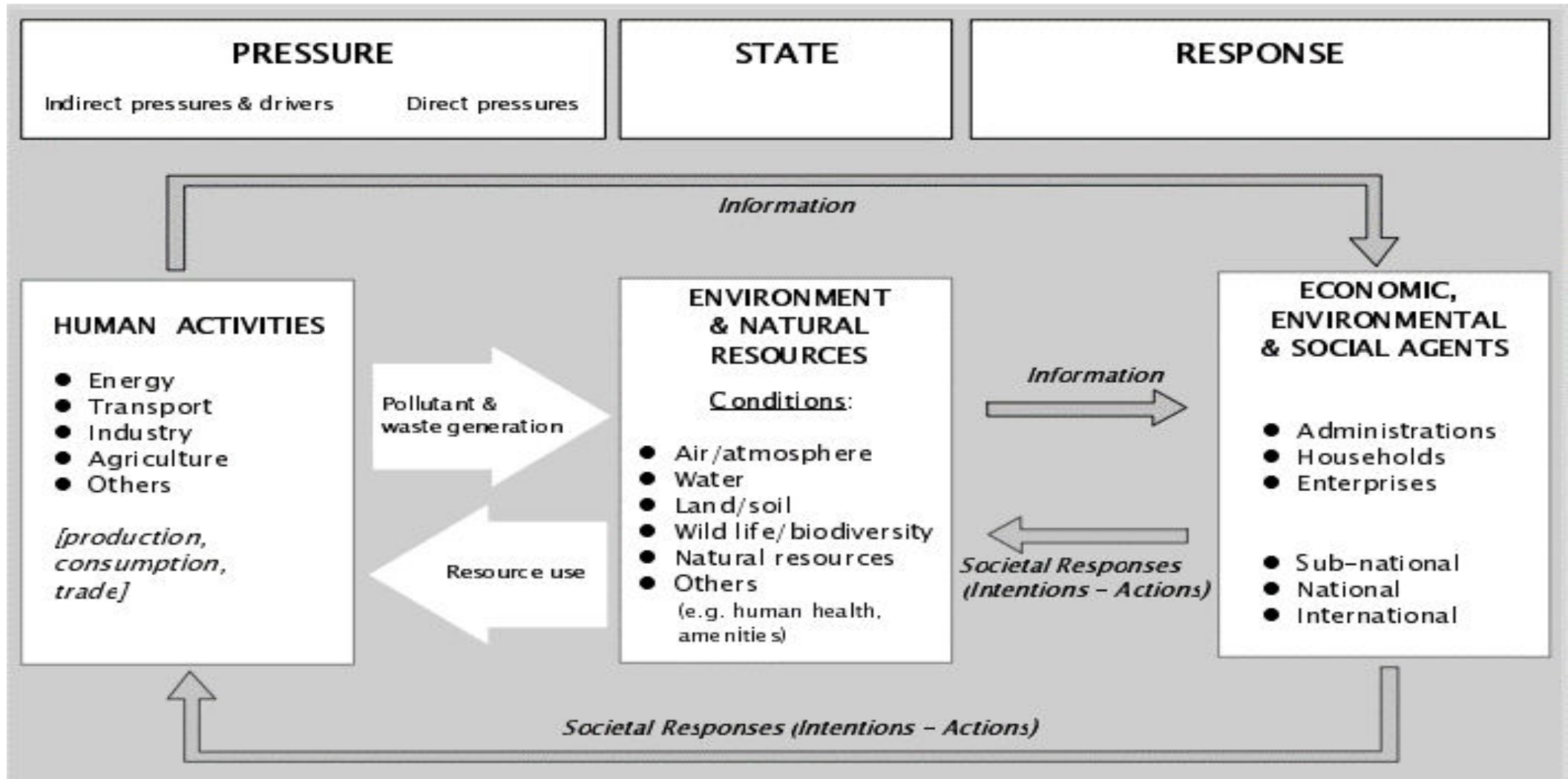


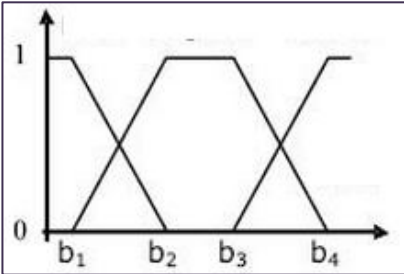
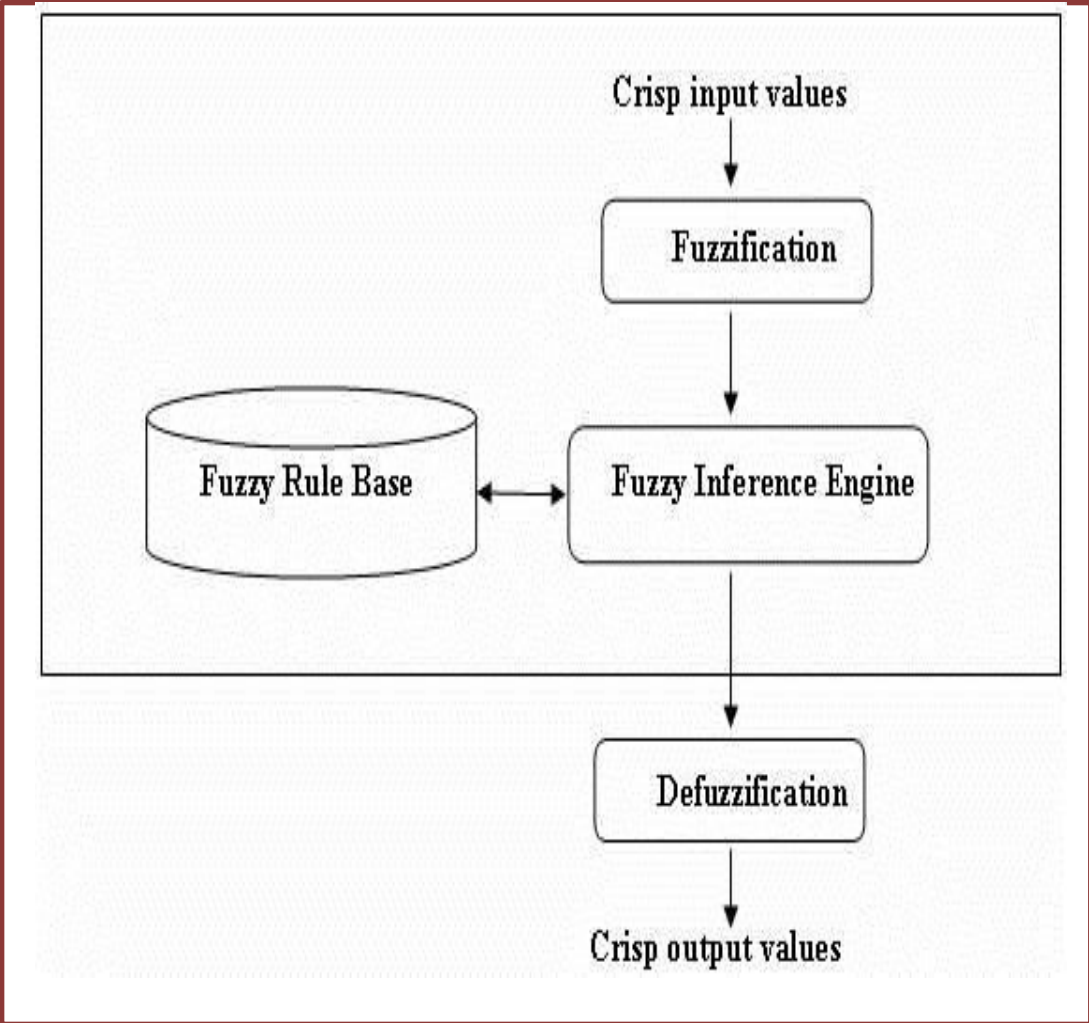
The 77.4% of the population and the 85% of Colombian economic activity is concentrated in the Andean region (Bernal, Martínez, Pabón, et al, 2010)

The Andean region counts only with the 13% of the country's total water supply (IDEAM, 2010)

The 29% of the total forest loss in Colombia is located in the Andean zone (IDEAM, 2013)

