



Crop Classification with SAR Data and Deep Learning Algorithms: A Method for Areas with Limited Labels and High Cloud Cover

IRB(P&D)

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Research Data Scientist | IRB(P&D)

Motivation – Crop Insurance Context

- Importance of agriculture

2024 TRADE BALANCE

Brazilian agribusiness reaches historic milestone in global food security



Growth in strategic sectors and market diversification strengthen Brazil's position as a global supplier of food, fiber, and energy

Published in Feb 03, 2025 05:13 PM

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Brazilian agribusiness exports totaled USD 164.4 billion in 2024, marking the second-highest value on record. The sector accounted for 49 percent of the country's total exports, demonstrating its resilience despite declining international prices for some major commodities.

Motivation – Crop Insurance Context

- Importance of agriculture
- High volatility
- High climate sensitivity
- Difficulty in risk assessment

2024 TRADE BALANCE

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Extreme weather events impose billions in losses on agribusiness

After strong El Niño, signs emerge of La Niña formation, which caused droughts in the South

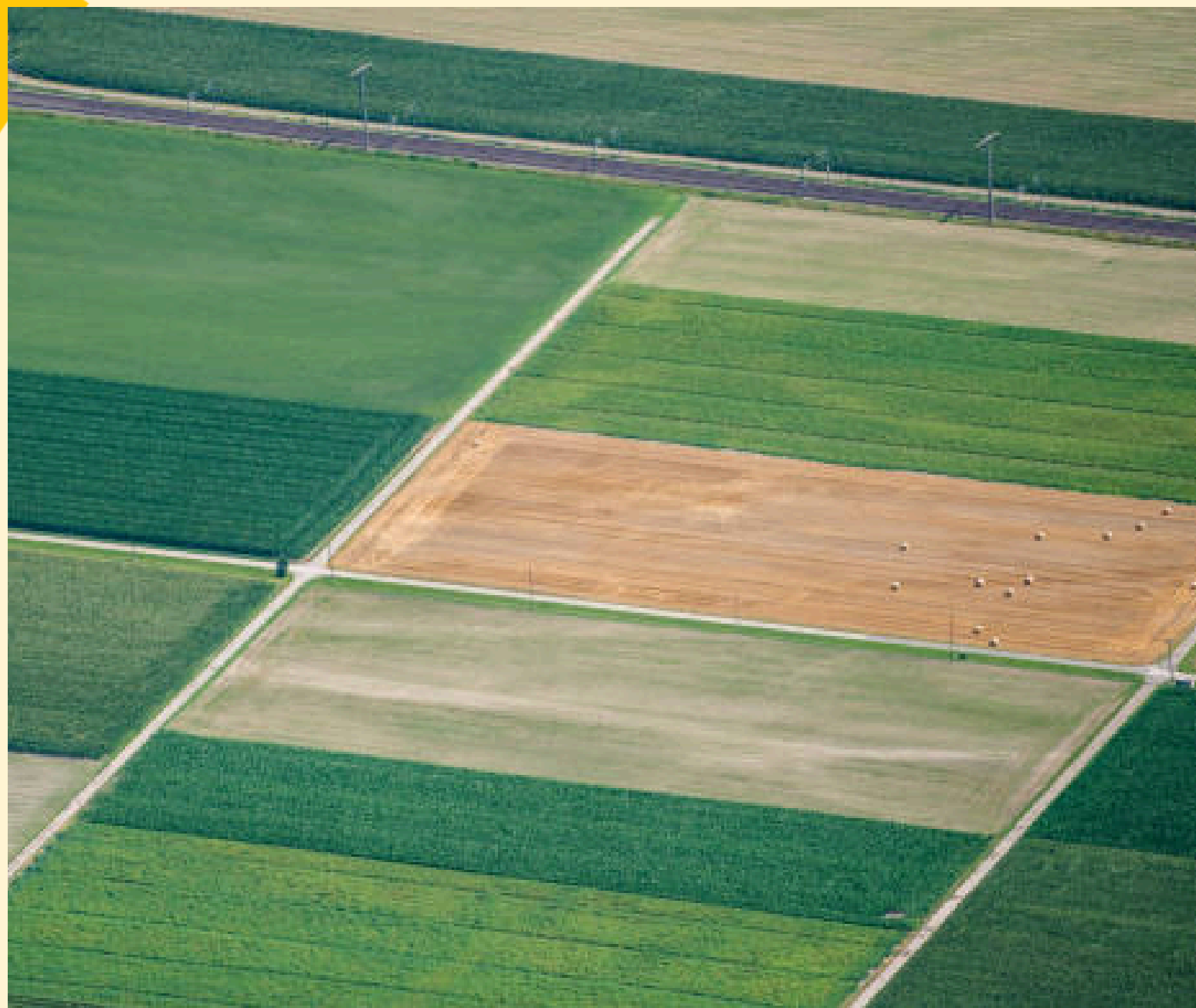
Por Rafael Walendorff, Raphael Salomão, Marcelo Beledeli — São Paulo

14/11/2023 08h45 - Atualizado há um ano

[f](#) [tw](#) [wh](#) [in](#)

Motivation – Crop Insurance Context

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- With crop information at the field plot level, we can achieve:
 - Regional market insights
 - Analysis of planting methods
 - Crop rotation analysis
 - Performance comparison among neighboring plots
 - Improved yield predictions

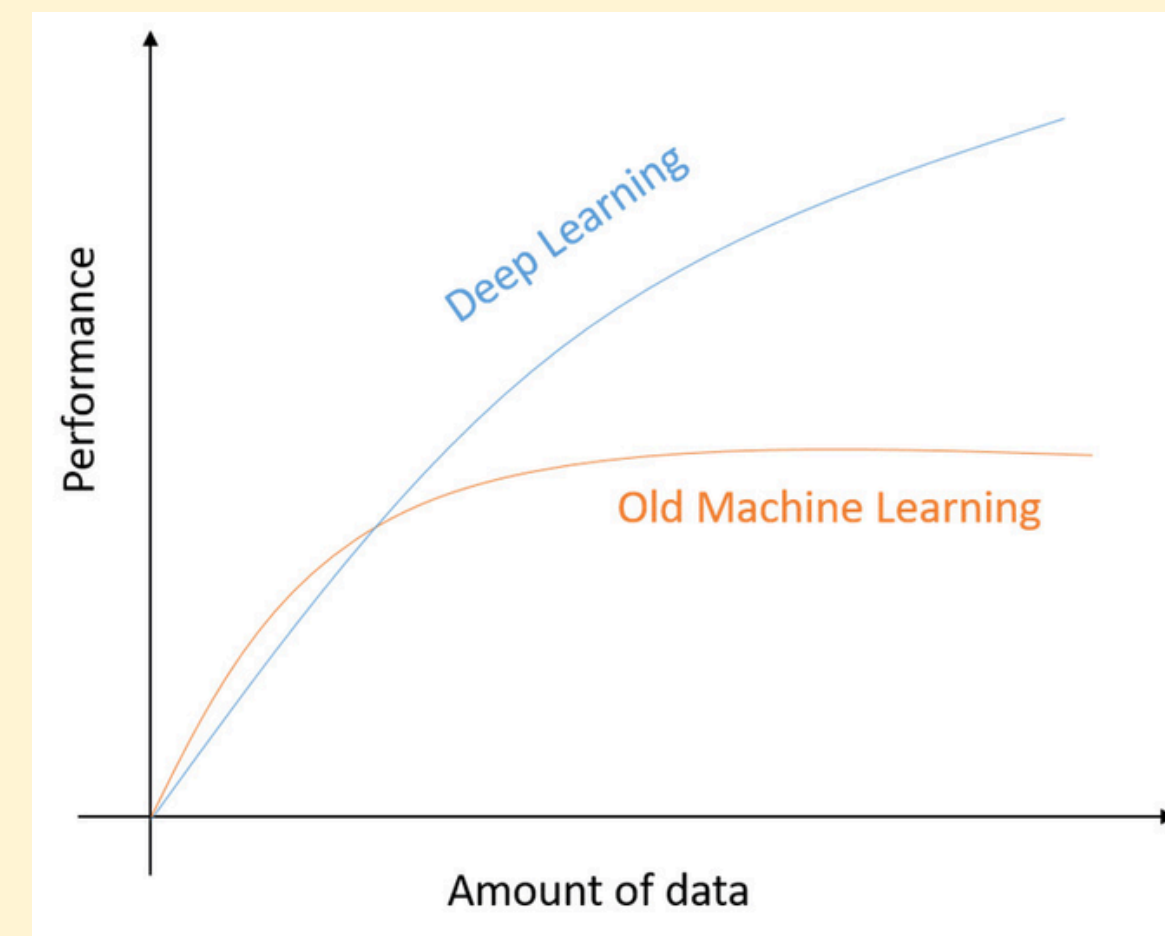
Motivation – Crop Insurance Context

IRB(P&D)



