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BEeS

The LifeWatch ERIC Biodiversity & Ecosystem eScience Conference

SMART ECOMOUNTAINS

Seville
22-24/05/23

Threats and challenges to biodiversity and ecosystem conservation from an eScience perspective

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AI applications developed in the context of Smart EcoMountains

Rohaifa Khaldi, Siham Tabik, Sergio Puertas-Ruiz, Julio Peñas de Giles, José Antonio Hódar Correa, Regino Zamora, Domingo Alcaraz-Segura

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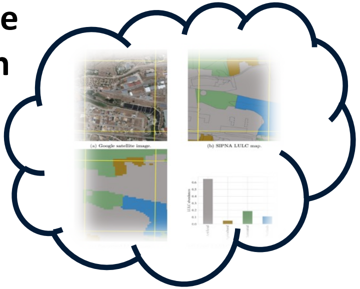
Introduction

Shrubs mapping

Abundance estimation



Diatoms recognition

Sierra Nevada
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Aerosols estimation

Estimation of cultural ecosystem services

Photosynthetic pigments estimation

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Motivation

- Understand the structure and dynamics of high mountain shrubs.
- Study the impact of climate change on persistent shrub dynamics and distribution.
- Monitor and protect high mountain biodiversity and ecosystems.

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- Study the impact of climate change on persistent shrub dynamics and distribution.
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How can we reach this?

✓ ***Juniperus* mapping.**

Juniperus

Motivation

Why ***Juniperus***?

- ✓ Long living shrub.
- ✓ Persistent shrub.
- ✓ Sentinel for climate change.

Juniperus

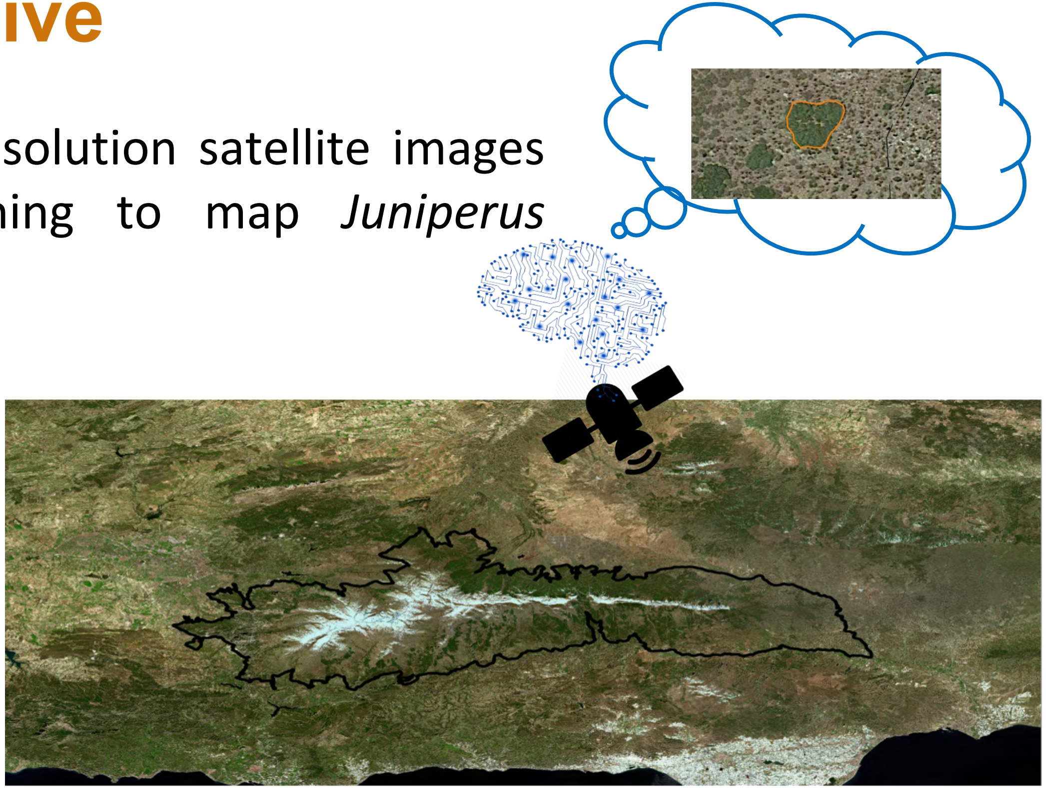
Problematic

The classical field surveying method is very challenging:

- ❗ Inaccessible areas.
- ❗ Labor-intensive.
- ❗ Pricey.
- ❗ Time-consuming.
- ❗ Unsustainable.

Objective

Use Very High-Resolution satellite images and Deep Learning to map *Juniperus* shrubs.