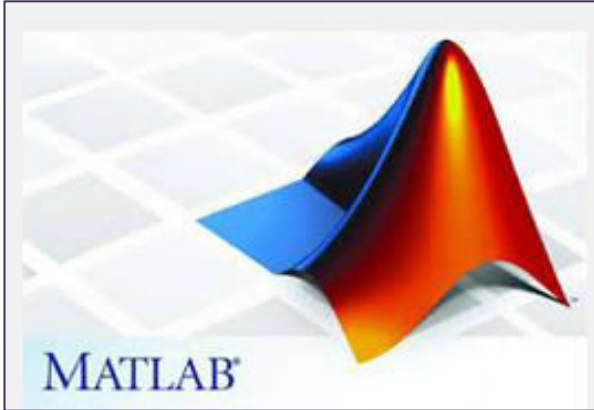

Pressure-State-Response Framework (OCDE, 2013)





A graph showing four fuzzy membership functions on a coordinate system. The vertical axis is labeled from 0 to 1. The horizontal axis has points b_1, b_2, b_3, b_4 . The functions are: a left-shoulder function starting at 1 at b_1 and decreasing to 0 at b_2 ; a triangular function starting at 0 at b_1 , peaking at 1 between b_2 and b_3 , and ending at 0 at b_4 ; a right-shoulder function starting at 0 at b_1 , peaking at 1 between b_2 and b_3 , and ending at 1 at b_4 ; and a right-shoulder function starting at 0 at b_1 and increasing to 1 at b_4 .