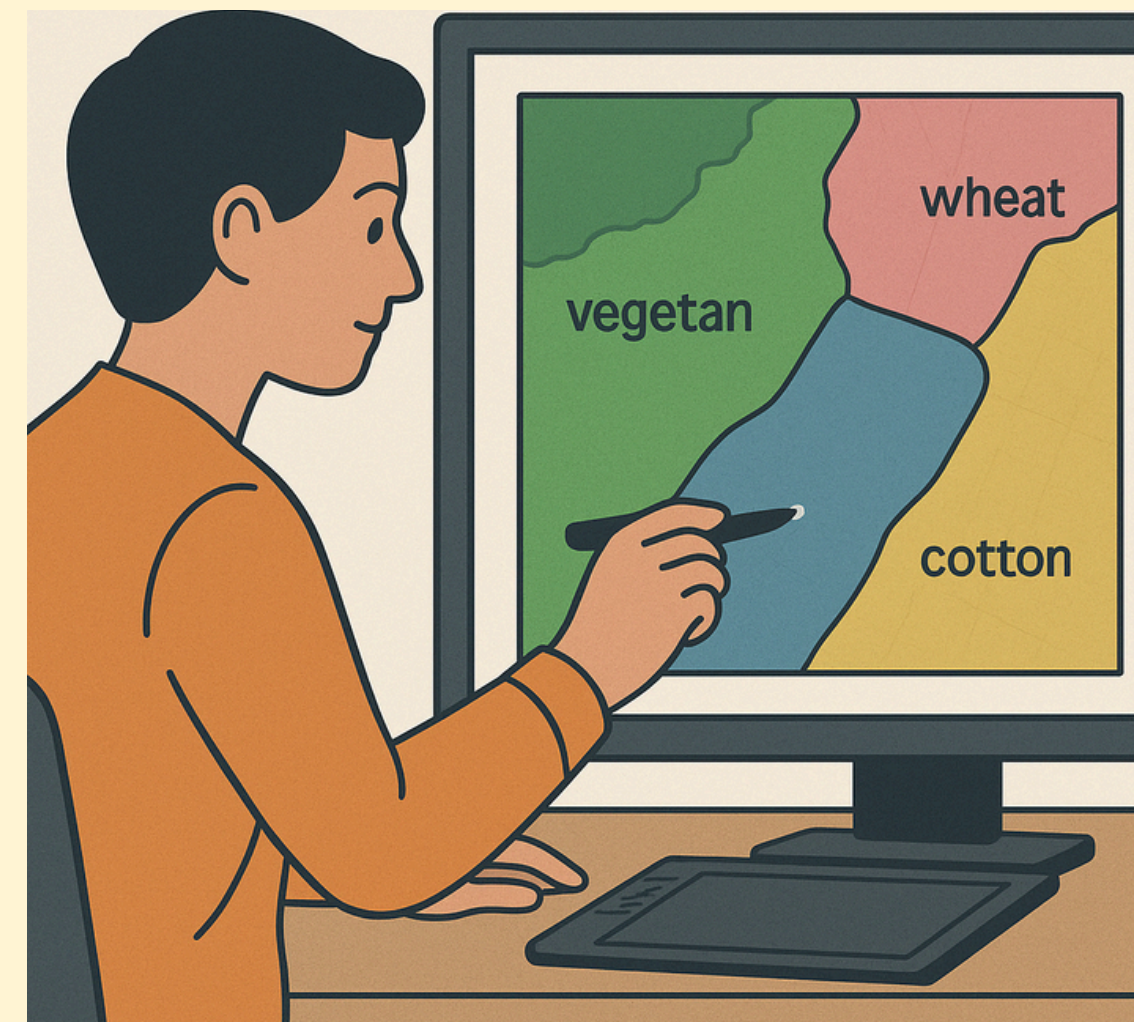
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- **Deep Learning (DL) Models**
 - State-of-the-art in Earth Observation (EO) image analysis
 - High predictive performance
 - Strong generalization capabilities
 - Require large volumes of training data



Motivation – Theoretical

- Annotating EO images at the pixel level is very costly.
