FUZZY RULES FOR SEGMENTATION OF REMOTELY SENSED IMAGES

FUZZY BASED SEGMENTATION OF REMOTELY SENSED IMAGES USING AN ADAPTIVE NEURO FUZZY INFERENCE SYSTEM (ANFIS).

MONTEMURRO ANDREA (747997) - A.MONTEMURRO23@STUDENTI.UNIBA.IT

WHAT WE ARE TALKING ABOUT?

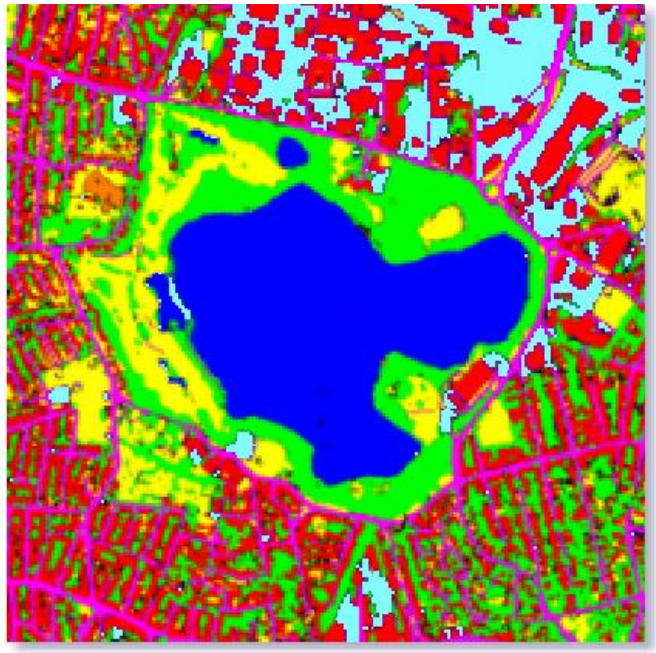
- REMOTELY SENSED IMAGES
- SEGMENTATION
- TASK

REMOTELY SENSED IMAGES

- **Remote sensing images** cover diversified applications in meteorology, agriculture, geology, biodiversity conservation, land use planning, education, intelligence, warfare.
- The images can be acquired in color in the visible spectrum (for example in the RGB spectral bands) or in other electromagnetic spectra (for example in the infrared).

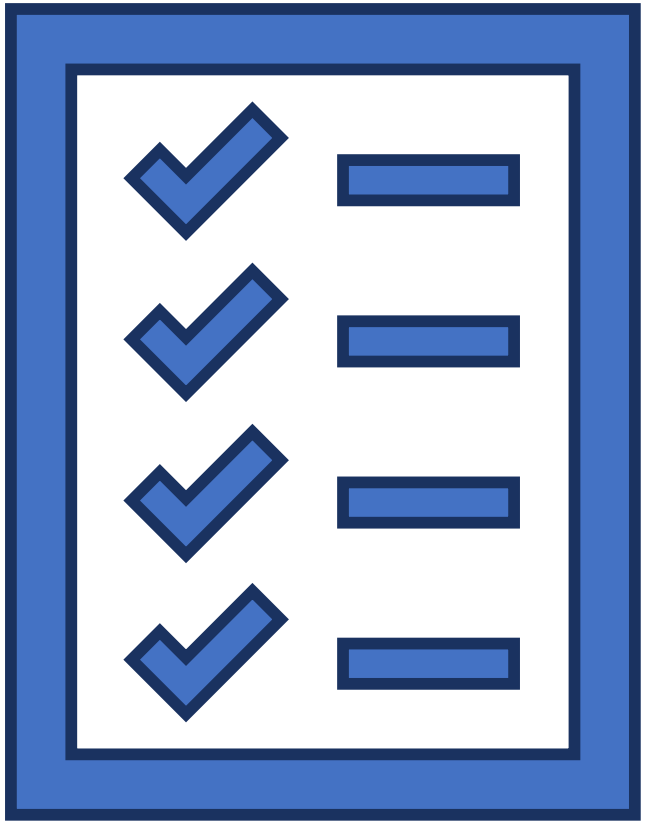
IMAGE SEGMENTATION

- In computer vision **image segmentation** is the process of partitioning a digital image into multiple segments (sets of pixels, also known as image objects).
- The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.



