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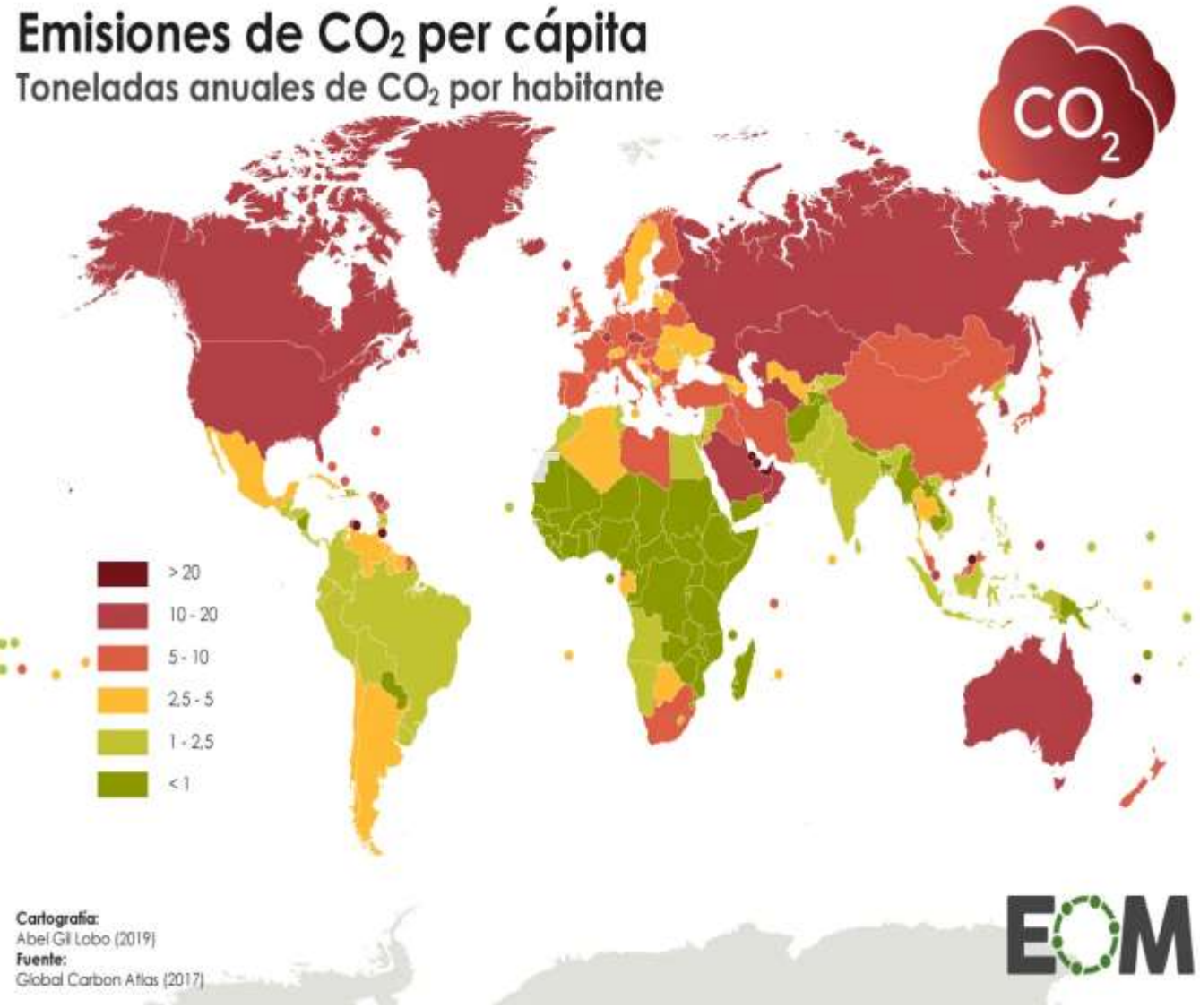
Towards an index with artificial intelligence to evaluate vulnerability to climate change in micro-watersheds in Colombia

Ph.D. Viviana Vargas-Franco
Universidad Nacional de Colombia
– Sede Palmira

Emisions of CO2 in the world



Climate change poses one of the most formidable challenges of the twenty-first century.

It has planet-wide causes and consequences, but its impacts are asymmetrical among regions, countries, sectors and socioeconomic groups, with those that have contributed the least to global warming being the hardest-hit.

Latin America and the Caribbean has made a minor contribution to climate change, given the region's low levels of greenhouse gas emissions, but is particularly vulnerable to its negative impacts.

In Colombia, rains in 2021 already leave 71 dead and more than 168,000 victims (Time, 2021)

Huracán Iota. Providencia-Colombia.
Photo: Castañeda, 2020

An avalanche caused by rain causes 234 deaths in Colombia, 2017

- Colombia is a country with two big oceans, big biodiversity and forest.
- **Colombia is at high risk from climate change impacts**.
- 45 percent of the country's municipalities have experienced emergencies since the beginning of this year.
- The majority of the population lives in the elevated Andes, where water shortages and land instability are already a reality, and on the coast, where the increase in sea level and floods can affect key human settlements and economic activities.