- There is room for research on how to optimize the performance of models trained with limited data.



Challenges

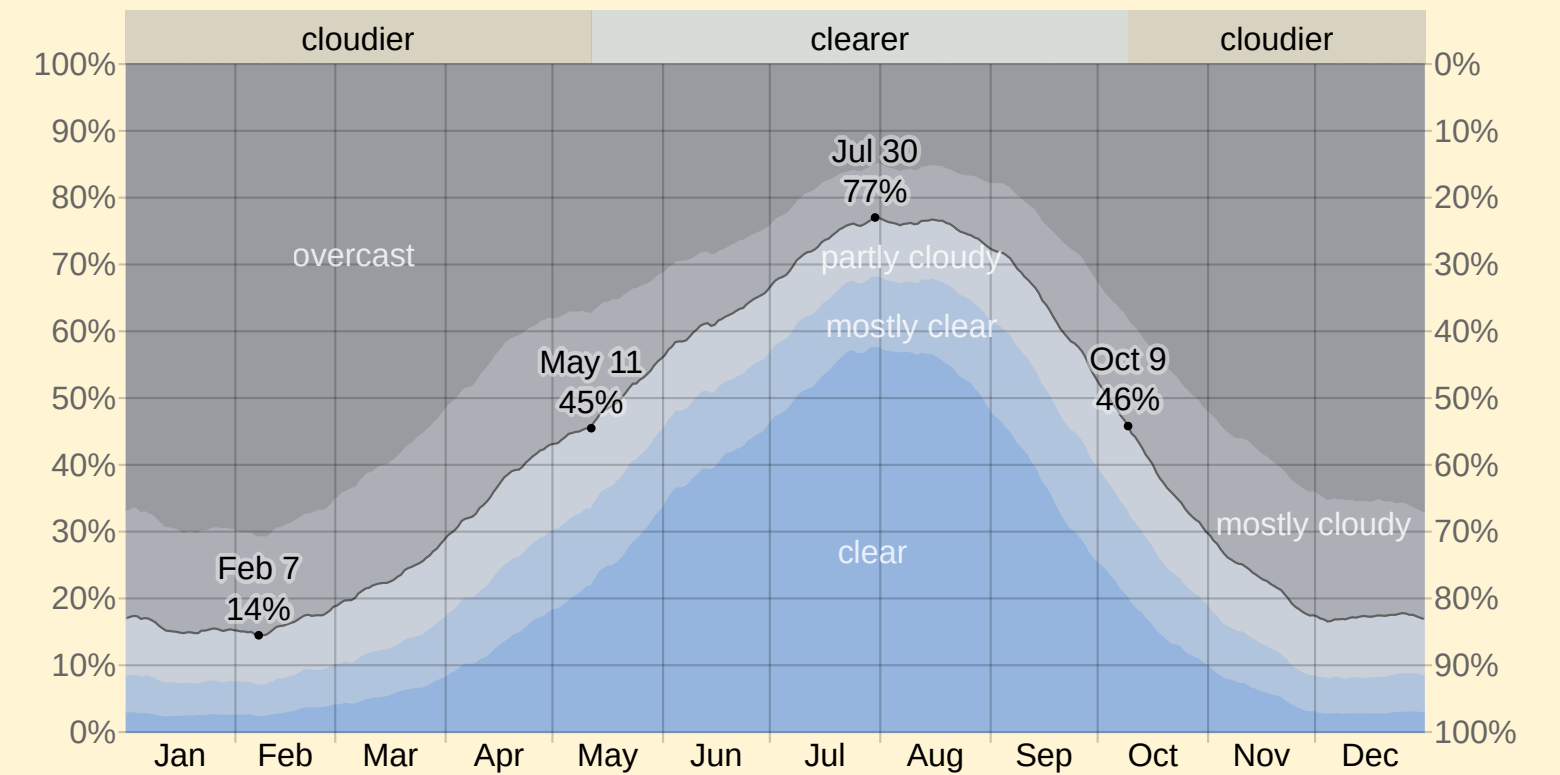
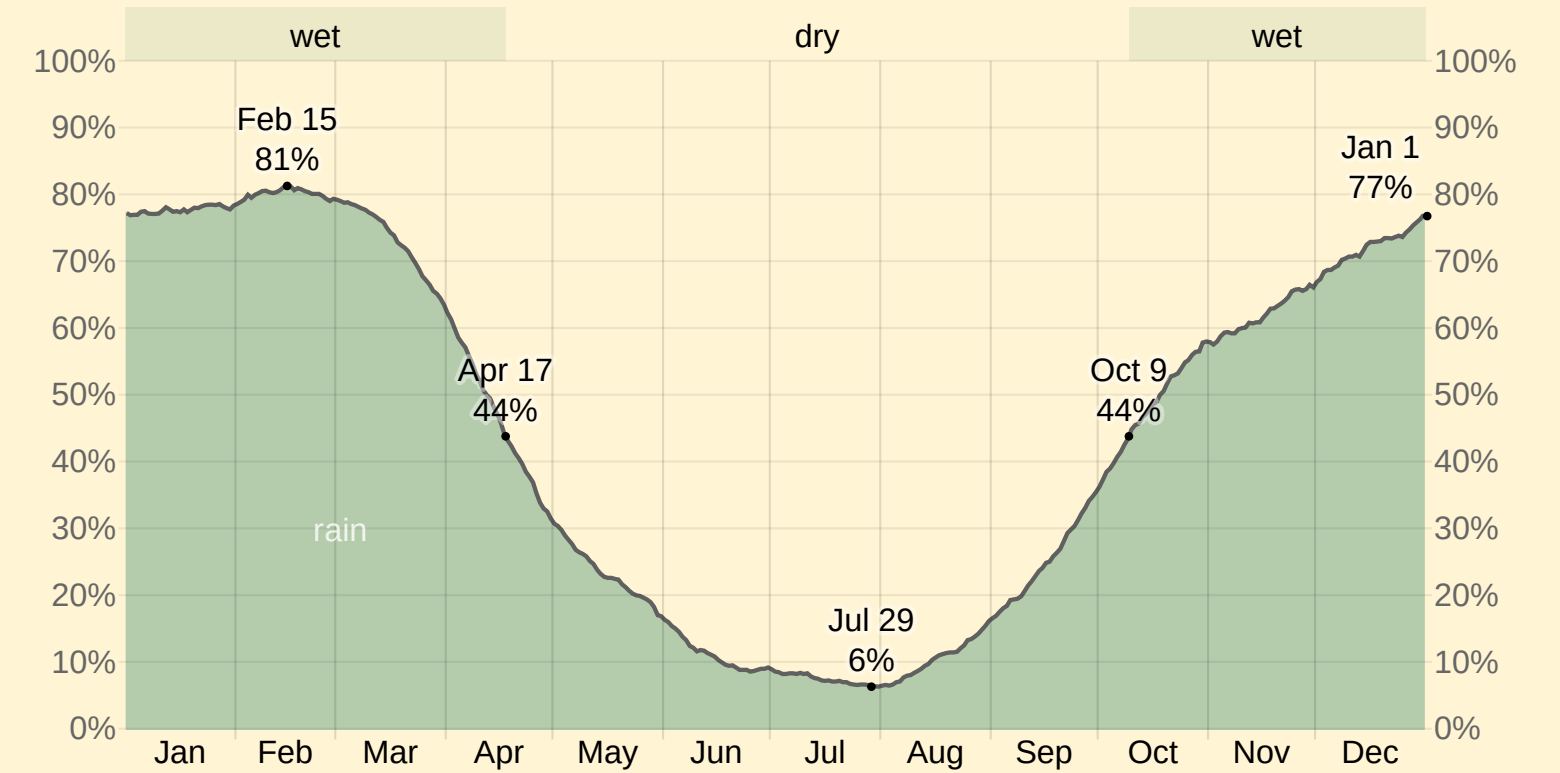
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- Few data on field plot geometries in Brazil.
- Limited data on field plots with crop type labels in Brazil.
- Significant differences in field plot patterns and crop types between Brazil and other countries.