TASK

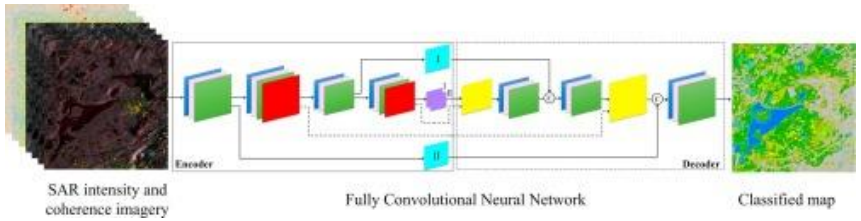
- **Goal**: semantic segmentation in 4 classes (water, vegetation, building, road) of the RS images.
- **Method**: generate Fuzzy Rules to classify each pixel of an image
- **Data**: RS images (RGB) and corresponding dense labeled images (supervised)



METHOD

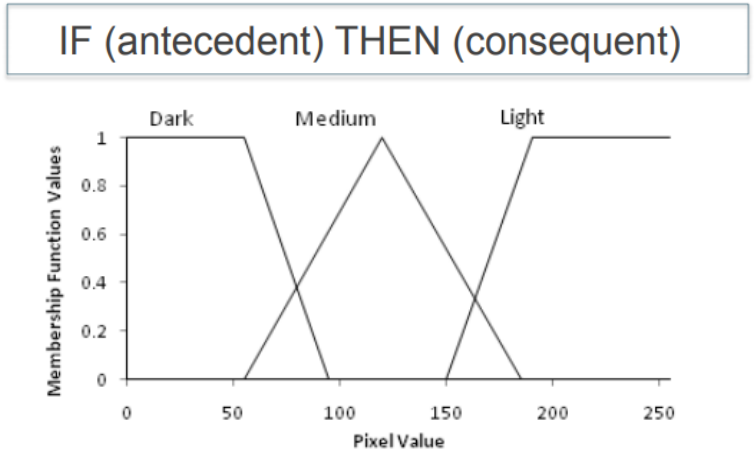
WHY FUZZY LOGIC?

- **State of Art** in image segmentation use approaches based on the use of CNN (for example FCN, U-Net, SegNet).



[E. Shelhamer J. Long and T. Darrell. Fully convolutional networks for semantic segmentation, 2015. Proc. IEEE Conf. Comput. Vis. Pattern Recognit. (CVPR), pp. 3431-3440]

- Fuzzy logic allows for **more explanatory** results. To exploit both the advantages of neural networks (ability to learn) and those of fuzzy logic in this work an ANFIS network was used.