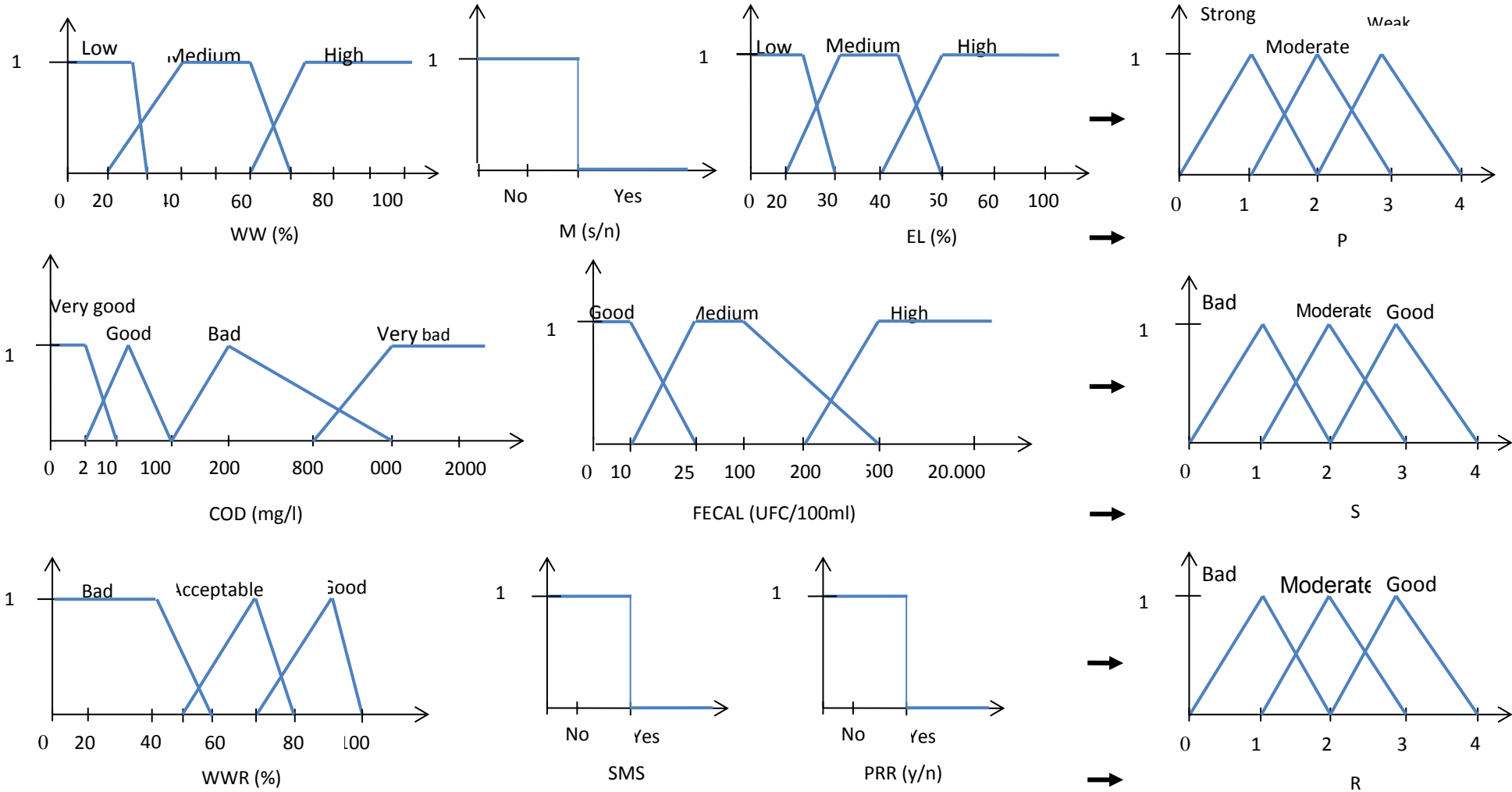
Diffuse rules

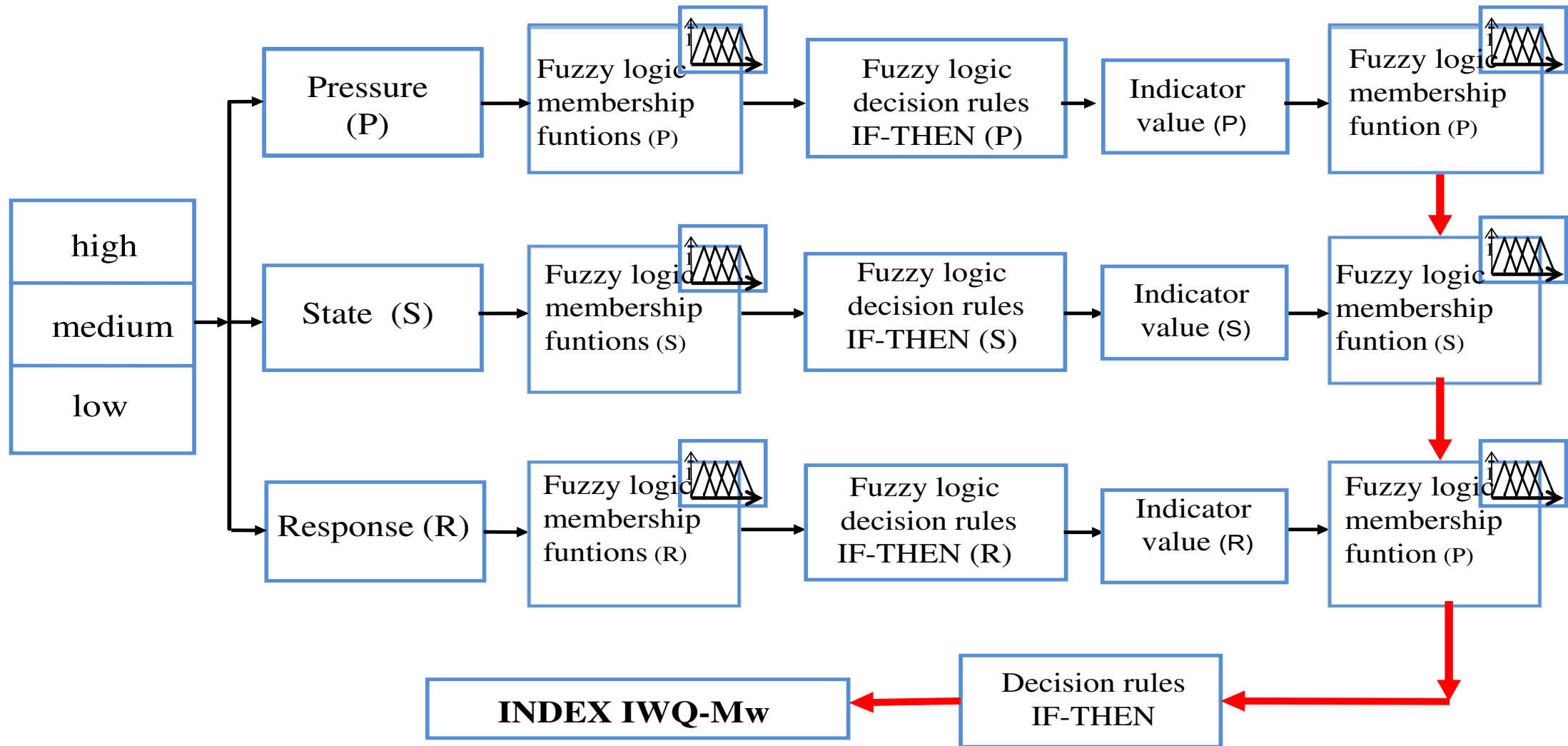


PSR indicators – WQI-Mw

Pressure	State	Response
Wastewater (WW)	Water contamination by Chemical oxygen demand COD (mg/L)	Wastewater treatment and reuse (WWR)
Mining (M)		Strategies of sustainable mining (SSM)