Challenges

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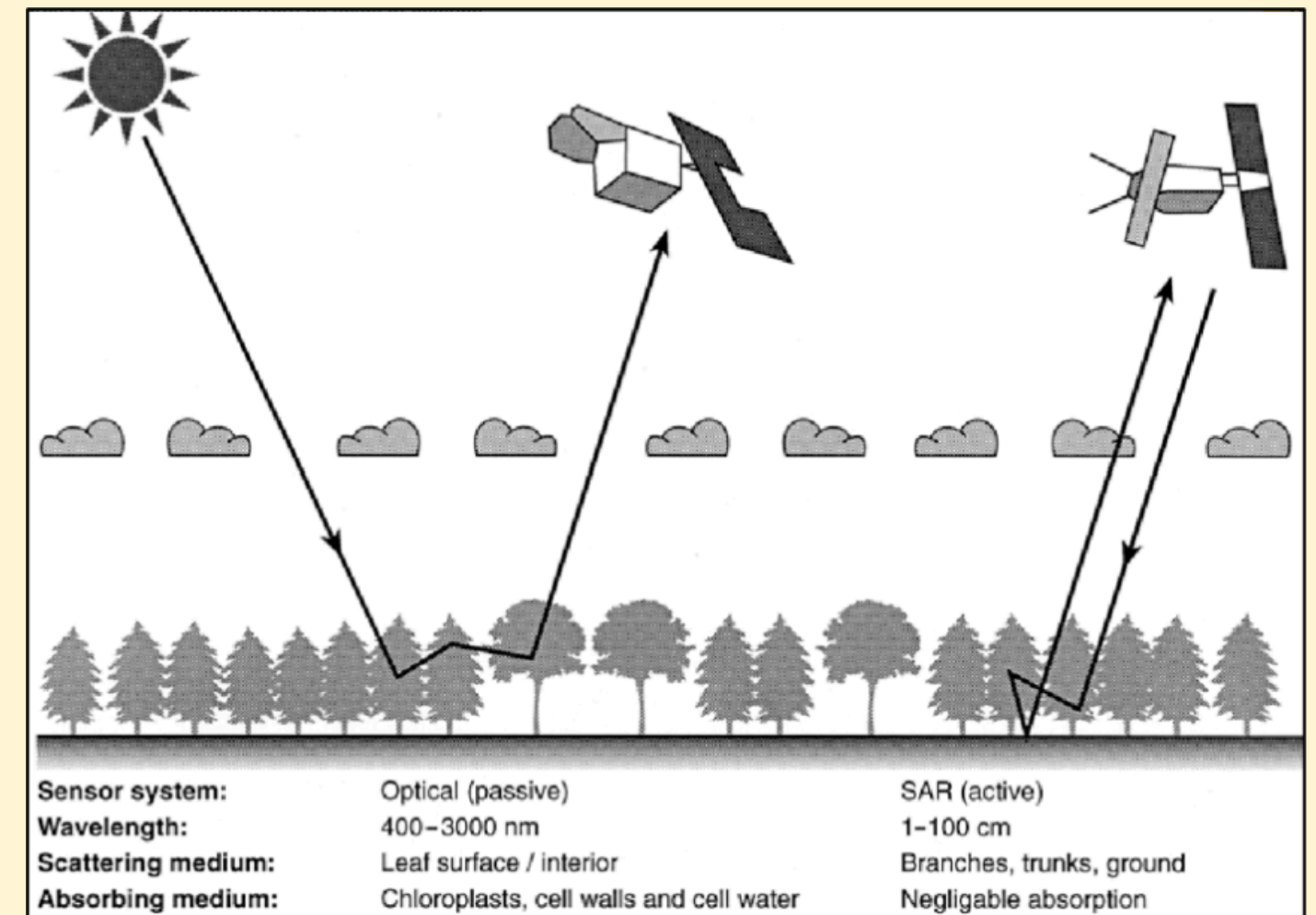
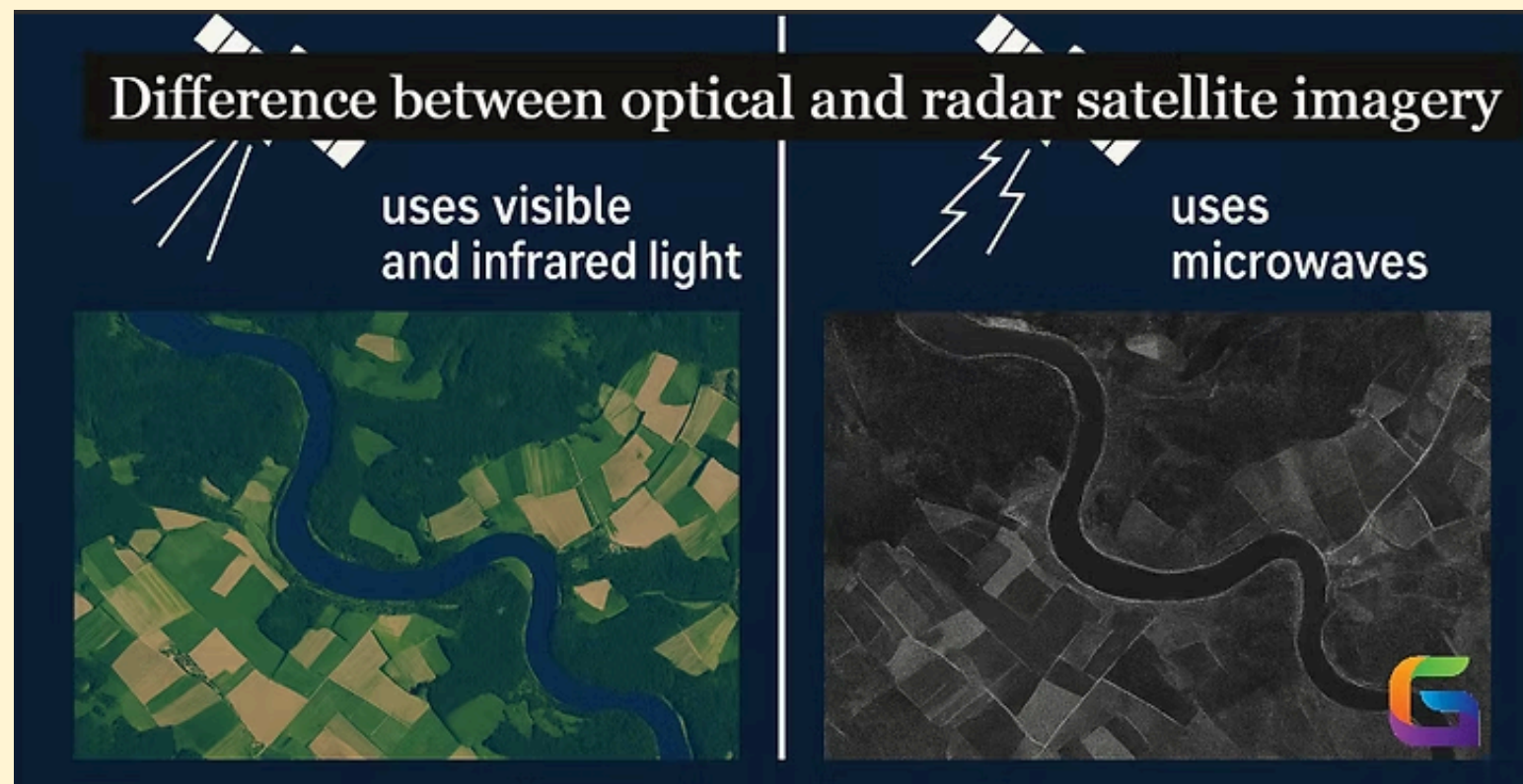
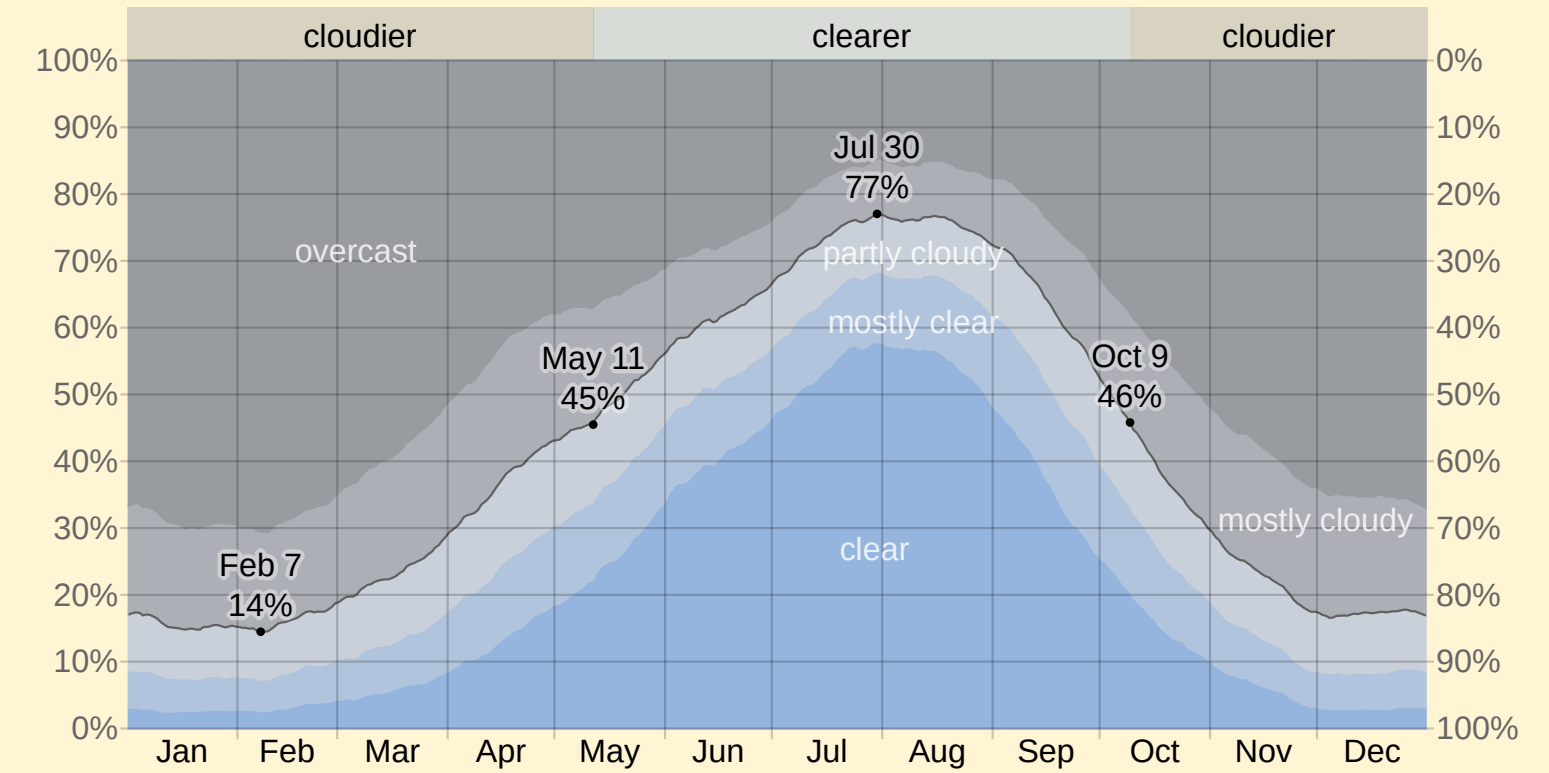
- During periods when crops are most visible (harvest seasons), the sky has significant cloud coverage.



Challenges

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- During periods when crops are most visible (harvest seasons), the sky has significant cloud coverage.
- Optical satellites provide rich information but don't work well with clouds.