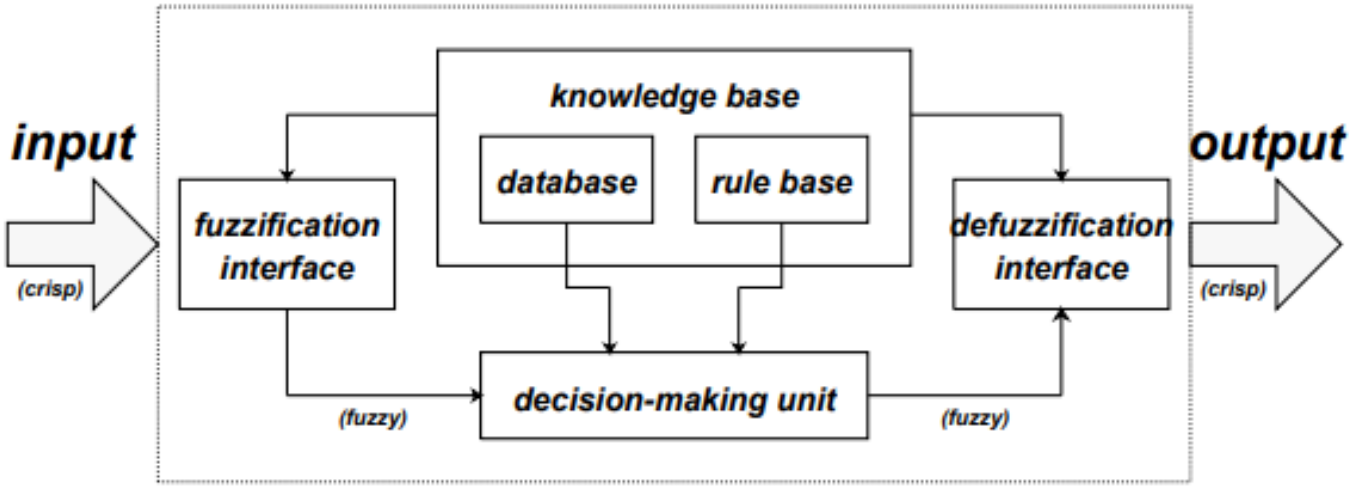


[Jensenr F. Qiu. Opening the black box of neural networks for remote sensing image classification. International Journal of Remote Sensing, 25(9):1749–1768, 2004]

FUZZY INFERENCE SYSTEM

A **fuzzy inference system** is composed of five functional blocks:

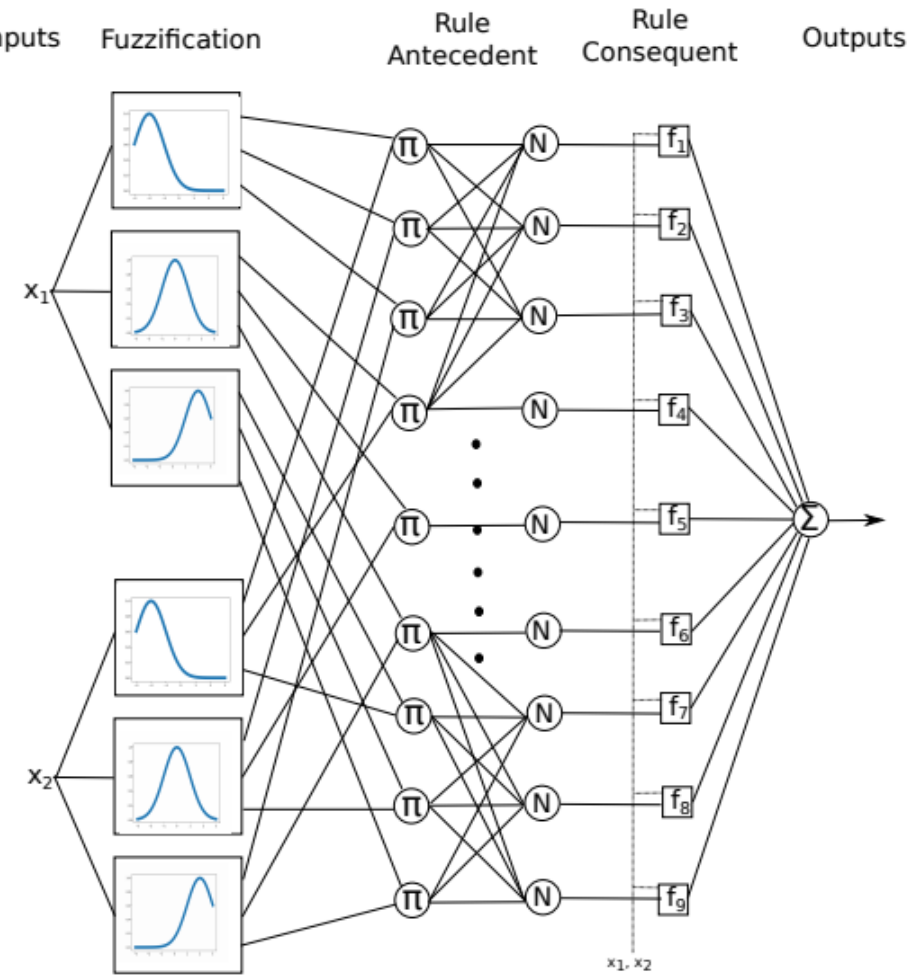
1. a rule base containing several fuzzy if-then rules;
2. a database which defines the membership functions of the fuzzy sets used in the fuzzy rules;
3. a decision-making unit which performs the inference operations on the rules;
4. a fuzzification interface which transforms the crisp inputs into degrees of match with linguistic values;
5. a defuzzification interface which transform the fuzzy results of the inference into a crisp output.