vulnerability of climate change

15 Jun-2021 (EUROPA PRESS)

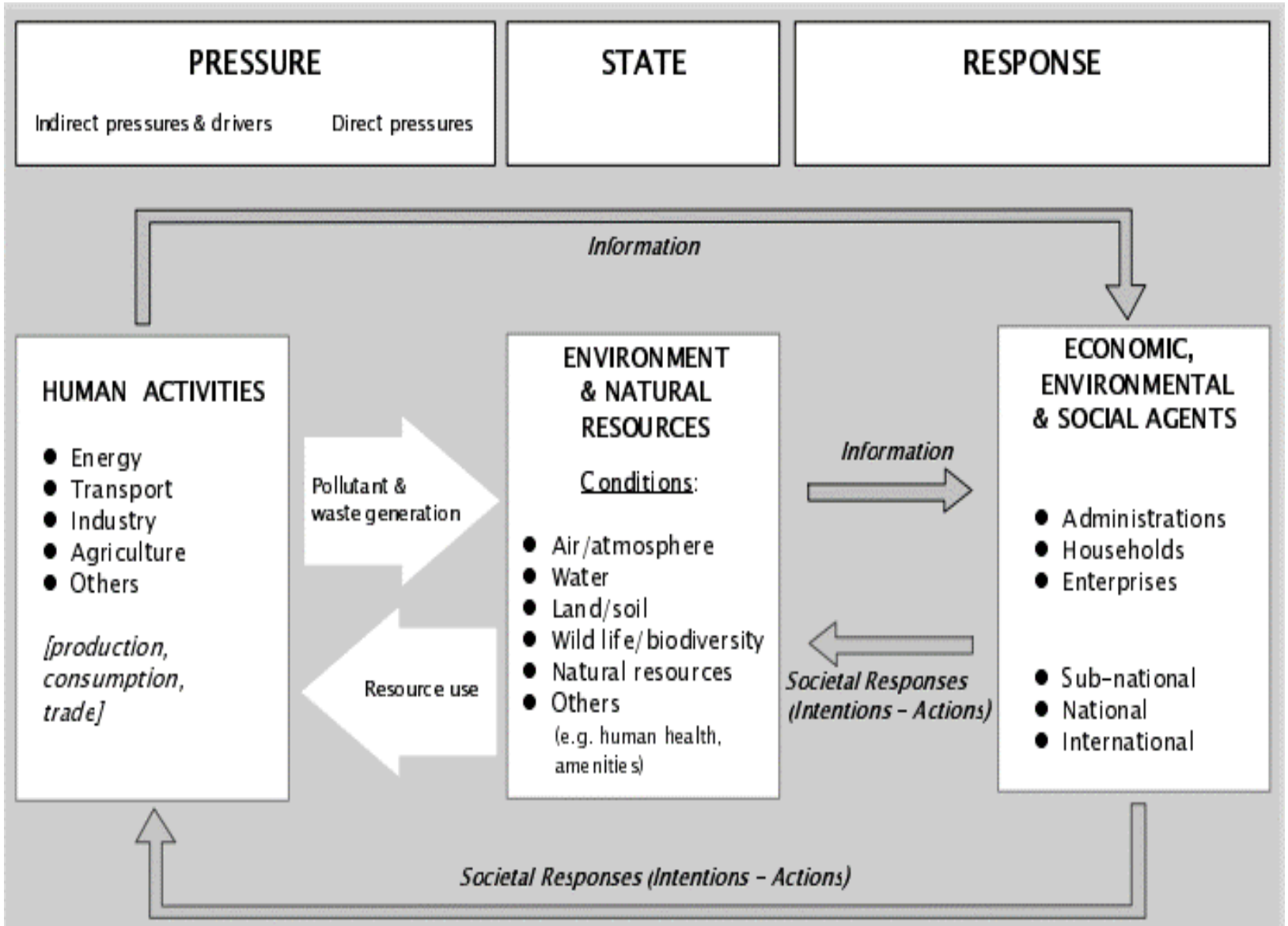
Generally, the communities does not have information and knowledge about your level of climate vulnerability. Climate vulnerability is a complex concept related with chaos theory

This study constructs and applies an index to estimate vulnerability level to climate change (CCI) in tropical Andean micro-watersheds.

The CCI was constructed with a combination of two analytical methodologies: Pressure-State-Response (PER) indicators and fuzzy logic from artificial intelligence.

The index CCI was applied to the tropical Andean microcuenca río Bolo located in the Department of Valle del Cauca in Colombia.

Methodology – PSR framework

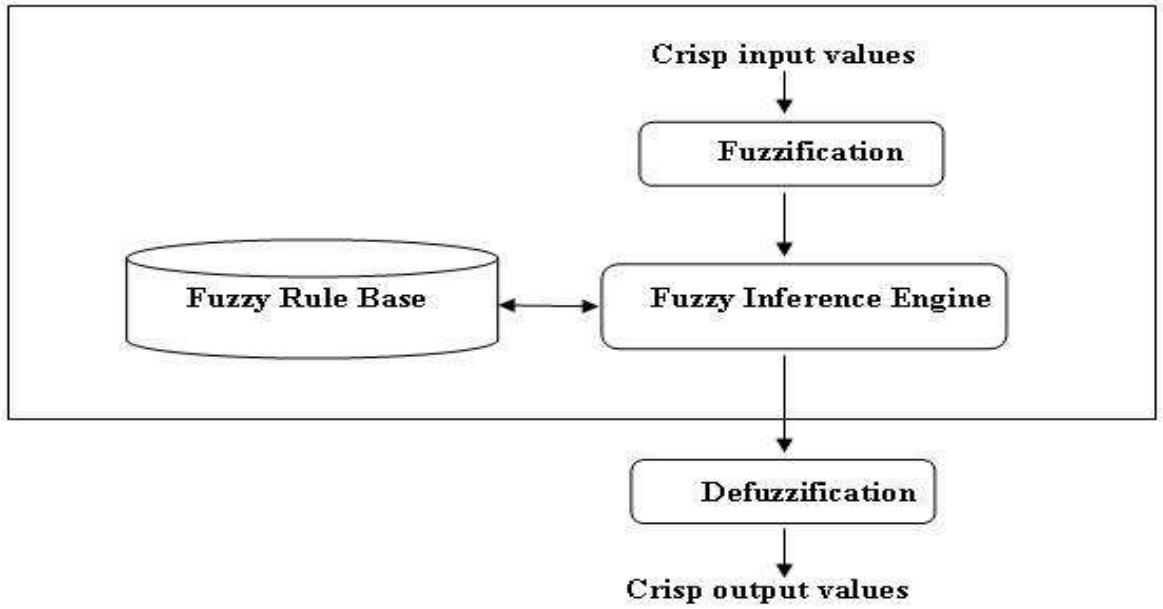


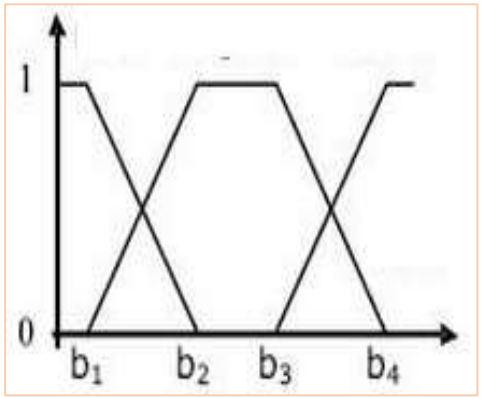
Pressure (P) perceived causes of adverse environmental effects, answer the questions: **why is it happening?** and what social, political, economic, market and other forces are involved?