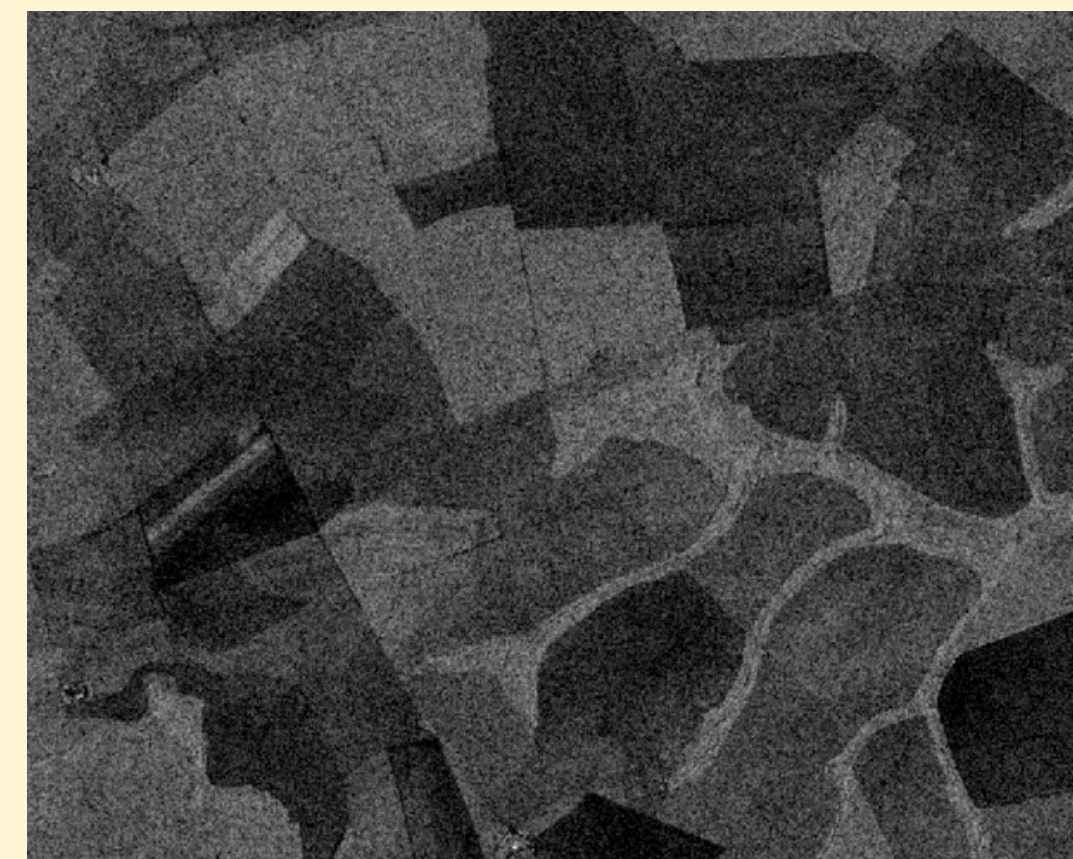
Proposal

- Efficiently segment crop field plots.



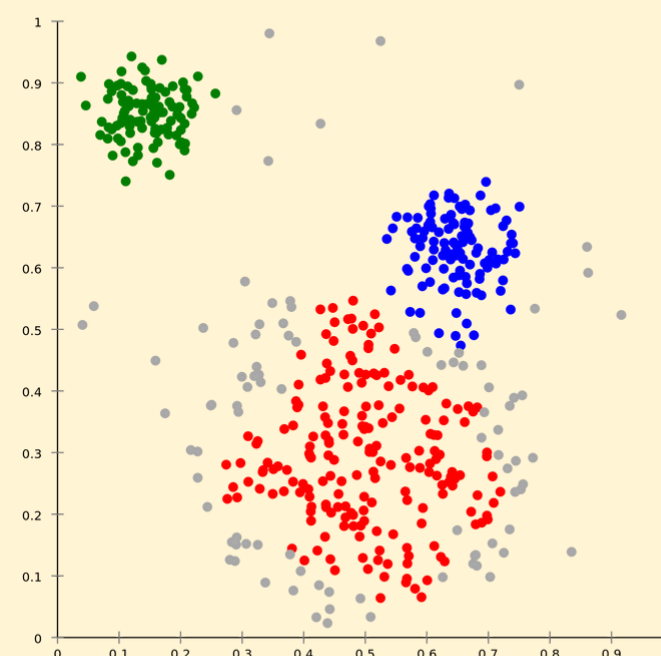
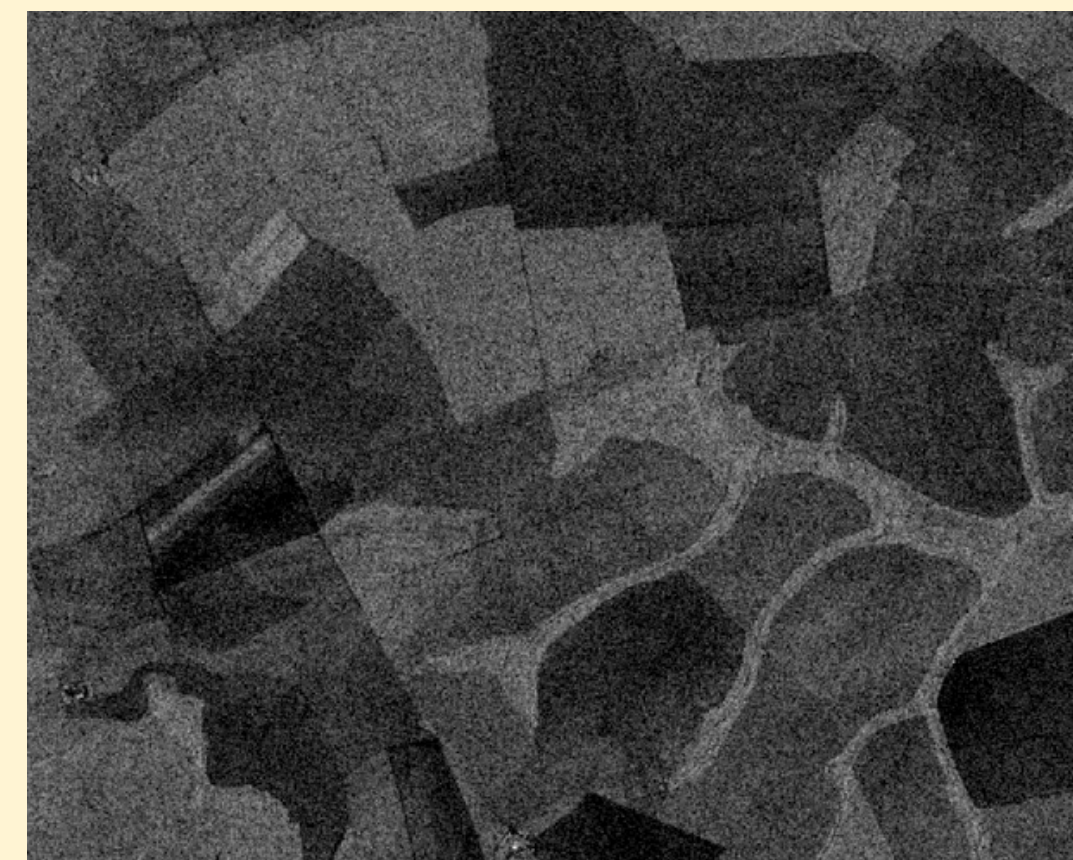
Proposal

- Efficiently segment crop field plots.
- Use radar (SAR) images to obtain information about field plots.