Methodology

1. Data acquisition and preprocessing

RGB orthophotos | *Juniperus* labeling

Training | Validation | Test

2. Model development and hyper-parameter optimization

CNN instance segmentation

Mask R-CNN (ResNet-101 C4)

Best CNN model parameters

3. Model validation

External validation data | Accuracy assessment

4. Results interpretation

Texture-based metrics | Shape-based metrics

5. Model deployment

Wall-to-wall map of *Juniperus* in Sierra Nevada

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Data acquisition and preprocessing

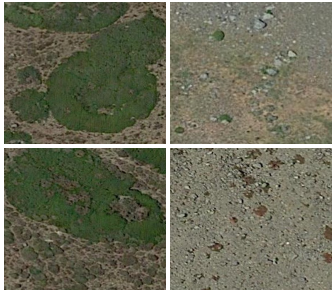
Different land covers

Different densities

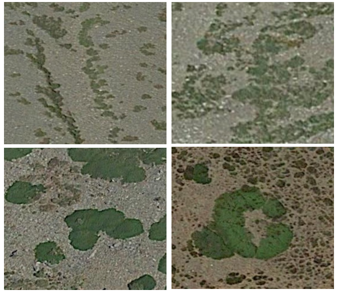
Different surroundings

Different colors

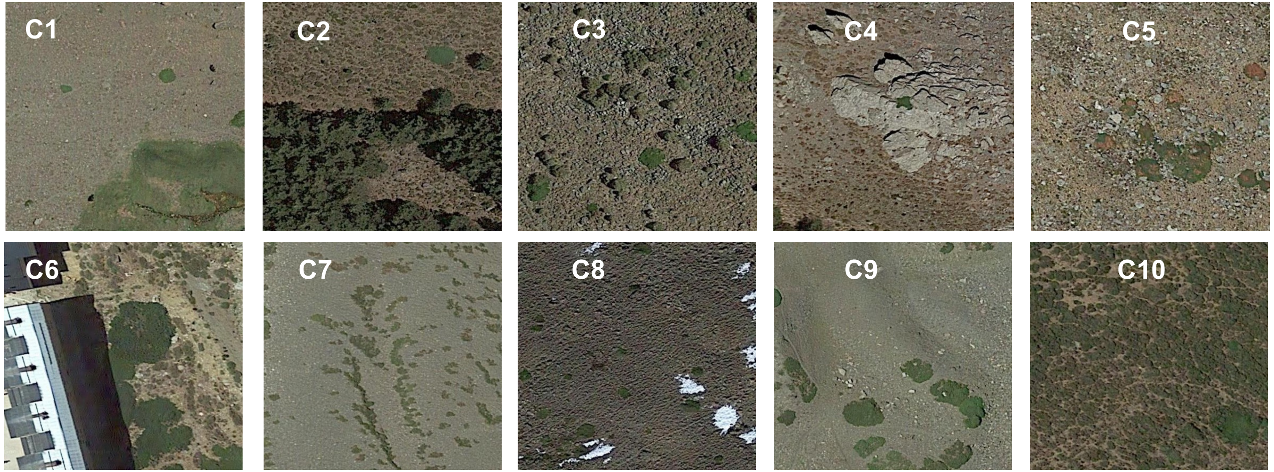
Different sizes



Different shapes



Data acquisition and preprocessing



Pattens Id	Images' patterns
C1	Juniperus near to borreguiles, rivers, and lakes
C2	Juniperus near to forests and trees
C3	Juniperus near to small plants and other scrubs
C4	Juniperus near to big rocks
C5	Sick Juniperus
C6	Juniperus near to urban areas
C7	Juniperus with Striped shape
C8	Juniperus near to snow lands
C9	Juniperus on barren lands
C10	Juniperus on shrub lands