Erosion Level (EL)	Microbiological contamination by fecal coliforms (FECAL CFU/100mL)	Reforestation and revegetation politics (RRP)

Micro-watershed El Chocho

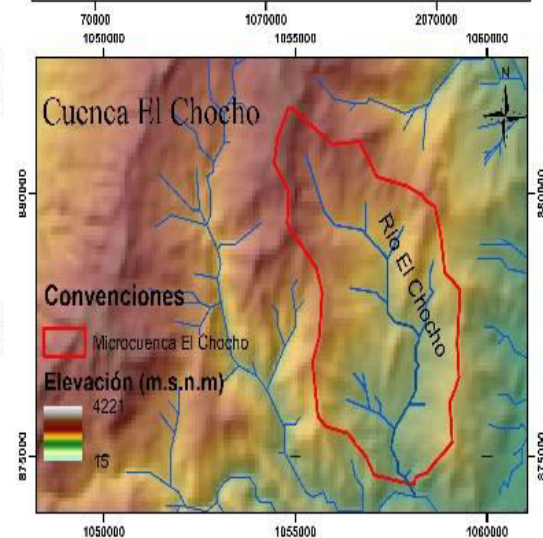
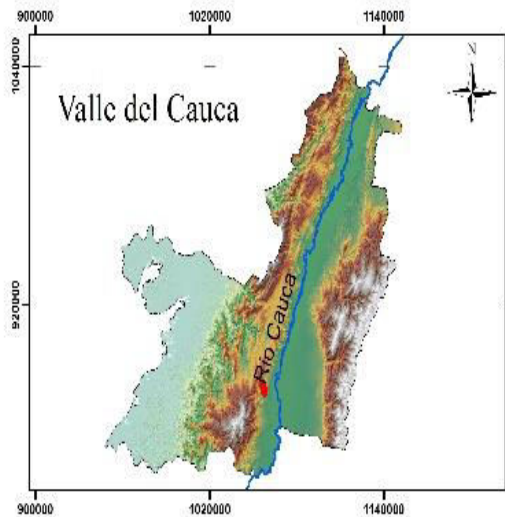
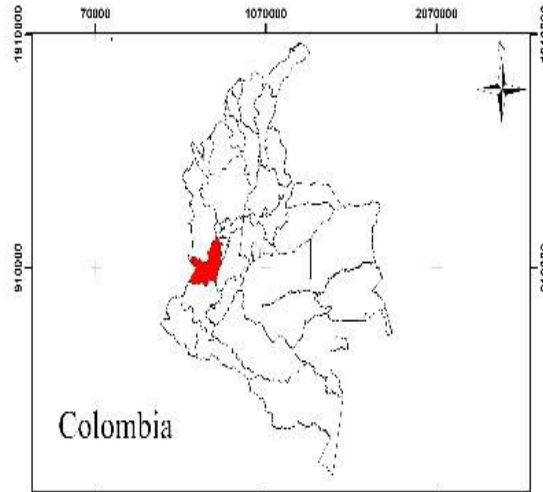