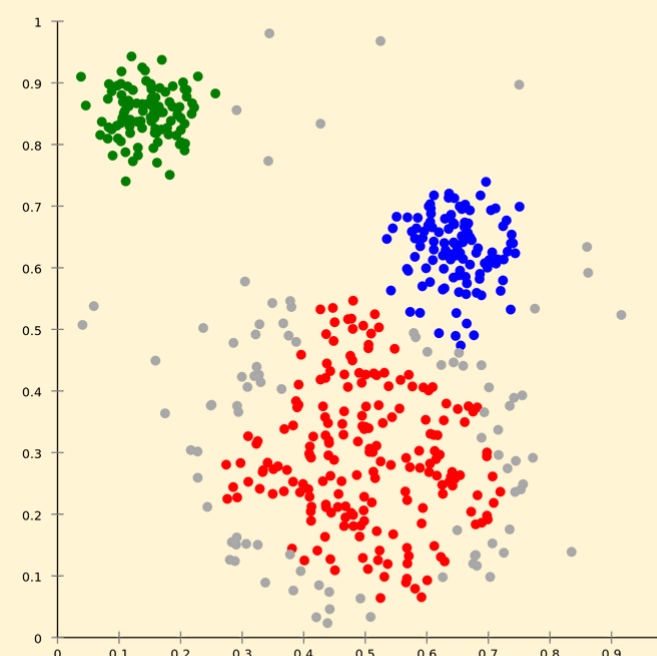
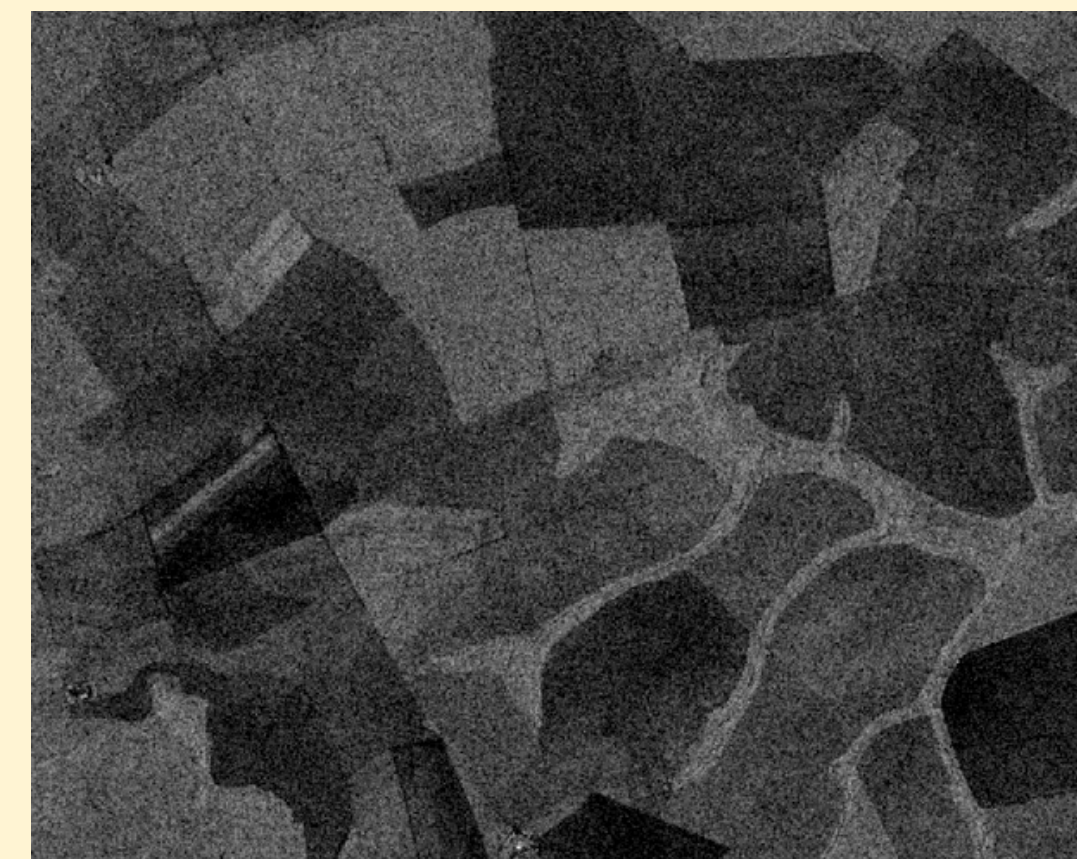
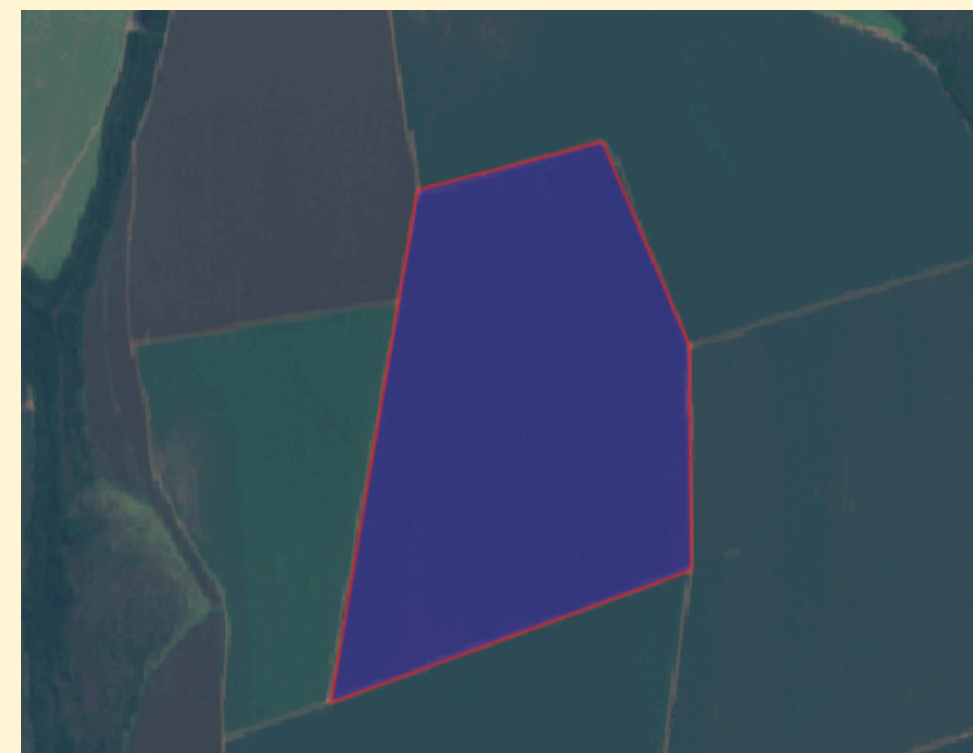
Proposal

- Efficiently segment crop field plots.
- Use radar (SAR) images to obtain information about field plots.
- Use clustering models to semantically group crops.

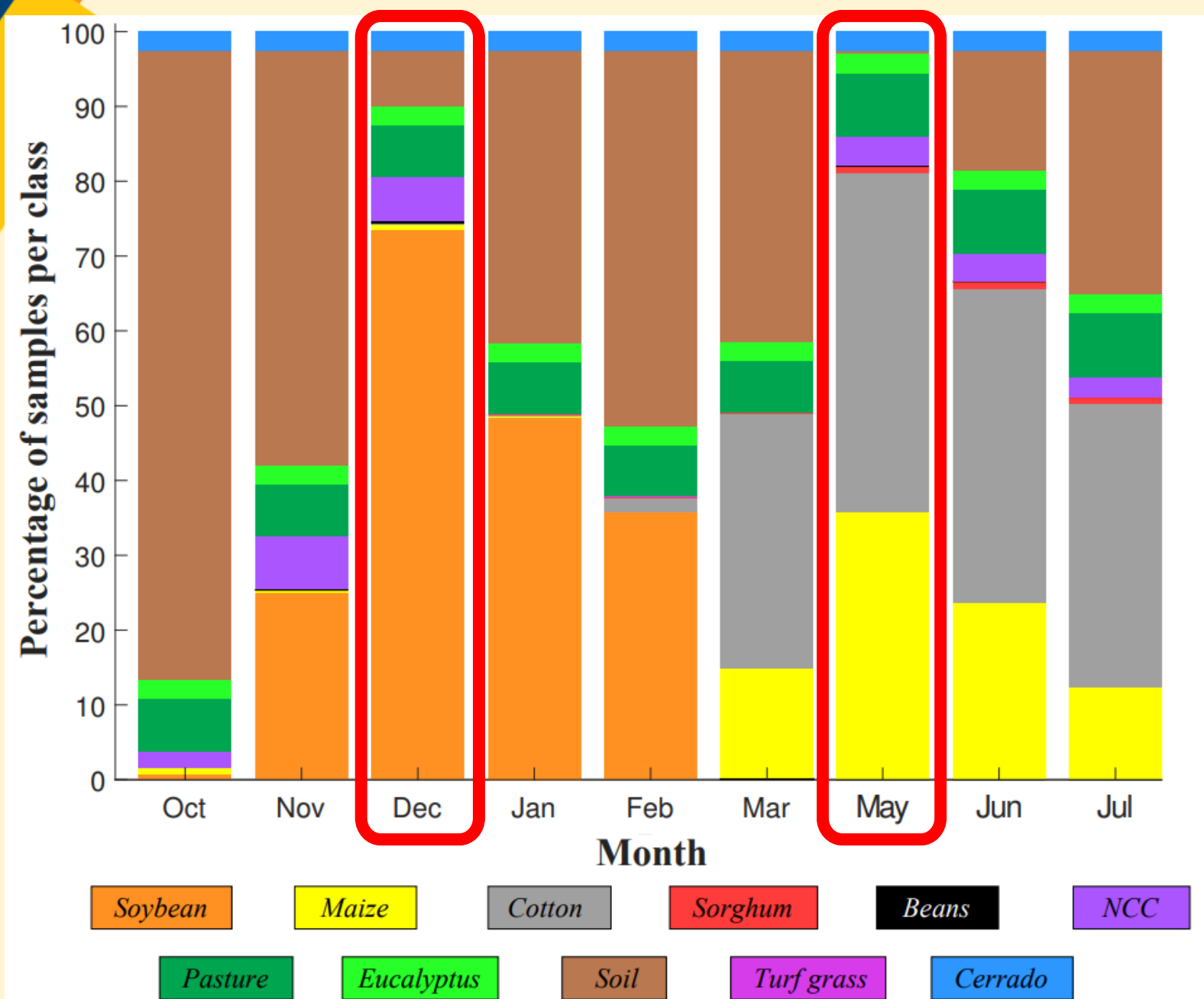


Proposal

- Efficiently segment crop field plots.
- Use radar (SAR) images to obtain information about field plots.
- Use clustering models to semantically group crops.
- Classify the entire municipality of Campo Verde with only 23.76% of it labeled.