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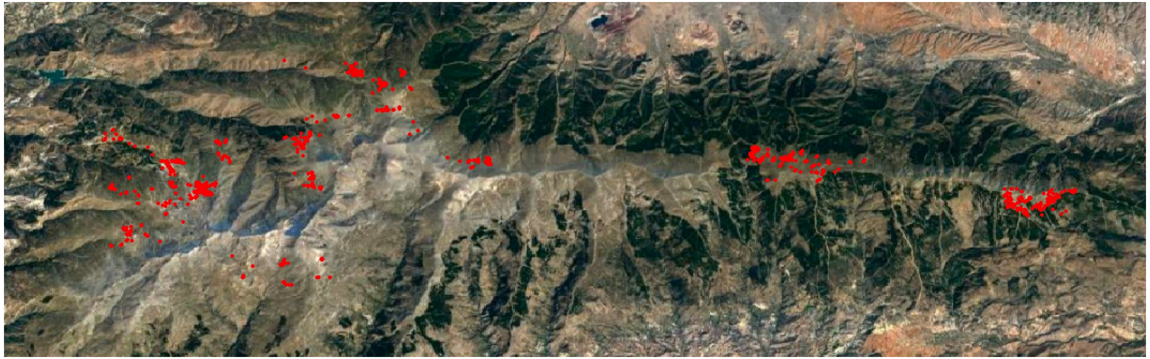
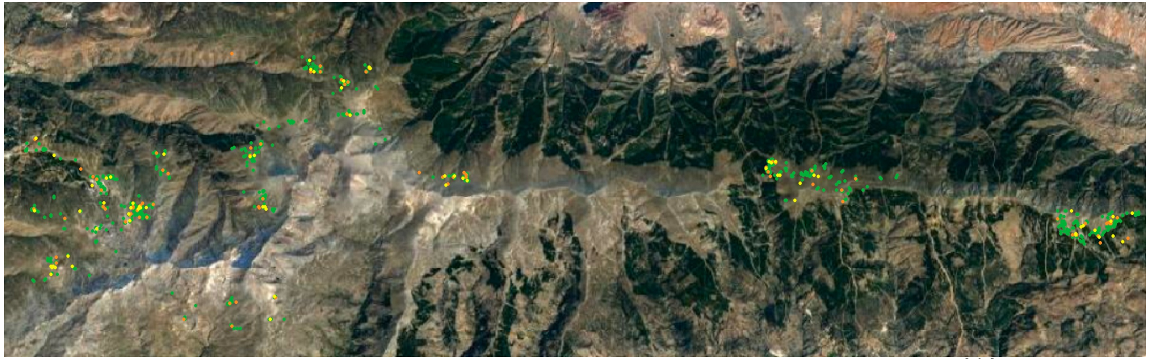
Data acquisition and preprocessing

Distribution of all instances.



Distribution of instances per data split: Train (green), Test(Orange), and Internal Validation (Yellow).



Data acquisition and preprocessing

Data name	Image size	Pixel size
Train	448 x 448	13 cm
Test	448 x 448	
Val	448 x 448	
External Val	420 x 336	

Data name	Number of images	Number of instances					
		All sizes	Very Small	Small	Medium	Large	Very Large
Train	570	5459	1397	1388	1333	1187	154
Test	75	690	120	165	199	172	34
Val	67	660	179	154	170	140	17
Total	712	6809	1696	1707	1702	1499	205

Statistics Per Areas (m2)								
Count	Mean	Std	Min	25%	50%	75%	97%	Max
6809	19,97	42,39	0,13	3,62	9,08	20,82	93,6	761,42

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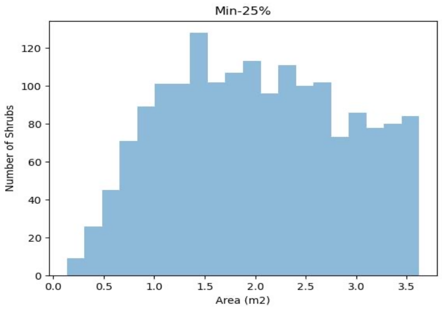
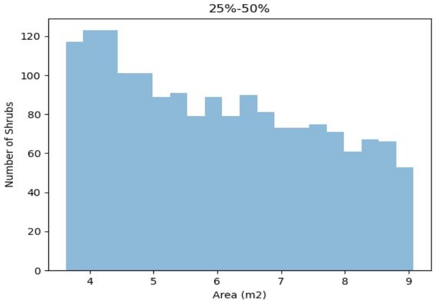
Data acquisition and preprocessing

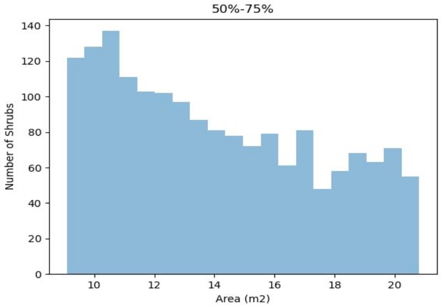
Very Small-sized Juniperus



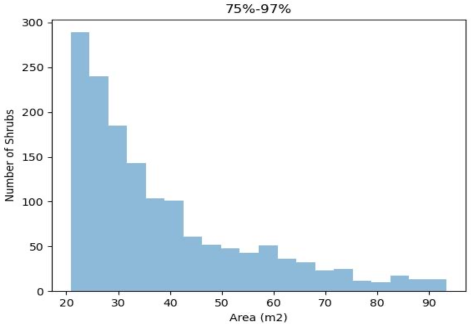
Small-sized Juniperus



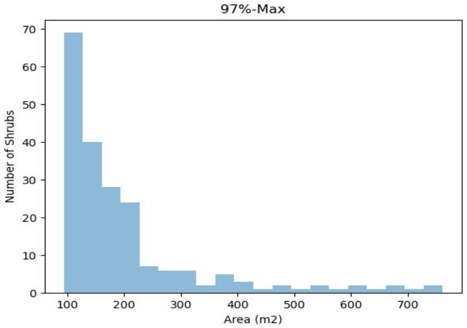
Medium-sized Juniperus



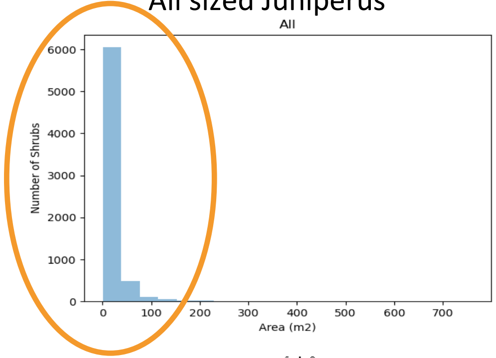
Large-sized Juniperus



Very Large-sized Juniperus



All sized Juniperus



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Model Development and Hyper-parameter Optimization