State (S) answer the question: **what is happening to the state of the environment of natural resources?** and these observations show: changes or trends in the physical or biological state of the natural world.

Response (R) answer the question; **what are we doing about the state and pressure, or what can be done about it?** and these observations show: actions adopted in response to environmental problems and concerns.

Methodology – fuzzy logic of artificial intelligence





Difuze rules

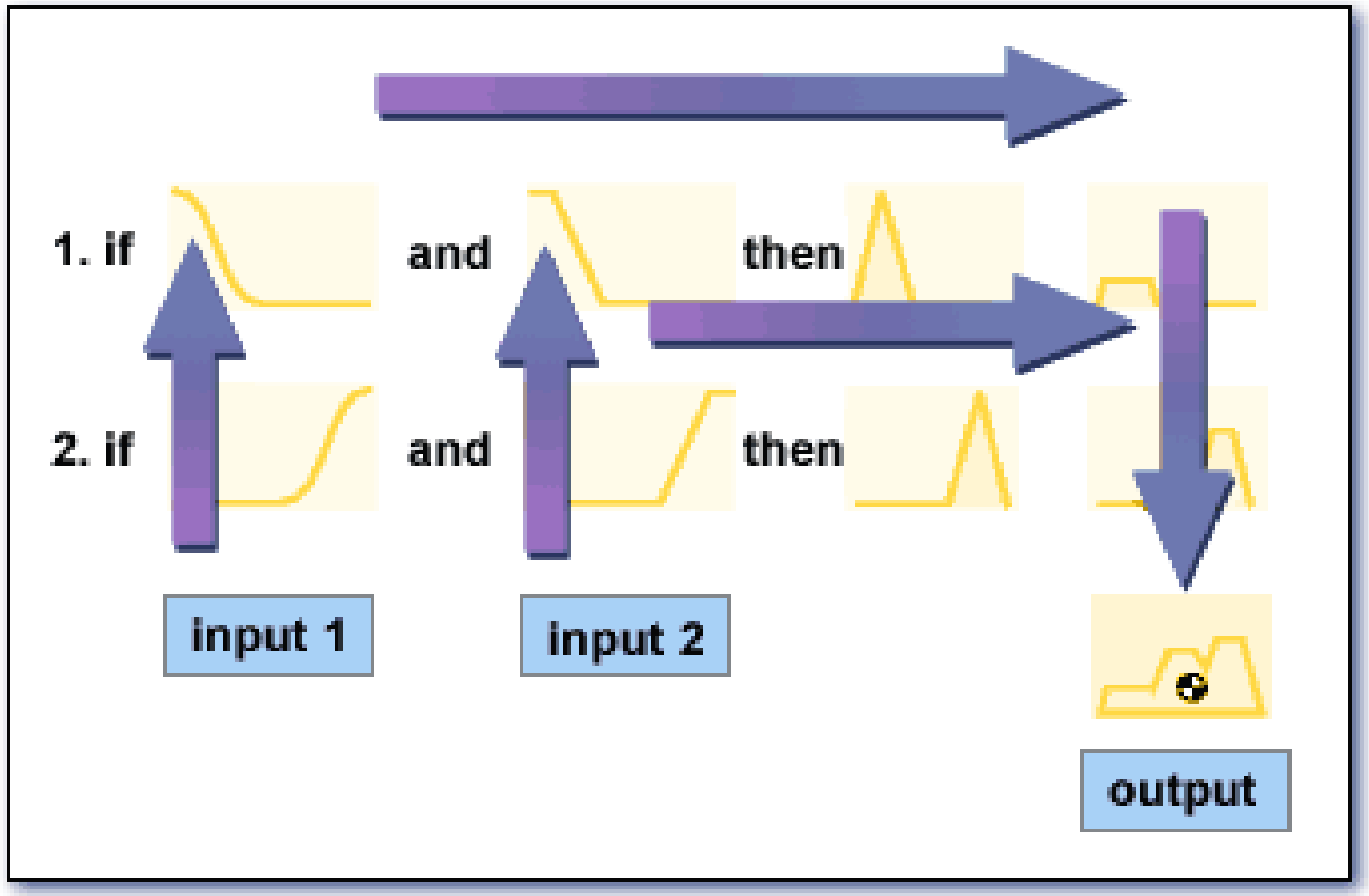
Fuzzy logic provides an inference system that enables approximate human reasoning capabilities to be applied to knowledge-based systems.

The theory of fuzzy logic provides a mathematical strength to capture the uncertainties associated with human cognitive processes, such as thinking and reasoning.

Fuzzy logic has been proposed as a systematic tool for assessment of sustainability.

Fuzzy logic can represent uncertain data, emulating skilled humans, and handling vague situation where traditional mathematics is ineffective and is a scientific tool that permits modelling a system without detailed mathematical descriptions using qualitative as well as quantitative data.