ADAPTIVE NEURO FUZZY INFERENCE SYSTEM (ANFIS)

This type of network is composed by five layers:

- A fuzzification layer that use a membership function to fuzzify the input;
- A layer that multiplies the incoming signals and sends the product out;
- The layer that compute the ratio of the i-th rule's firing strength to the sum of all rules' firing strengths
- A layer that computes the weights of the Rule Consequents;
- The final layer that defuzzify the rule consequent and predict a class.



EXPERIMENT

TOOLS AND EXECUTION ENVIRONMENT

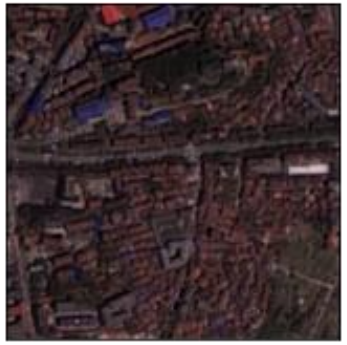
- A **Python** implementation with **PyTorch** of the *Adaptive Neuro Fuzzy Inference System* was used in the experiment.
- Other libraries were used to preprocess the images, such as **OpenCV** and **Scikit-image**.
- **Google Colaboratory** was used as the execution environment: it offers a single core hyper threaded Xeon Processors@ 2.3Ghz CPU (1 core, 2 threads) and a Tesla K80 GPU,having 2496 CUDA cores, 12GB GDDR5 VRAM.

DATASET










DATASET

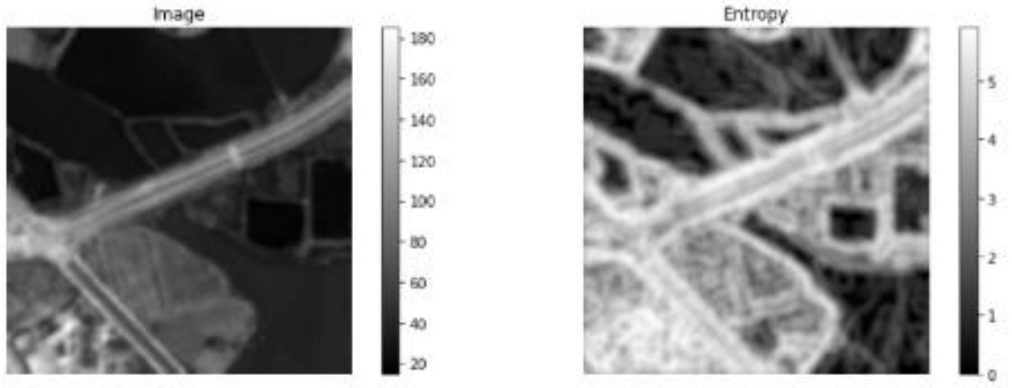
Class	%
Building	22
Road	16
Vegetation	50
Water	12

- The dataset is made up of **65536 pixels** extracted from ten 256x256 images manually selected from the WHDLD dataset. For each pixel we have the relative RGB and entropy (every image is preprocessed) values and the class to which it belongs.

The table describes the dataset composition in terms of classes.

[Yang K. Zhou W. Shao, Z. Evaluation of single-label and multi-label remote sensing image retrieval using a dense labeling dataset. Remote Sensing, 10(6):964, 2018]