- Maximum number of iterations.
- Optimization algorithm.
- Learning rate.
- Learning rate scheduler.
- Batch size.
- Number of boxes per image to sample from RPN.
- Data augmentation.
- Backbone.

Model Evaluation

Juniperus Segmentation					
Metric @ IoU threshold	**Very Small**	**Small**	**Medium**	**Large**	**Very Large**
Recall @ 0.50	0,78	0,87	0,92	0,92	0,97
Precision @ 0.50	0,71	0,84	0,90	0,90	0,95
F1 @ 0.50	0,739	0,856	0,911	0,911	0,962
Recall @ 0.75	0,55	0,74	0,84	0,85	0,88
Precision @ 0.75	0,41	0,68	0,81	0,82	0,85
F1 @ 0.75	0,469	0,709	0,823	0,836	0,865
AR @ All	0,47	0,59	0,70	0,74	0,77
AP @ All	0,38	0,54	0,67	0,71	0,73
AF1 @ All	0,422	0,563	0,684	0,725	0,750

Model Validation

Data name	Image size	Number of images	Number of instances
External Val	420 x 336	141	1828

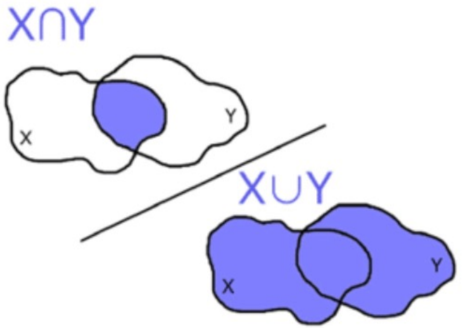
Model Validation

Evaluation algorithm using IoU metric:

1- Look for all detections B_i overlapping with the ground truth A.

2- For each detection B_i compute the overlapping metric with the ground truth:

$$IoU(A, B_i) = \frac{|A \cap B_i|}{|A \cup B_i|}$$



3- Select the detection B_s with the highest IoU:

$$B_s = \underset{B_i}{\text{argmax}}\{IoU(A, B_i) : i \in [n]\}$$

4- If $IoU(A, B_s) \geq \theta$:

A is true positive (TP).

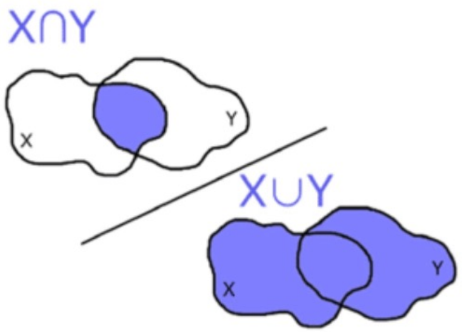
else:

A is false negative (FN).

Model Validation

IoU is an unfair evaluation metric in our case:

- ! Overlapping objects (densely packed).
- ! Significant variation in size.
- ! Estimated annotations.
- ! Many detections of small parts of the shrub are penalized.



Model Validation

New adapted overlapping evaluation metrics:

Evaluation algorithm using IoGTA metric:

1- Look for all detections B_i overlapping with the ground truth A.

2- For each detection B_i compute the overlapping metric with the ground truth:

$$IoGTA(A, B_i) = \frac{|A \cap B_i|}{|A|}$$

3- Select the detection B_s with the highest IoU:

$$B_s = \underset{B_i}{\operatorname{argmax}}\{IoGTA(A, B_i) : i \in [n]\}$$

4- If $IoGTA(A, B_s) \geq \theta$:

A is true positive (TP).

else:

A is false negative (FN).

Model Validation

New adapted overlapping evaluation metrics:

Evaluation algorithm using MIoGTA metric:

1- Look for all detections B_i overlapping with the ground truth A.

2- Compute the overlapping metric between the ground truth and **all** the detections:

$$MIoGTA(A, \{B_i : i \in [n]\}) = \frac{\sum_{i=1}^{n} |A \cap B_i|}{|A|}$$

3- If $MIoGTA(A, \{B_i : i \in [n]\}) \geq \theta$:

A is true positive (TP).