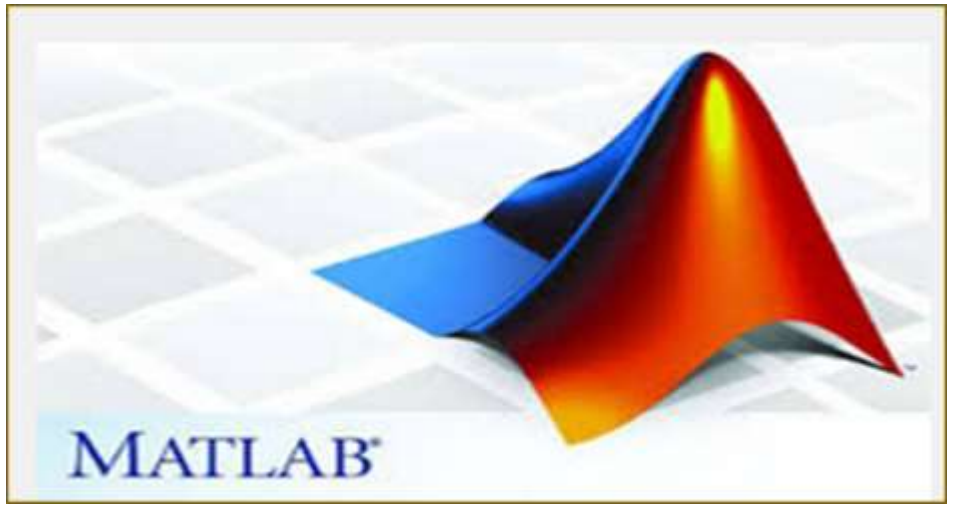
Methodology



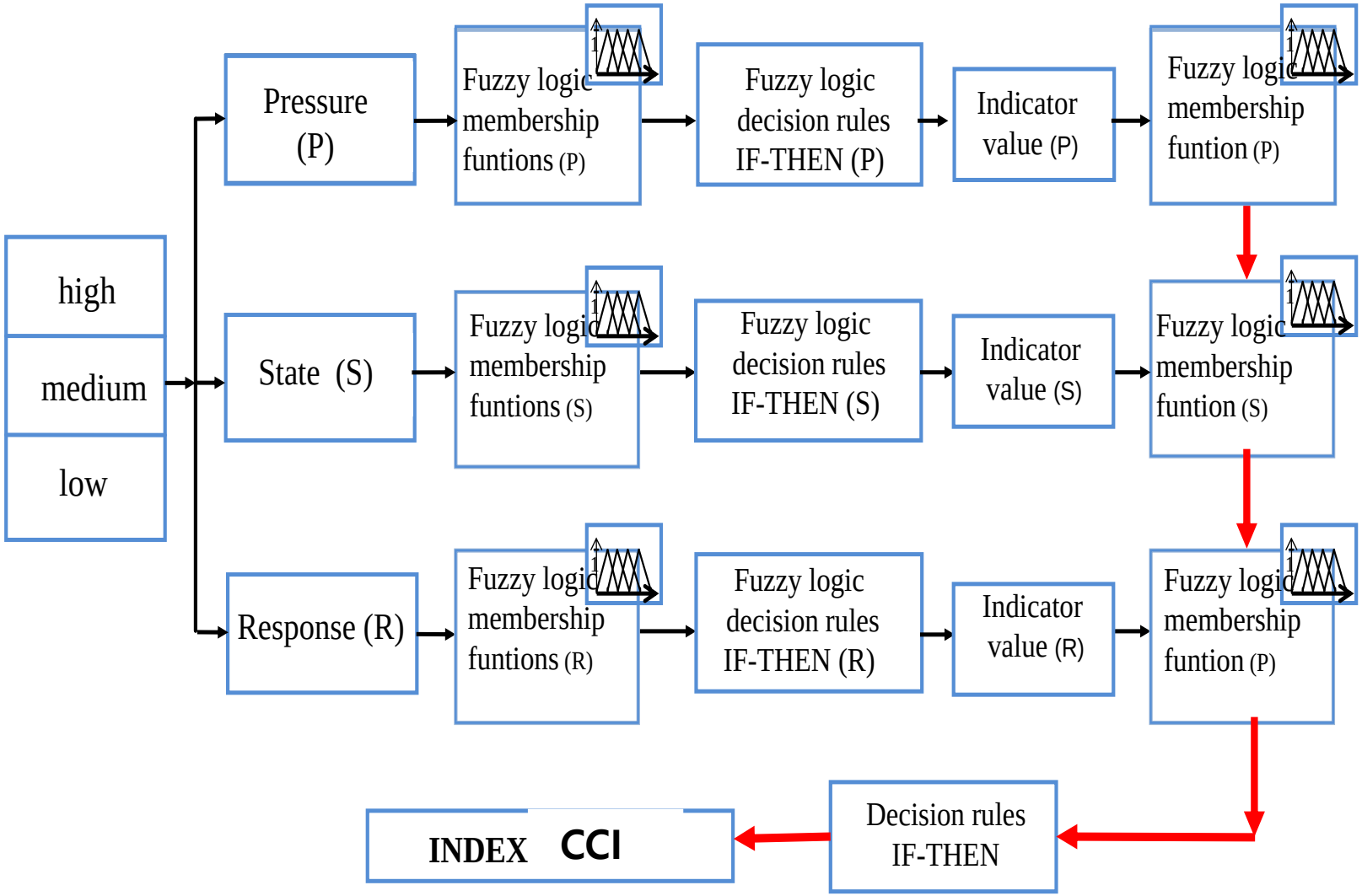
Interpreting the Fuzzy Inference Diagram

Each indicator is associated with a fuzzy logic function.

MATrix LABoratory is a proprietary multiparadigm programming language and numeric computing environment developed by MathWorks.