ENTROPY OF A GRAY-SCALE IMAGE



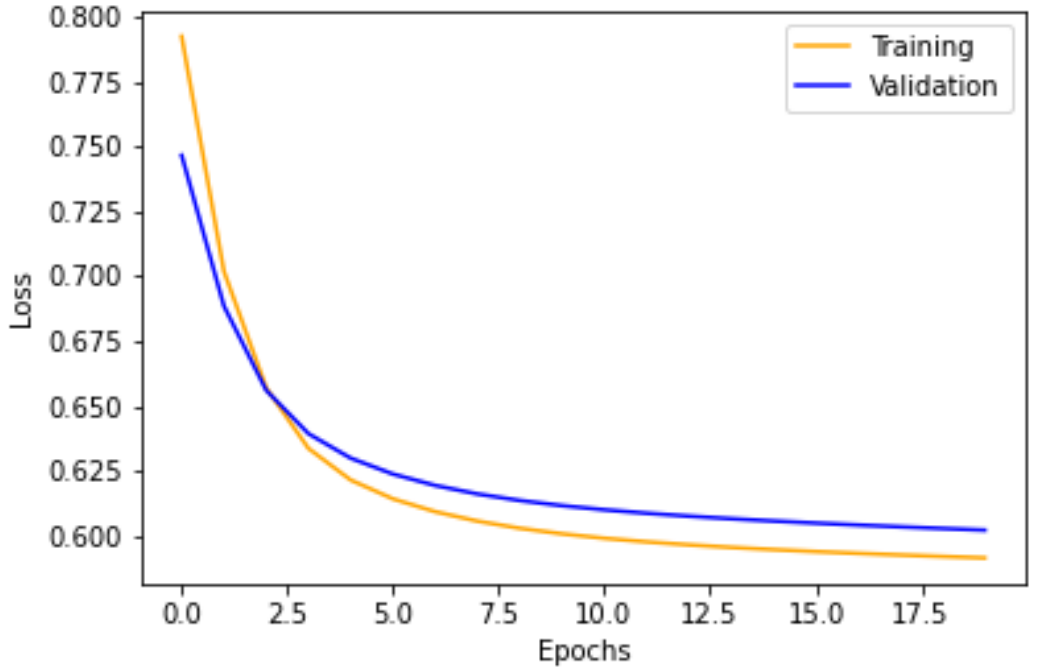
The **Entropy** can be included to better classify every pixel. It is used to make a kind of **texture extraction**.

$$-\sum_{i=0}^{n-1} p_i \log_b p_i$$

NETWORK TRAINING

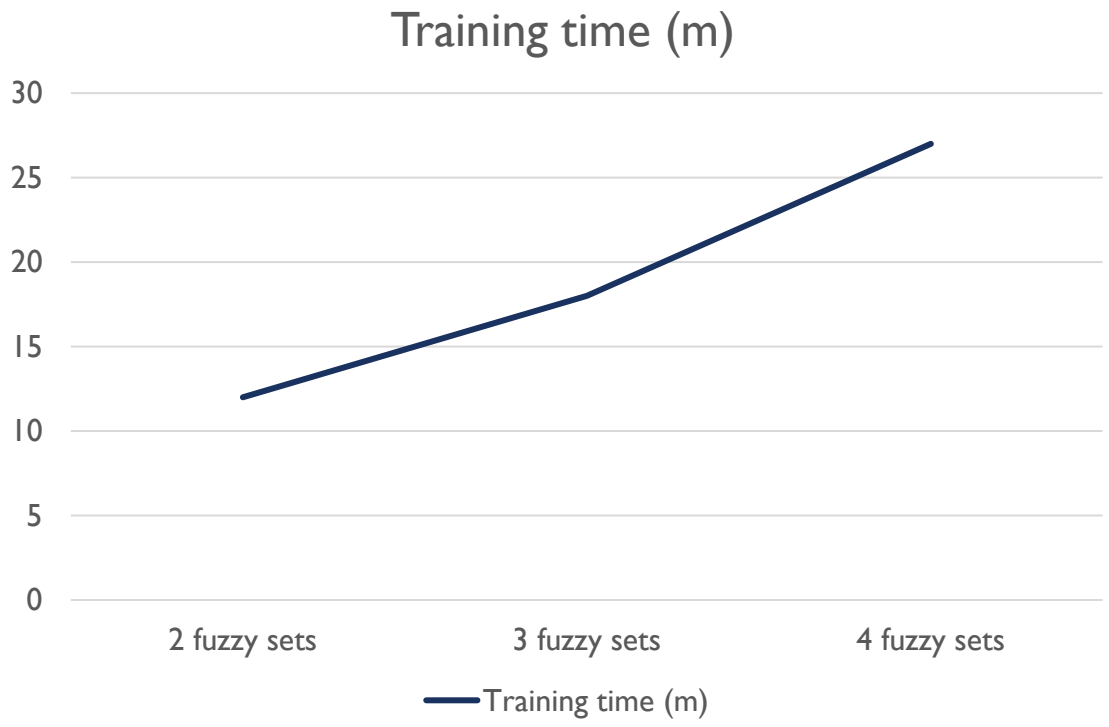
- Different experiment settings with 2,3 and 4 fuzzy sets were tested
- Stratified train/test splitting were used

In all three cases, the network was trained using 20 epochs and 32 as batch size.