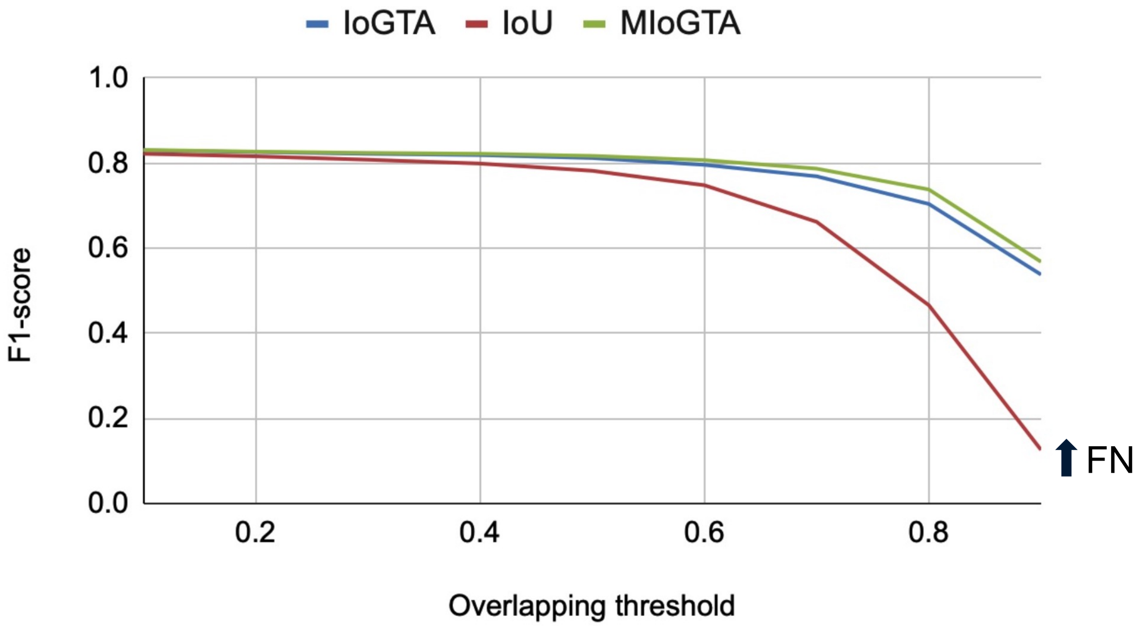
else:

A is false negative (FN).

Model Validation

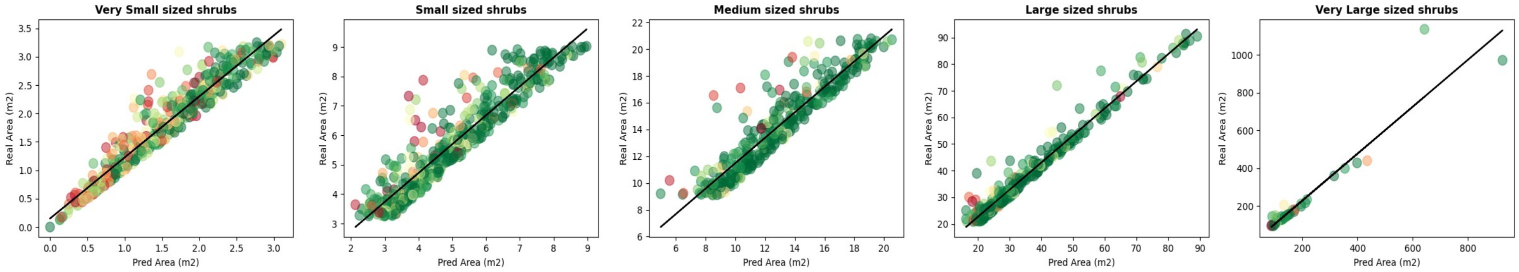
Comparison between the overlapping metrics

IoGTA and MIoGTA are less sensitive to the increase in overlapping threshold compared to IoU.