Methodology– conceptual structure for index ICC

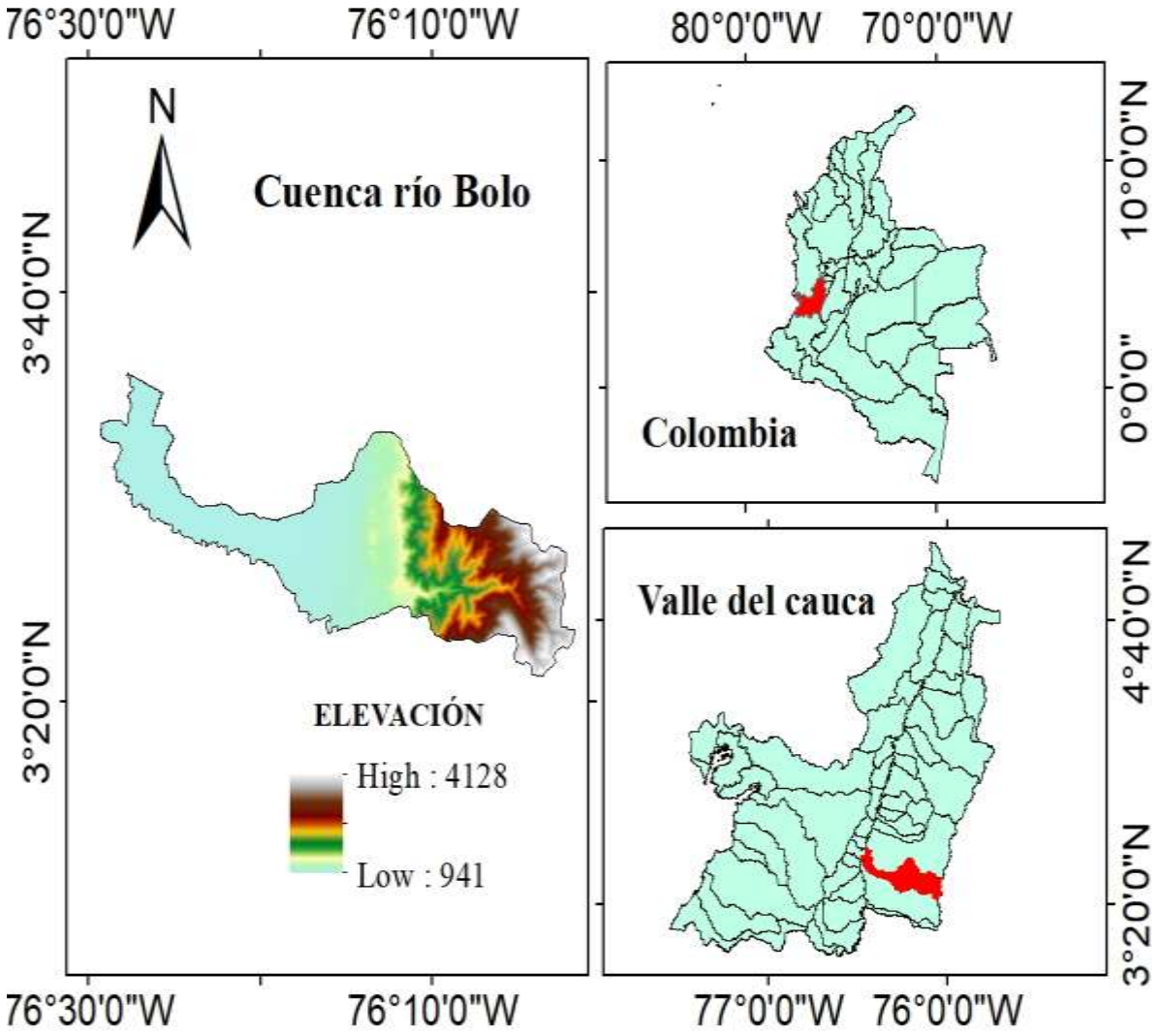


The inputs are the indicators PSR values in each zone in a watershed.

The inputs of each indicator are provided by the user through knowledge, information or data.

By using fuzzy logic functions and IF-THEN rules, these inputs are combined to build a composites index as output.

Methodology



The index CCI was applied to the tropical Andean micro watershed river Bolo located in the Department of Valle del Cauca in Colombia.

Río Bolo is a river in Valle del Cauca and has an elevation of 948 metres. Río Bolo is situated west of Dos Cabas, close to Zanjón del Bolo.

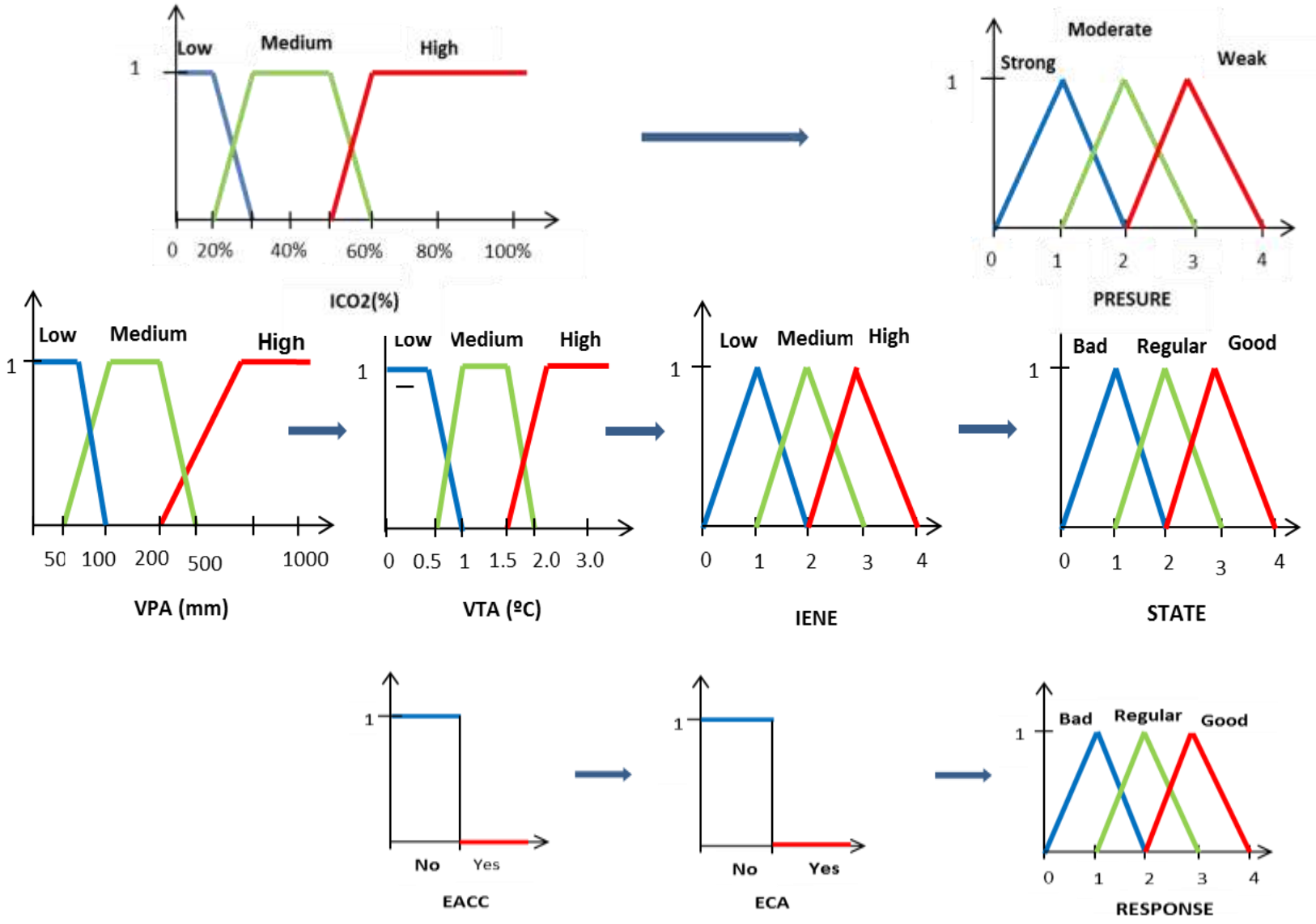
This river is located in the Upper Cauca River basin in Colombia, and they are the main water resources of Candelaria, Florida and Pradera municipalities.