Dataset



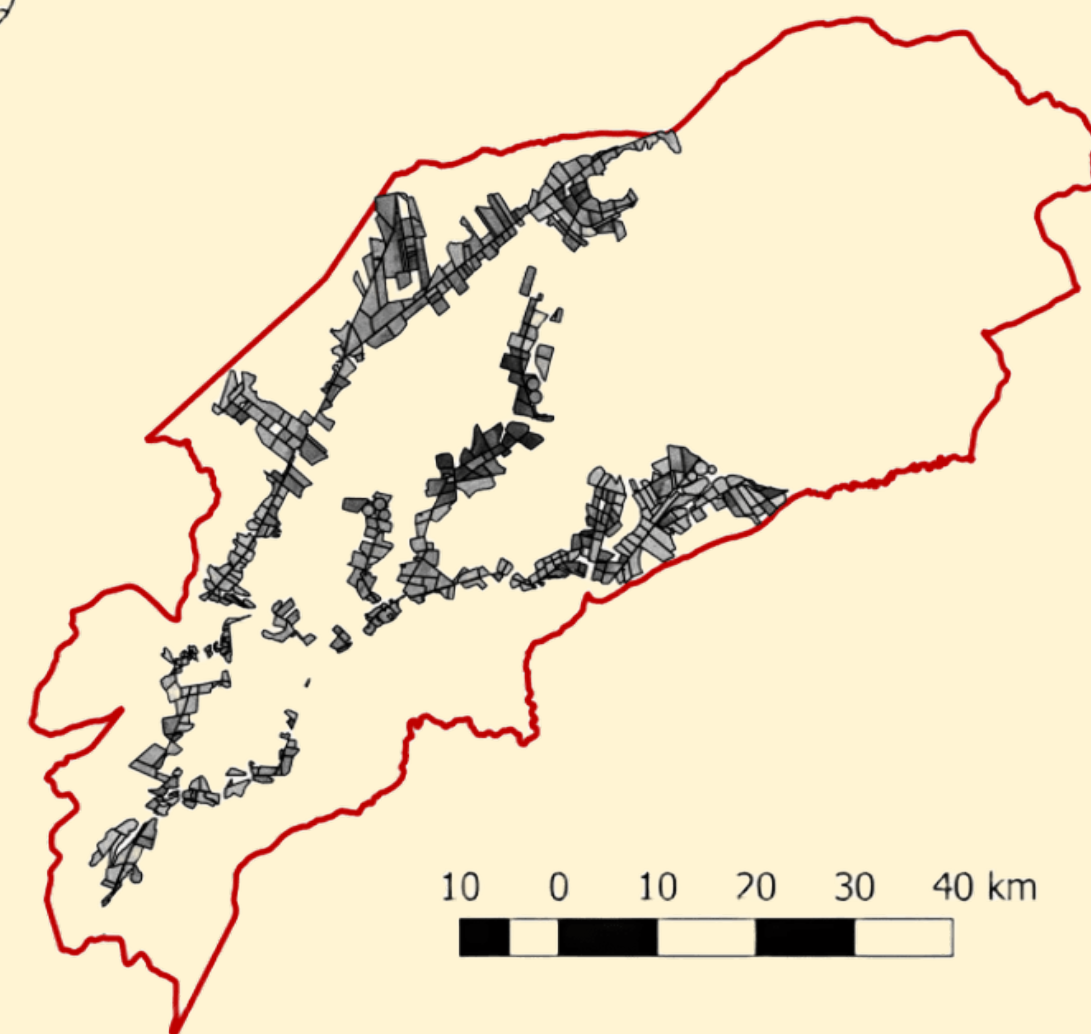
Brazil



Mato Grosso state



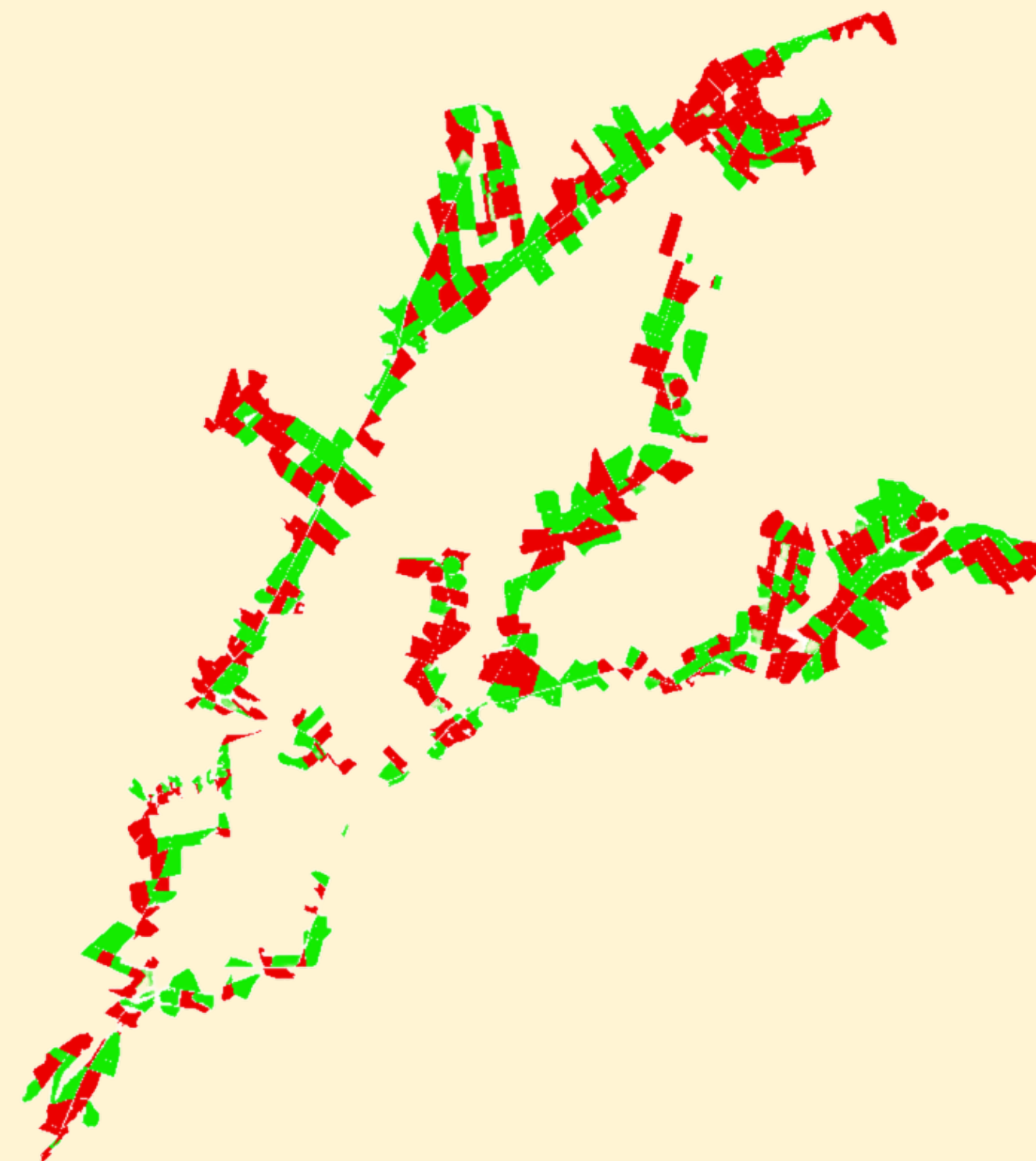
Campo Verde



- 520.29 km²
- 513 labeled field plots

Crop	N#	Percentage
Soybean	4288	37,09
Maize	2076	17,96
Cotton	2694	23,30
Sorghum	47	0,41
Beans	10	0,09
NCC*	583	5,04
Pasture	854	7,39
Eucalyptus	284	2,46
Soil	442	3,82
Cerrado	284	2,46
Total	11562	100,00