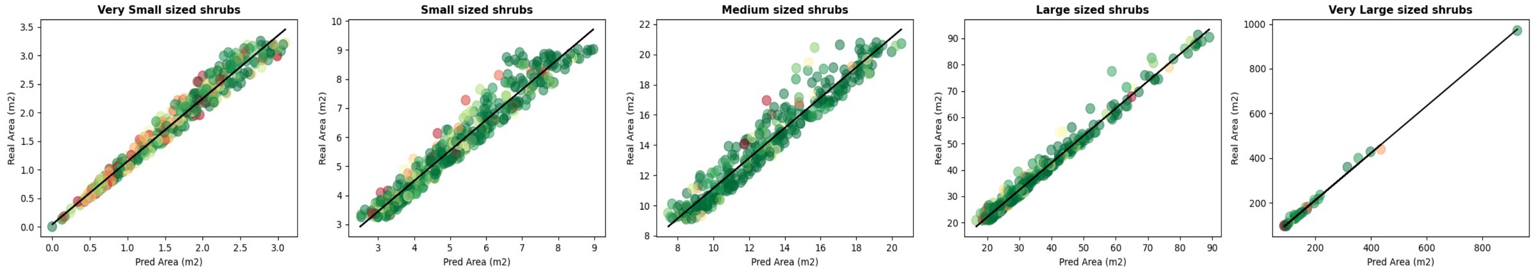


Model Validation

MIoGTA threshold = 0.5



MIoGTA threshold = 0.75



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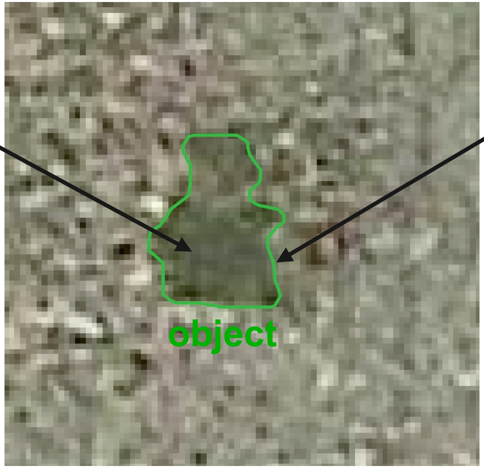
Results Interpretation

Texture

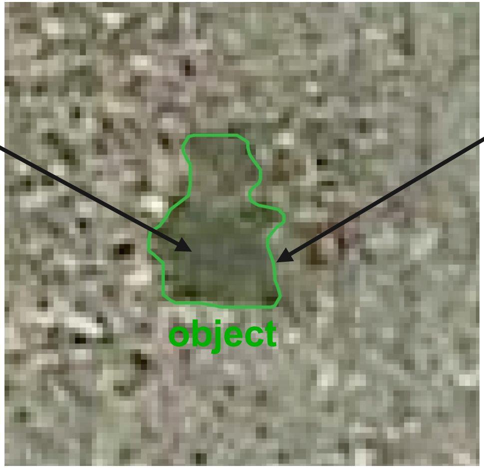


Shape

Results Interpretation

Texture

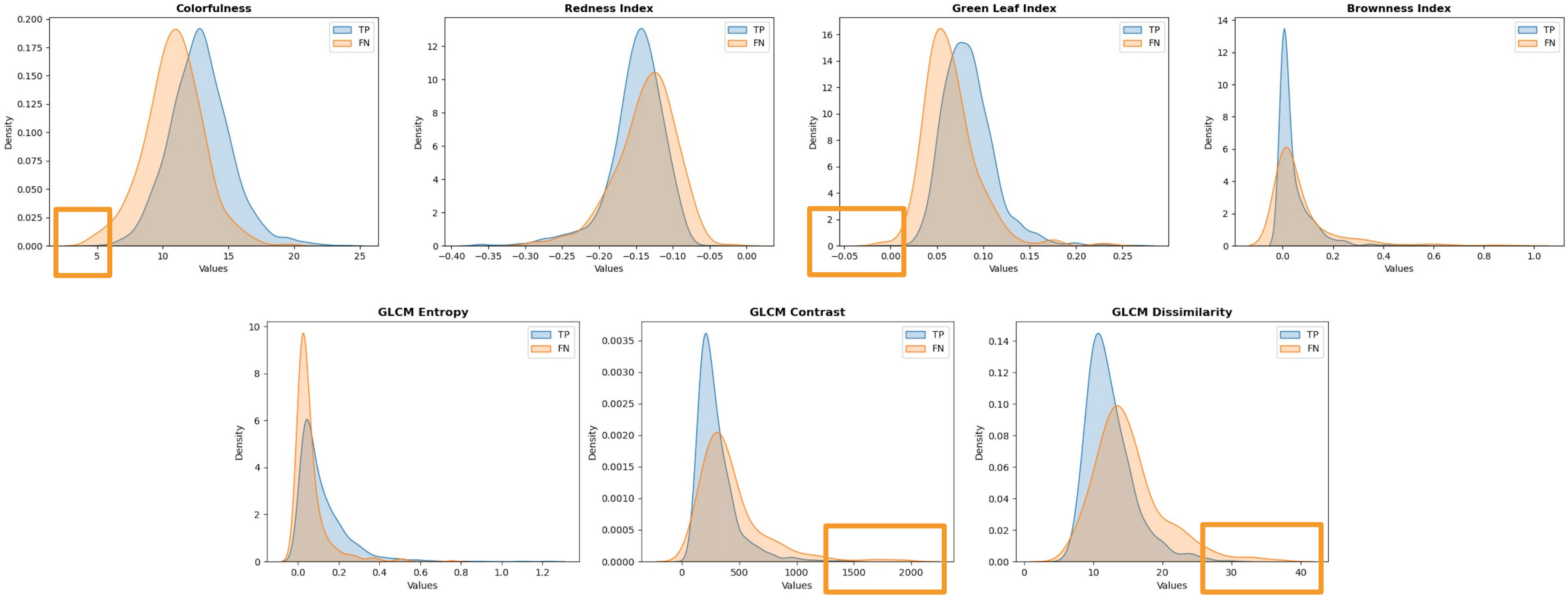
- Colorfulness
- Redness index
- Green leaf index
- Browenness index
- Entropy
- Contrast
- Dissimilarity
- Homogeneity
- Energy
- Correlation