Results – Pressure-State-Response (PER)

Pressure	State	Response
Increase emissions carbon dioxide (ICO2)	**Precipitation variation (PVA)** **Temperature variation (TVA)** **Increase extreme natural events (IENE)** (Droughts, floods, landslides)	**Strategies for mitigation and adaptation to climate change (SACC)** **Investment in abatement and control air pollution (IACP)**

PRS indicators were defined as quantitative and qualitative components. In this table is presented the set indicators proposal.

Methodology- fuzzy logic funtions



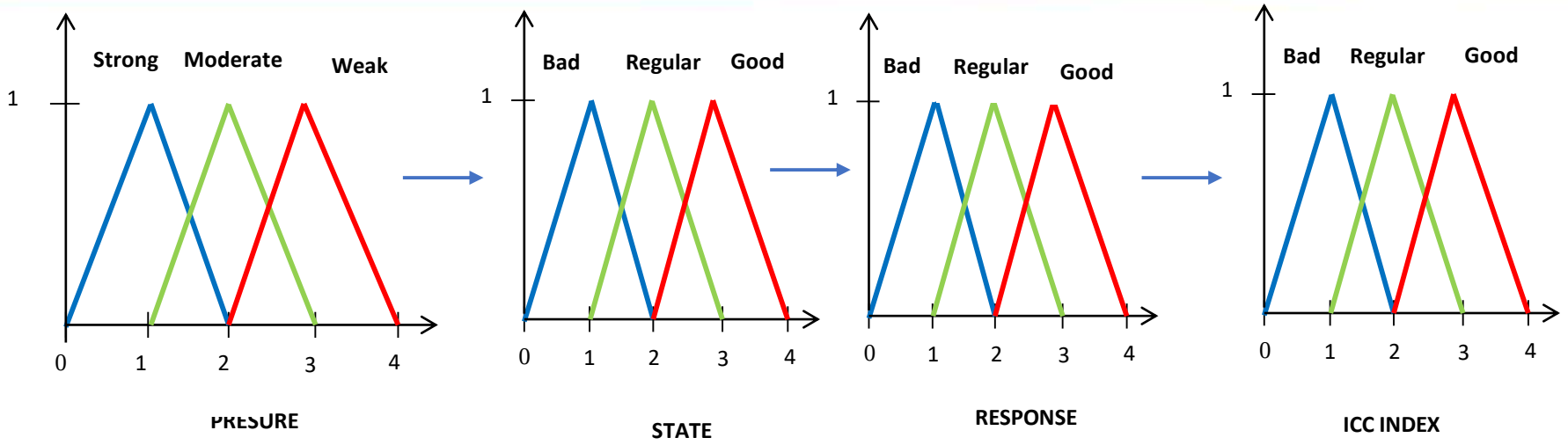
Triangular, singleton, trapezoidal functions were assigned to each PSR indicator.

These functions were defined through both literature review and expert judgement.

Logic functions is shown in this figure.

The build of these functions were about the expert knowledge and literature review

Methodology- examples of rules



No.	Rules
1	IF (VPA IS LOW) AND (VTA IS LOW) AND (IENE IS LOW) THEN STATE IS GOOD
2	IF (VPA IS LOW) AND (VTA IS MEDIUM) AND (IENE IS LOW) THEN STATE IS GOOD
3	IF (VPA IS LOW) AND (VTA IS HIGH) AND (IENE IS LOW) THEN STATE IS GOOD
…	…..
…	…..
25	IF (VPA IS HIGH) AND (VTA IS LOW) AND (IENE IS HIGH) THEN STATE IS BAD
26	IF (VPA IS HIGH) AND (VTA IS MEDIUM) AND (IENE IS HIGH) THEN STATE IS BAD
27	IF (VPA IS HIGH) AND (VTA IS HIGH) AND (IENE IS HIGH) THEN STATE IS BAD