The graph shows the trend of the loss function for training and validation data, in the configuration with 2 fuzzy sets per variable.

TRAINING TIME AND ACCURACY



Fuzzy Sets	Overall Accuracy
2	75,01%
3	76,42%
4	77,18%

HOW THE ANFIS PERFORM ?

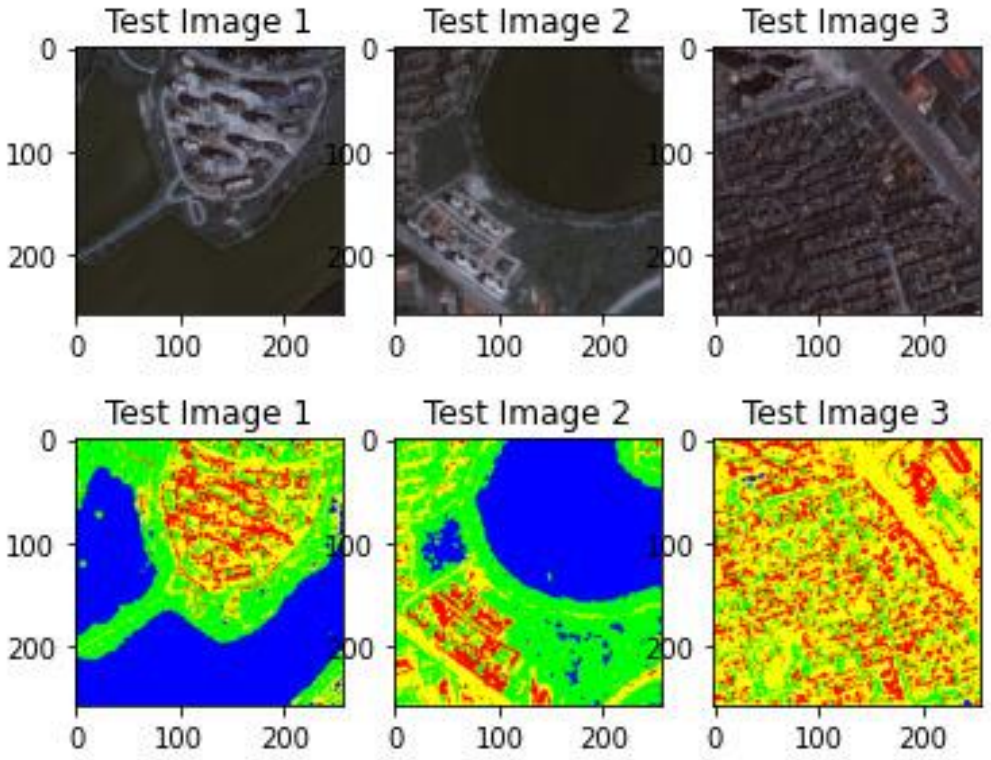
*(WITH 2 FUZZY SETS)

- **Very good** performance in classify pixel that belongs to the *Vegetation* and *Water* classes
- **Accettable** performance in classify *Building* class
- **Not good** in classify *Road* class

Table 5. Test scores.

Label	precision	recall	f1-score
Building	0.75	0.62	0.68
Road	0.51	0.52	0.51
Vegetation	0.79	0.88	0.83
Water	0.89	0.77	0.83
accuracy			0.75
macro avg	0.74	0.70	0.71
weighted avg	0.75	0.75	0.75

… BUT BEYOND THE NUMBERS WHAT CAN WE SEE?