Shape

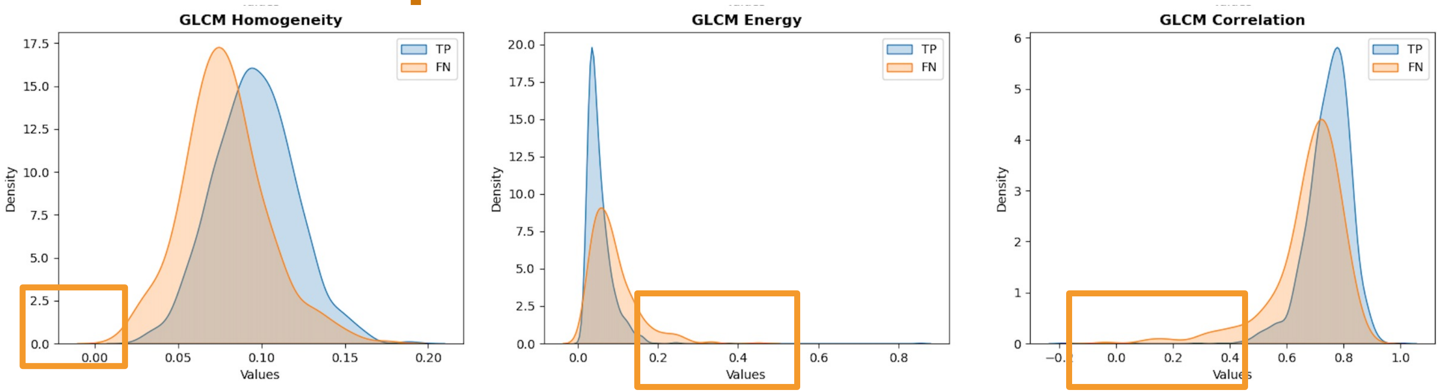
- Compactness
- Complexity
- Elongation
- Convexity