Results – some problems in Bolo river


Acid mine drainage


Occupancy of the protetive zone


Wastewater


Mining


Change in land use, livestock


Conflic for soil use


Water contamination


Contamination for mining

Conflicts for water use

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 solid wastes

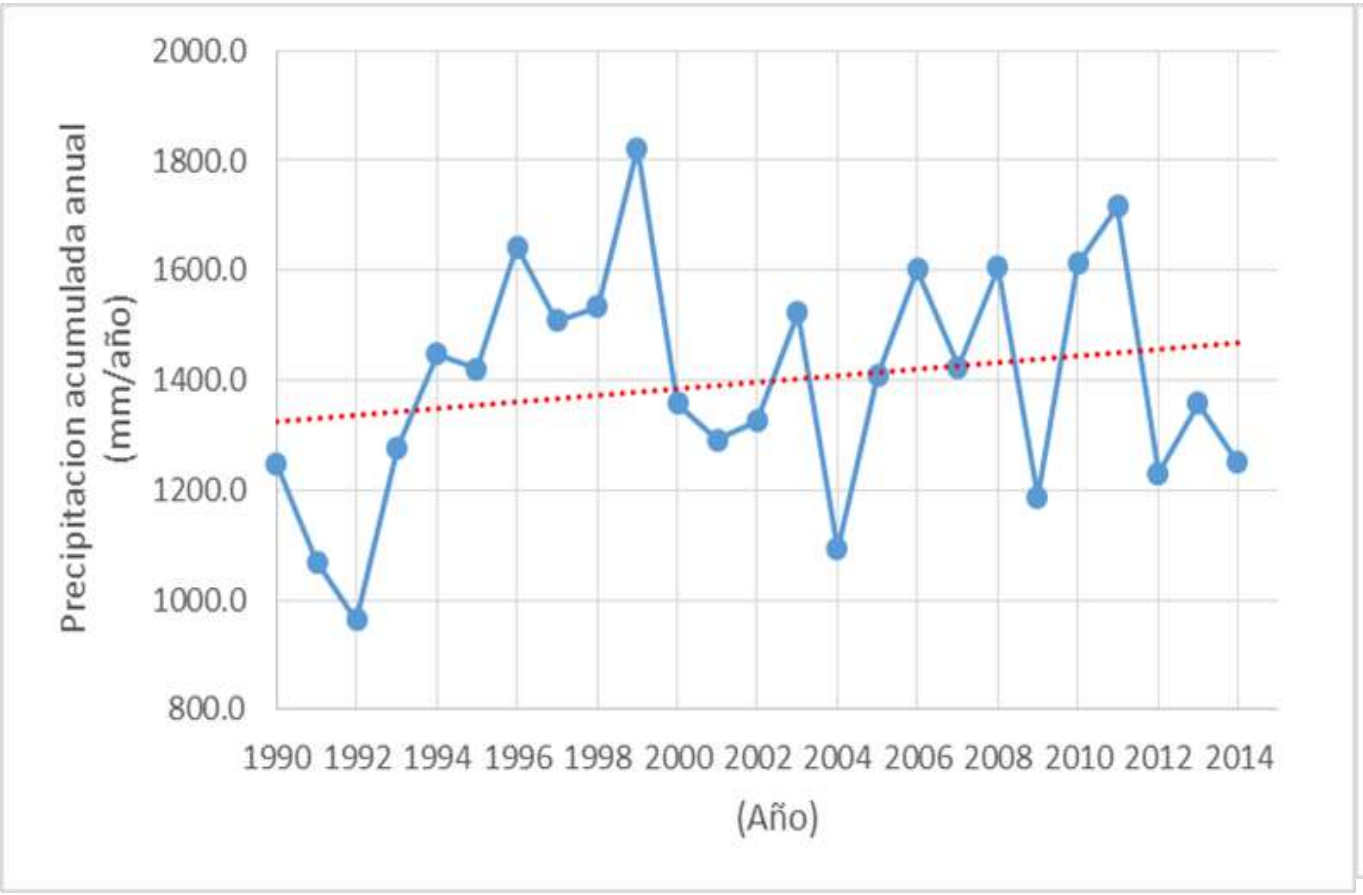
Discharge of acid

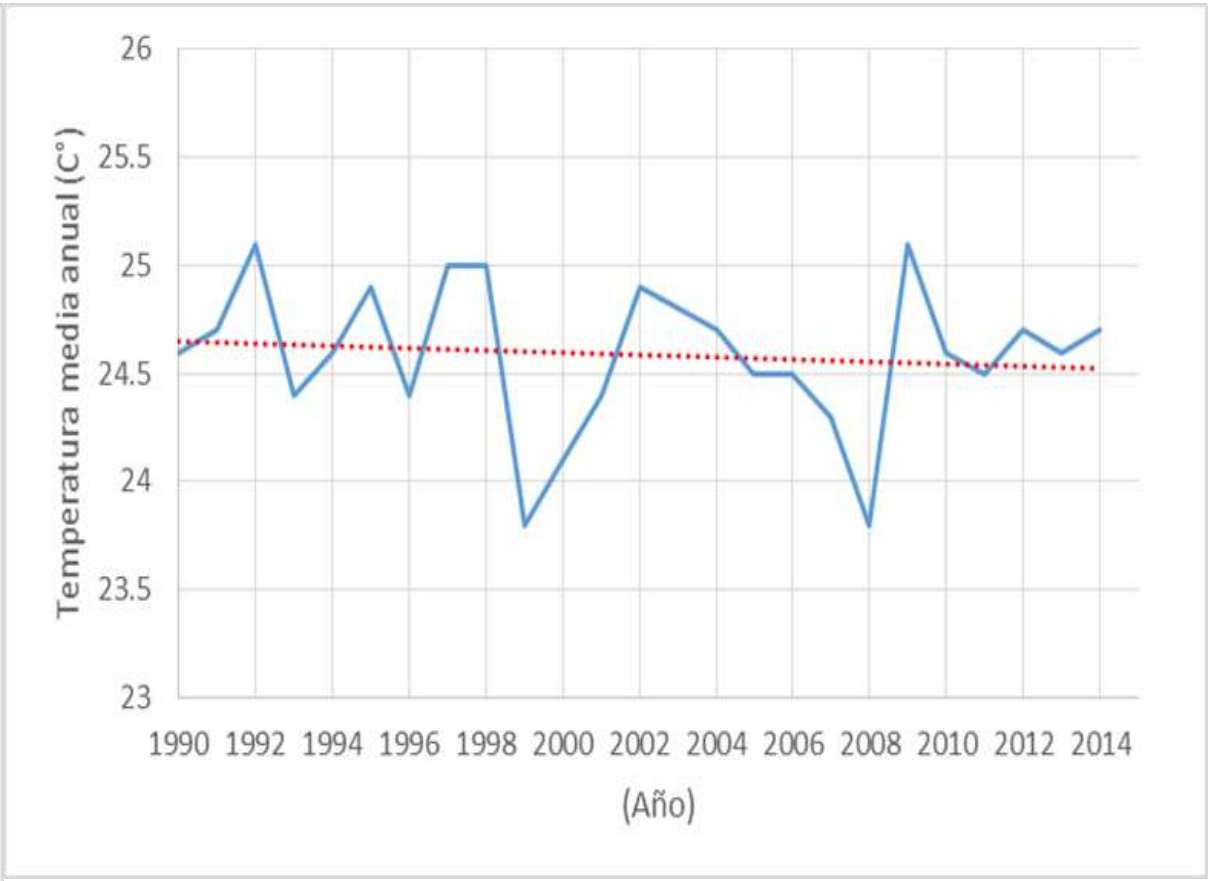
Conflicts caused by the use of the water and soils