Rules for pressure indicator – IWQ-Mw

Rule No.	WWR	Mining	Erosion Level	Pressure	Rule
1	Low	Yes	Low	Strong	IF (WWU IS Low) AND (M IS Yes) AND (EL IS Low) THEN PRESSURE IS Strong
2	Low	Yes	Medium	Strong	IF (WWU IS Low) AND (M IS Yes) AND (EL IS Medium) THEN PRESSURE IS Strong
3	Low	Yes	High	Strong	IF (WWU IS Low) AND (M IS Yes) AND (EL IS High) THEN PRESSURE IS Strong
4	Medium	Yes	Low	Strong	IF (WWU IS Medium) AND (M IS Yes) AND (EL IS Low) THEN PRESSURE IS Strong
5	Medium	Yes	Medium	Strong	IF (WWU IS Medium) AND (M IS Yes) AND (EL IS Medium) THEN PRESSURE IS Strong
6	Medium	Yes	High	Strong	IF (WWU IS Medium) AND (M IS Yes) AND (EL IS High) THEN PRESSURE IS Strong
7	High	Yes	Low	Strong	IF (WWU IS High) AND (M IS Yes) AND (EL IS Low) THEN PRESSURE IS Strong
8	High	Yes	Medium	Strong	IF (WWU IS High) AND (M IS Yes) AND (EL IS Medium) THEN PRESSURE IS Strong
9	High	Yes	High	Strong	IF (WWU IS High) AND (M IS Yes) AND (EL IS High) THEN PRESSURE IS Strong
10	Low	No	Low	Weak	IF (WWU IS Low) AND (M IS No) AND (EL IS Low) THEN PRESSURE IS Weak
11	Low	No	Medium	Weak	IF (WWU IS Low) AND (M IS No) AND (EL IS Medium) THEN PRESSURE IS Weak
12	Low	No	High	Strong	IF (WWU IS Low) AND (M IS No) AND (EL IS High) THEN PRESSURE IS Strong
13	Medium	No	Low	Moderate	IF (WWU IS Medium) AND (M IS No) AND (EL IS Low) THEN PRESSURE IS Moderate
14	Medium	No	Medium	Moderate	IF (WWU IS Medium) AND (M IS No) AND (EL IS Medium) THEN PRESSURE IS Moderate
15	Medium	No	High	Strong	IF (WWU IS Medium) AND (M IS No) AND (EL IS High) THEN PRESSURE IS Strong
16	High	No	Low	Strong	IF (WWU IS HIGH) AND (M IS No) AND (EL IS Low) THEN PRESSURE IS Strong
17	High	No	Medium	Strong	IF (WWU IS HIGH) AND (M IS No) AND (EL IS Medium) THEN PRESSURE IS Strong
18	High	No	High	Strong	IF (WWU IS High) AND (M IS No) AND (EL IS High) THEN PRESSURE IS Strong

Micro-watershed El Chocho



This micro-watershed has suffered a huge environmental damage, as a consequence of the

- Change in the use of the land
- Increase of the population
- Discharge of wastewater
- Poor management of the solid wastes
- Discharge of the acid
- Conflicts caused by the use of the water and soils
- Institutions problems
- Low local participation

Main problems in microwatershed “el Chocho”