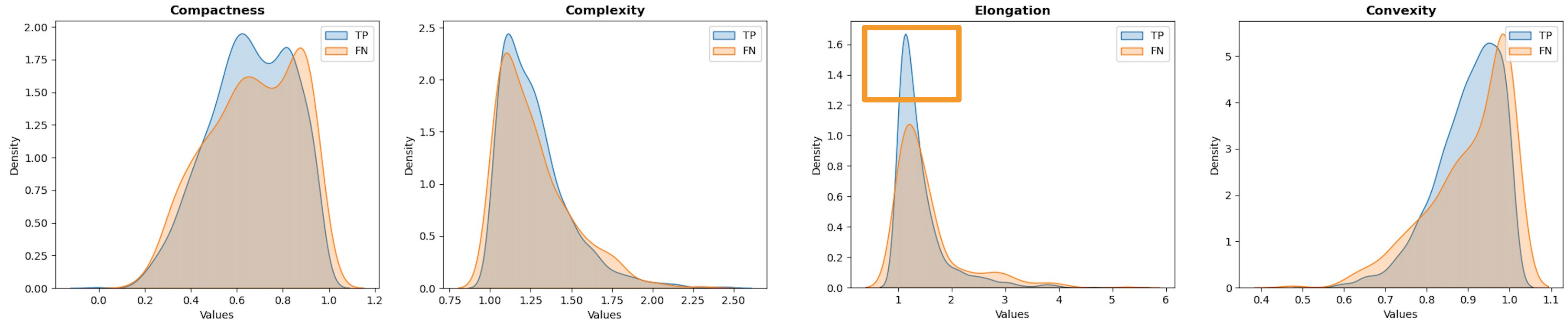
Results Interpretation



Results Interpretation

Support model decision





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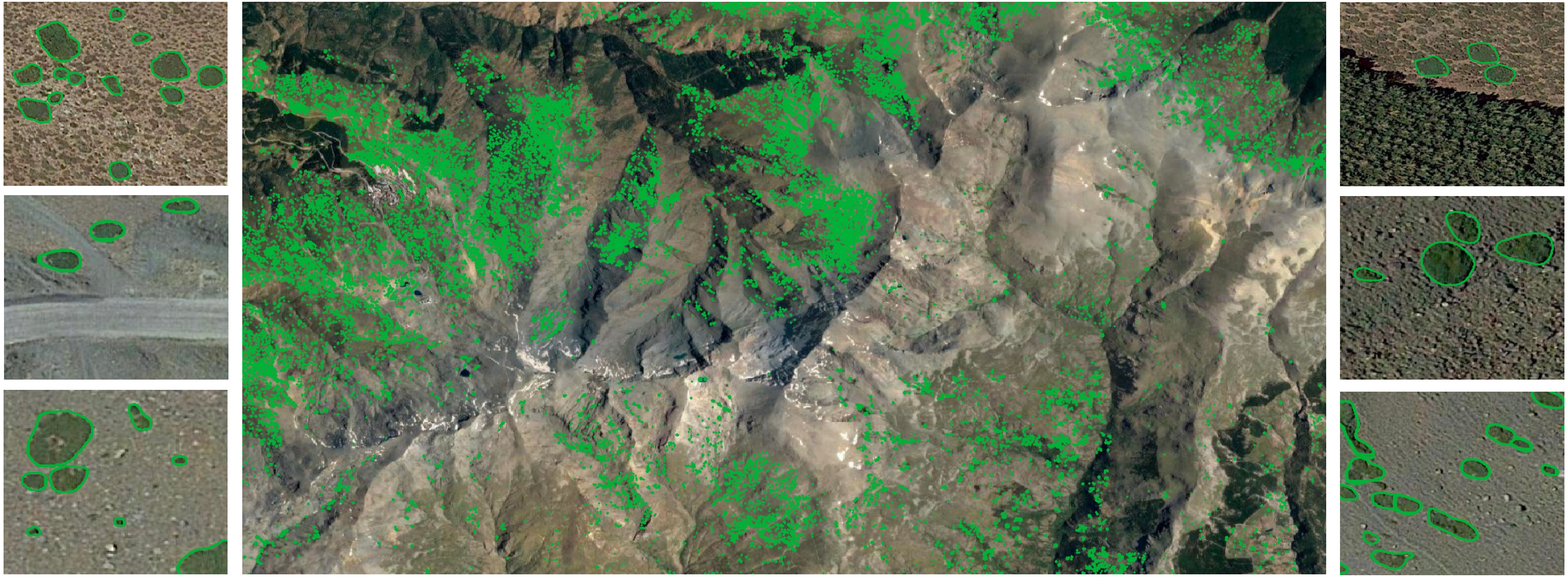
Model Deployment



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Conclusion

- We digitized more than 6809 Juniperus *shrubs.*
- We created a Deep learning-based model for high mountain shrubs detection.
- We validated the model using external validation data.
- We proposed two new overlapping metrics for model evaluation.
- We proposed an object-based interpretation design.
- We created a wall-to-wall map of shrubs in Sierra Nevada with high accuracy.

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Thank you! | www.lifewatch.eu/bees-2023

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IoU is an unfair evaluation metric in our case:

$IoU(A, B_1) = 0.4$

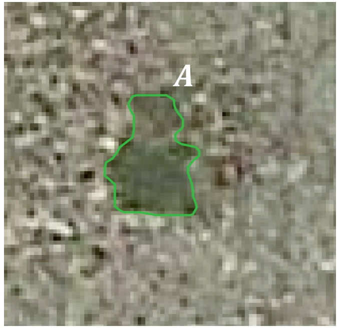
$IoU(A, B_2) = 0.6$

$\theta = 0.7$

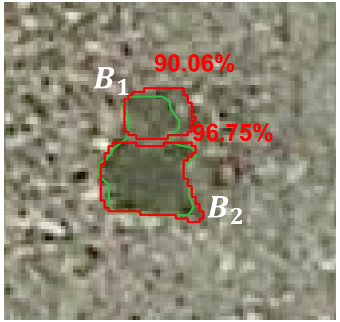
$B_s = B_2$

$B_s < \theta$

A is FN ✗



Ground truth A

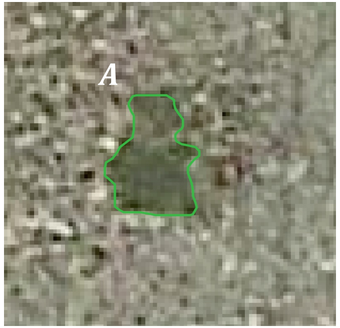


Model predictions $\{B_1, B_2\}$

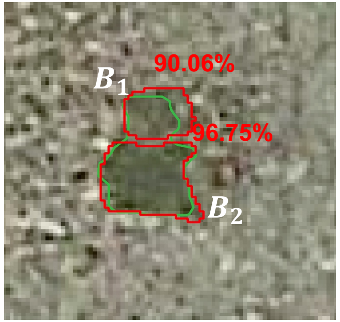
New adapted overlapping evaluation metrics:

$$MIoGTA(A,\{B_1,B_2\}) = 0.95 \geq \theta = 0.7$$

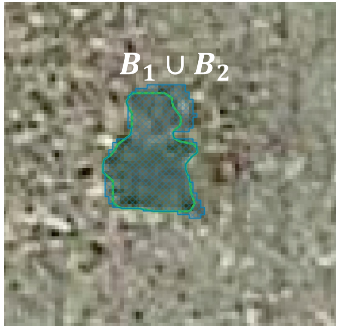
A is TP



Ground truth A



Model predictions $\{B_1, B_2\}$



Model final prediction