Institutions problems

Low local participation

Variation of precipitation and temperature

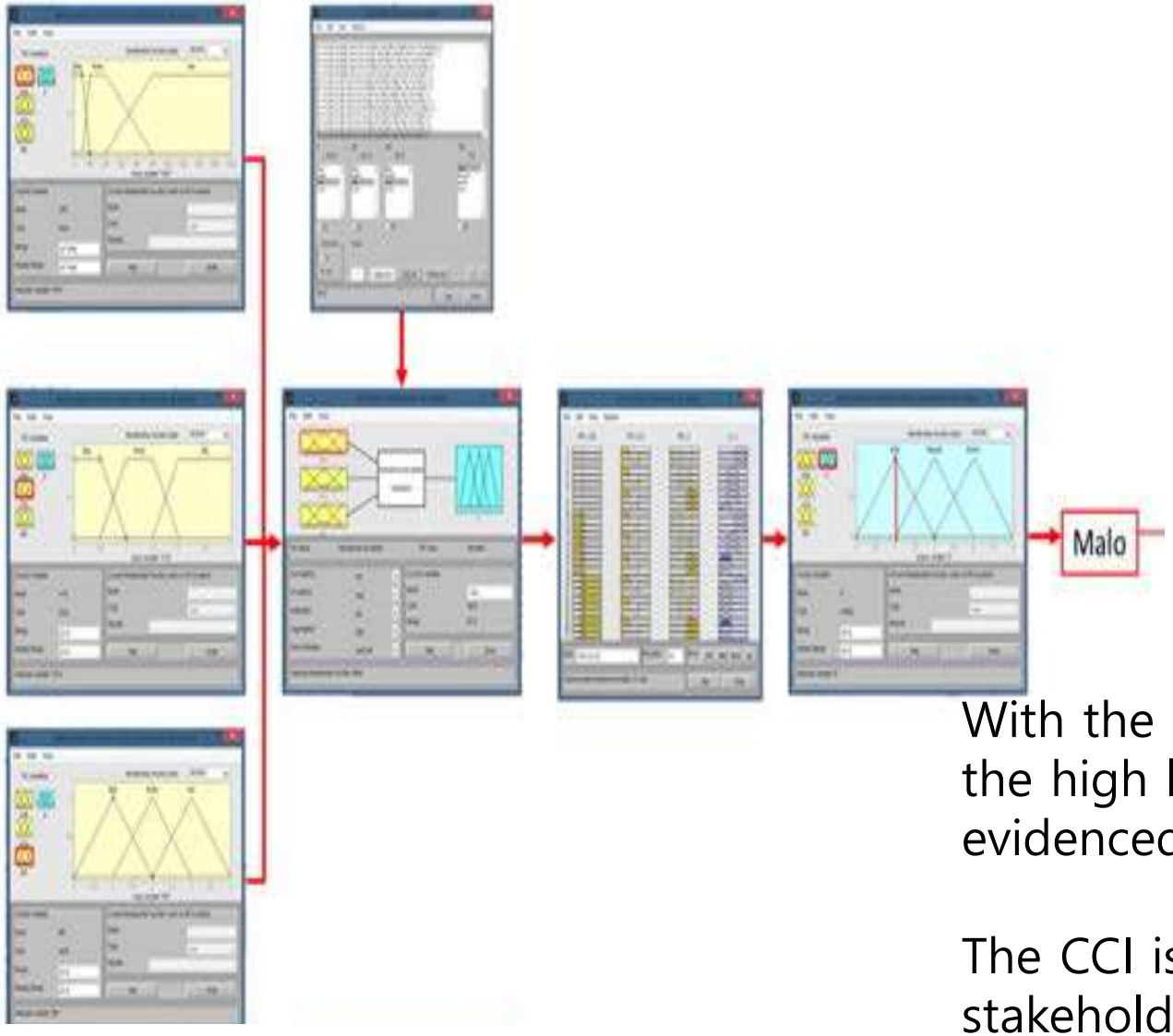


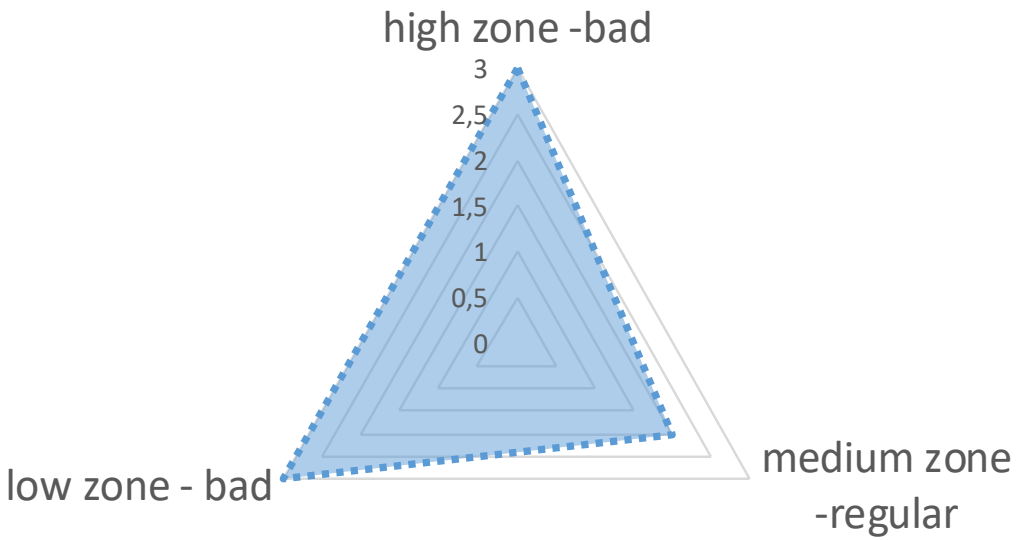


Results – indicators values in Bolo river

Zone	Pressure	State	Response
High	ICO_2 = 60%	VPA=309mm VTA=0,3 C IENE = Medium	EACC=No ECA=No
Medium	ICO_2 = 40%	VPA=332mm VTA=0,3 C IENE = Medium	EACC=No ECA=No
Low	ICO_2 = 60%	VPA=355mm VTA=0,3 C IENE = Medium	EACC=No ECA=No

Results- Values CCI





With the application of the CCI index in this micro-basin, the high level of vulnerability of this micro-watershed was evidenced in the low, medium and high zone.

The CCI is a support for the decision-makers and different stakeholders in the micro-watershed.

Some conclusions

- Using artificial intelligence as linguistic variables, linguistic rules and pressure-state-response indicators were built an approximation of a index to evaluated the vulnerability of climate change.

- The index can be used to assessment the vulnerability of climate change level in different temporal and spatial scales.

- The situation of the Bolo River micro-watershed is worrying at the level of vulnerability to climate change.

- It is necessary to do more applications in others micro-watersheds to evaluated the indicators and the index results. It is necessary to do applications in other scale levels: sub-watershed and watershed.

¡¡Thank you very much!!