In the **segmented images**…

- There is some confusion in urban areas
- Pixel that represents trails are often classified as *road*
- Sometimes darker *vegetation* is classified as *water*

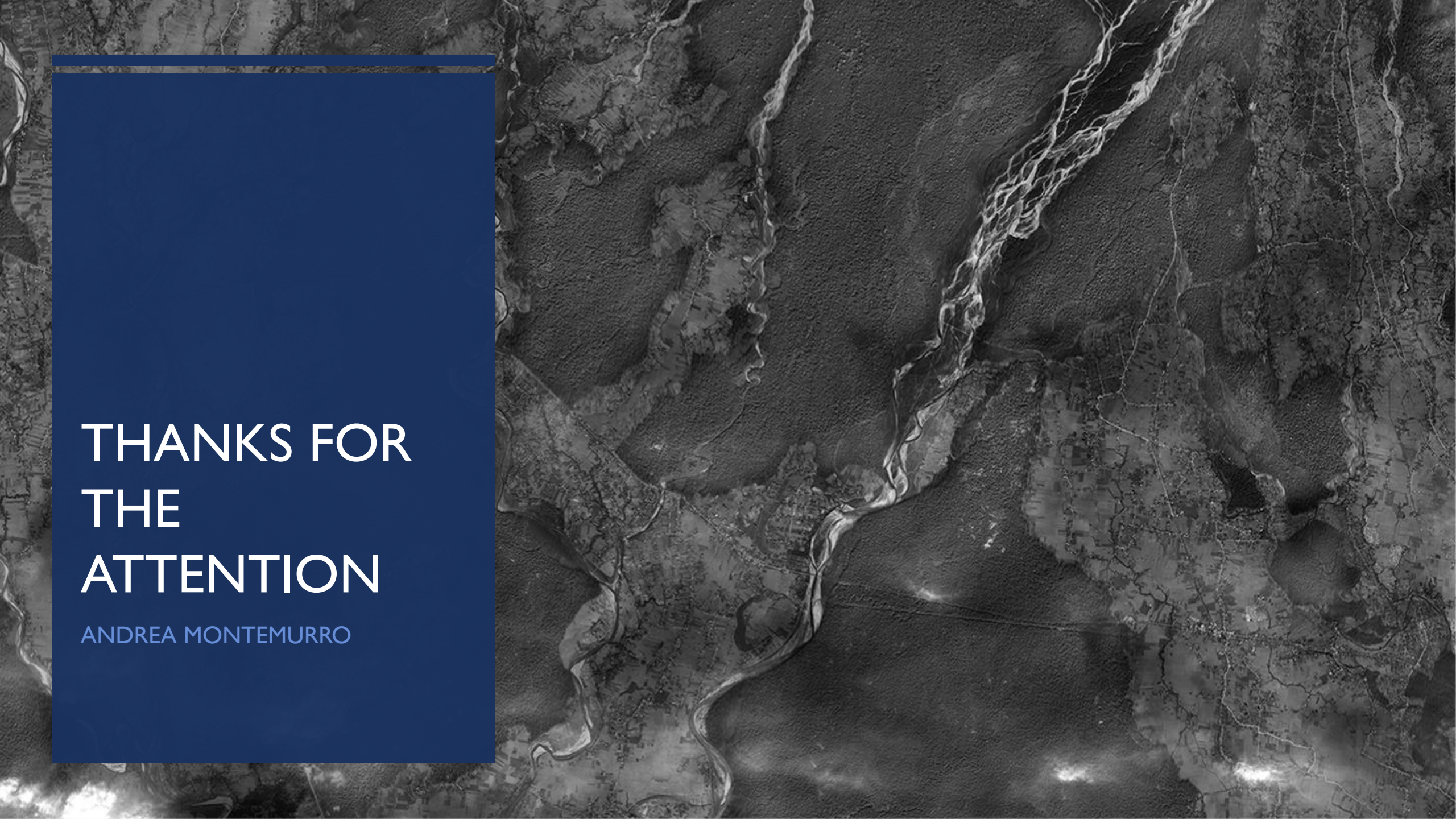
But although there are **flaws**, the segmentation provides an **understandable** result.

POSSIBLE IMPROVEMENTS

- A possible improvement is to **use a Multispectral High Resolution dense labeled image** to build the pixel dataset instead the RGB images.

Colors in the photo, in fact, can be affected by the metherogical situation !!

- Use the **Gabor filter** instead of the **Entropy** to make the texture extraction, but requires an analysis for the choice of parameters…



THANKS FOR THE ATTENTION

ANDREA MONTEMURRO