Acid mine drainage



Occupancy of the protective zone



Wastewater



Mining



Change in land use, livestock



Conflic for water use



Water contamination



Contamination for mining



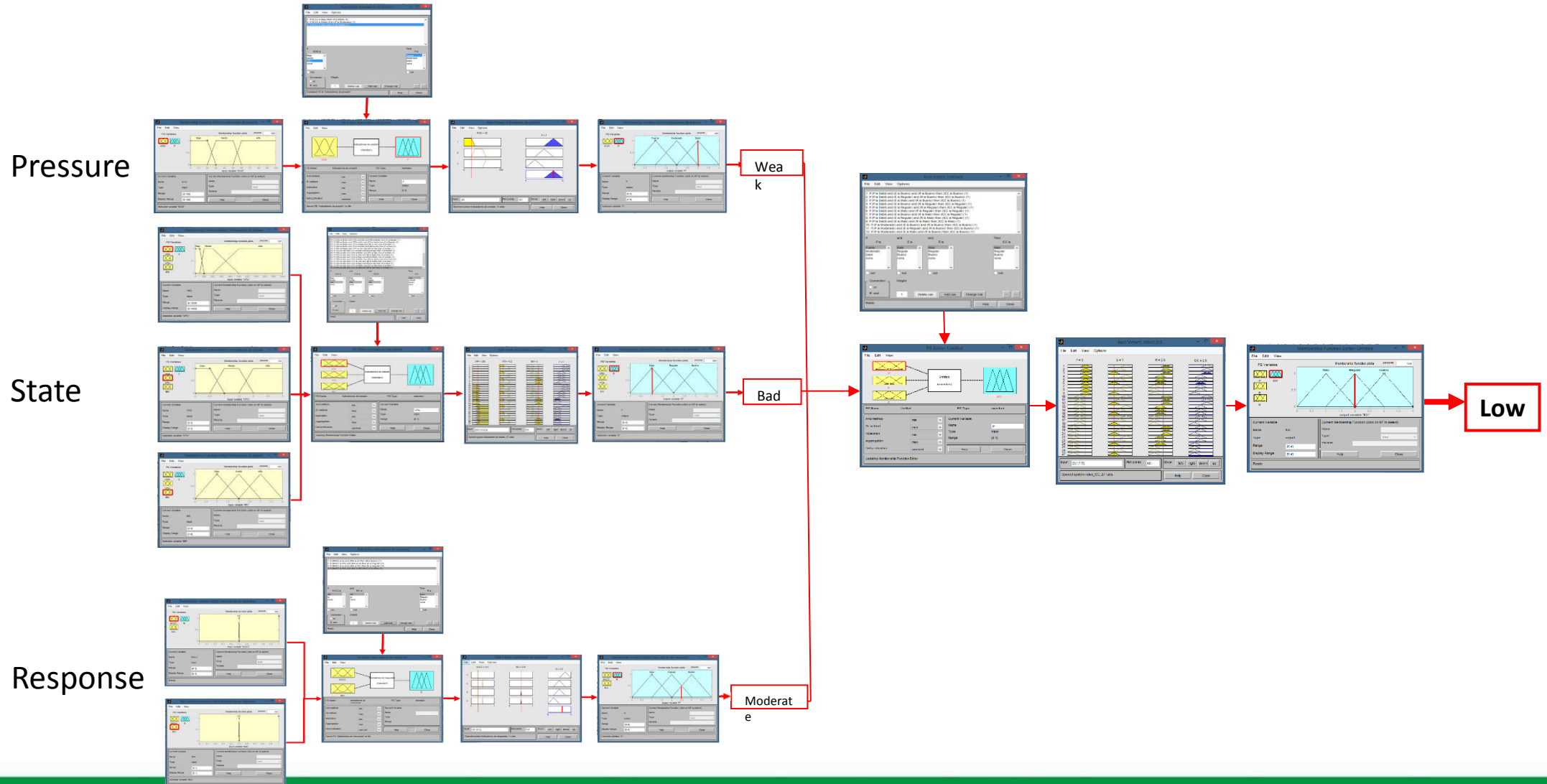
Conflicts for water use

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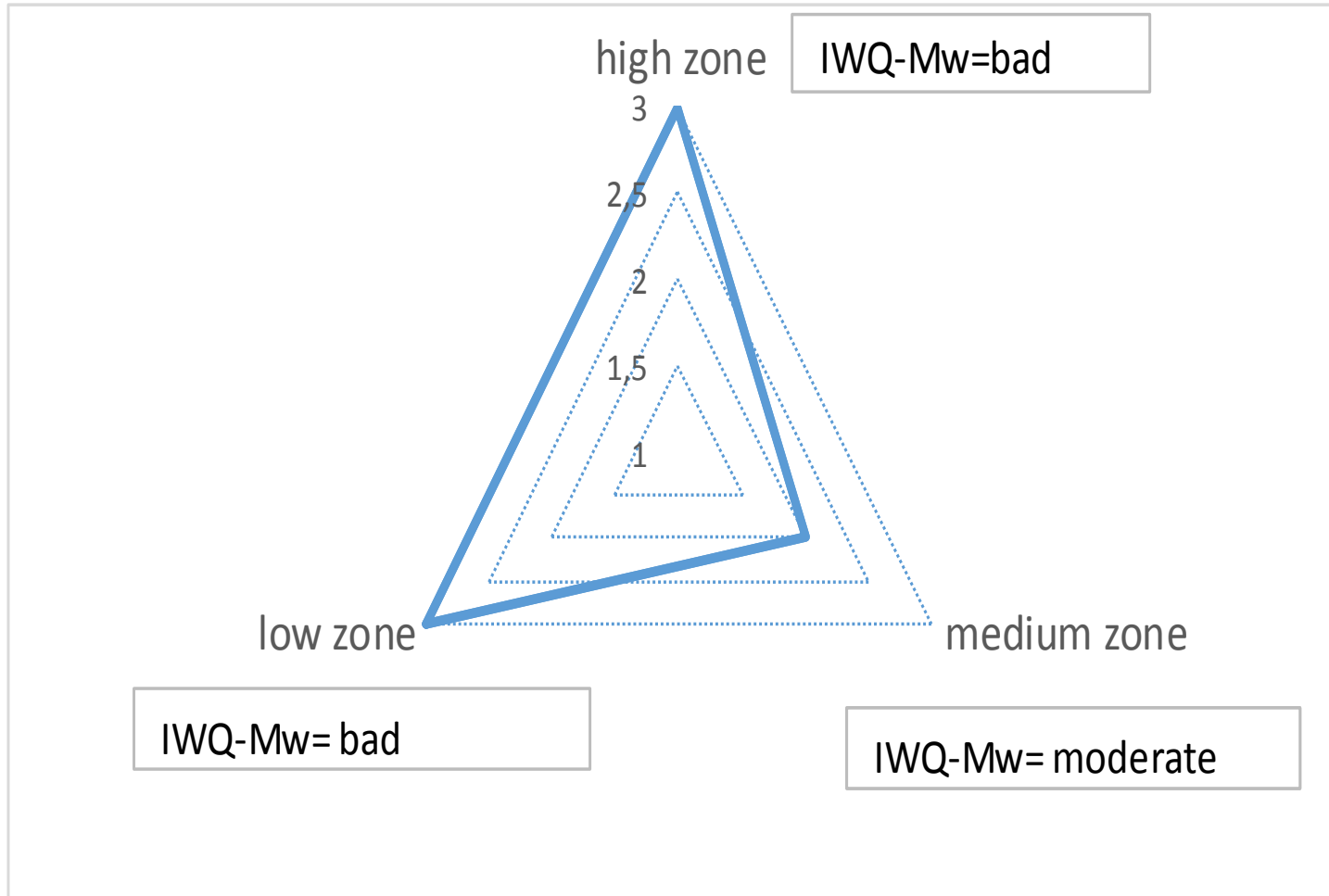
Micro-watershed El Chocho indicators values

Zone	Pressure	State	Response
High	WW \approx 90% M \equiv Yes EL \approx 50%	COD=400 (mg/L) FC=1.000(UFC/100ml)	WWT \approx 0% SMS \equiv No PRR \equiv No
Medium	WWU \approx 80% M \equiv Yes EL \approx 60%	COD=800mg/L FC=20.000(CFU/100mL)	WWT \approx 0% SMS \equiv No PRR \equiv No
Low	WWU \approx 80% M \equiv Yes EL \approx 60%	COD=800mg/L FC=20.000(CFU/100ml)	WWT \approx 0% SMS \equiv No PRR \equiv No

Matlab results –WQI-Mw in Chocho



WQI-Mw in Chocho



- A new index for the assessment of the water quality in micro-watershed Andean was developed –IWQ-Mw
- The index can be used to assessment the quality of the water in different temporal and spatial scales
- It is necessary to do more applications in others Andean micro-watersheds to evaluated the indicators and the index results
- It is necessary to do applications in other scale levels: sub-watershed and watershed

Thanks for your attention