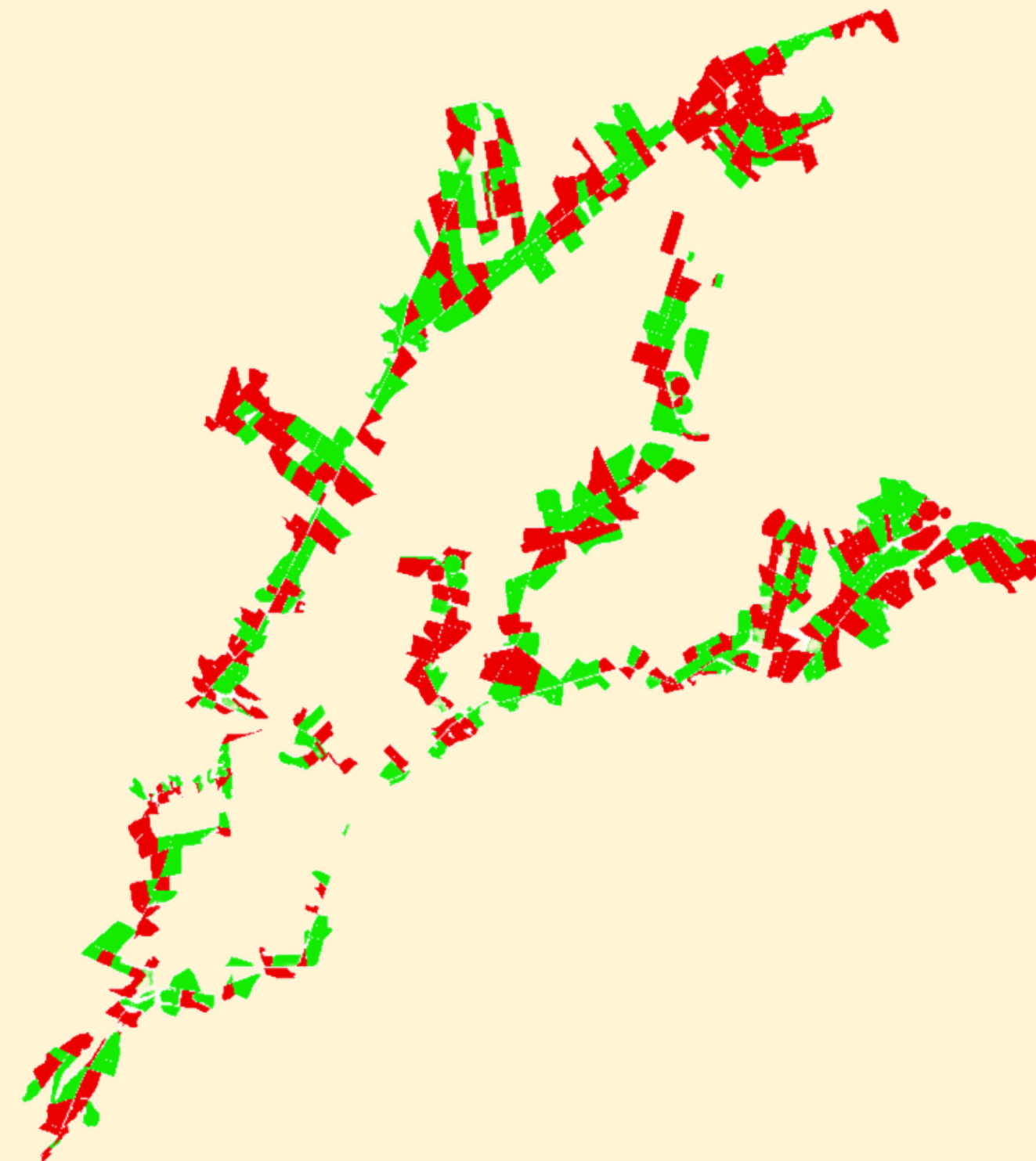
*NCC refers to Non-Commercial Crops.



Red Train - Green Test

Crop	N#	Percentage
Soybean	4288	37,09
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Total	11562	100,00

78.35%



Red Train - Green Test

*NCC refers to Non-Commercial Crops.

Methodology

Automatic Field Plot Mask Generator

IRB(P&D)



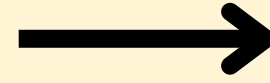
- Sentinel-2
- Level 1C
- 10m per pixel
- Composition of 4 months per image
- Cloud Score+
- Patches 1024×1024
- Overlap 256 pixels

Automatic Field Plot Mask Generator

IRB(P&D)



Segment Anything Model 2



- Sentinel-2
- Level 1C
- 10m per pixel
- Composition of 4 months per image
- Cloud Score+
- Patches 1024×1024
- Overlap 256 pixels

Automatic Field Plot Mask Generator

IRB(P&D)



Segment Anything Model 2

SAM2

**Raw
Masks**

Filters

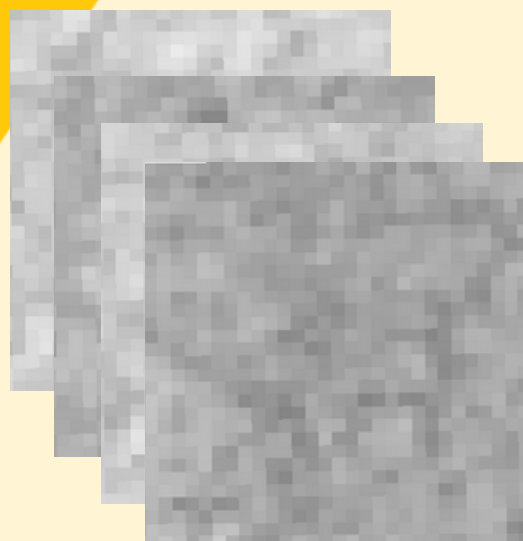
**Final
Masks**

- Sentinel-2
- Level 1C
- 10m per pixel
- Composition of 4 months per image
- Cloud Score+
- Patches 1024×1024
- Overlap 256 pixels

- Size
- Overlap
- Cultivation area
 - MapBiomass

Crop Clustering and Classification

IRB(P&D)



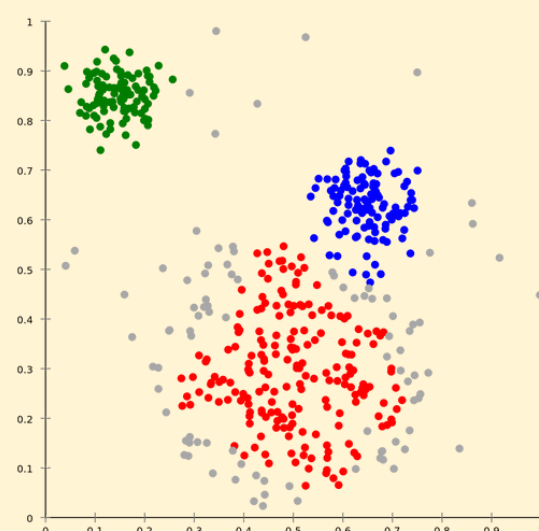
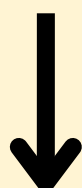
- Sentinel-1
- SAR images
- 10m per pixel
- 2 channels per image
- Concatenates 5 images
- Oct-Feb = 1st harvest
- Mar-Jul = 2nd harvest
- Patches 30×30

Crop Clustering and Classification

IRB(P&D)



Masked Siamese
Networks



- Sentinel-1
- SAR images
- 10m per pixel
- 2 channels per image
- Concatenates 5 images
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Crop Clustering and Classification

IRB(P&D)



Masked Siamese
Networks

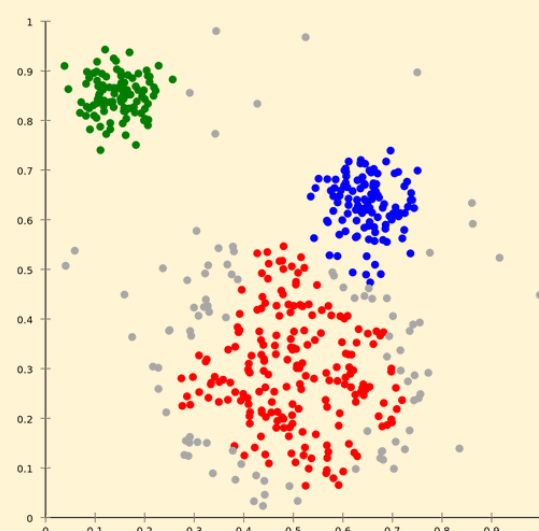


Multi-layer
perceptron



- Sentinel-1
- SAR images
- 10m per pixel
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- Oct-Feb = 1st harvest
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- Patches 30×30

- 2 hidden layers
- 128x64
- Batch Normalization
- ReLU



Crop Clustering and Classification

IRB(P&D)



Masked Siamese Networks



Multi-layer perceptron

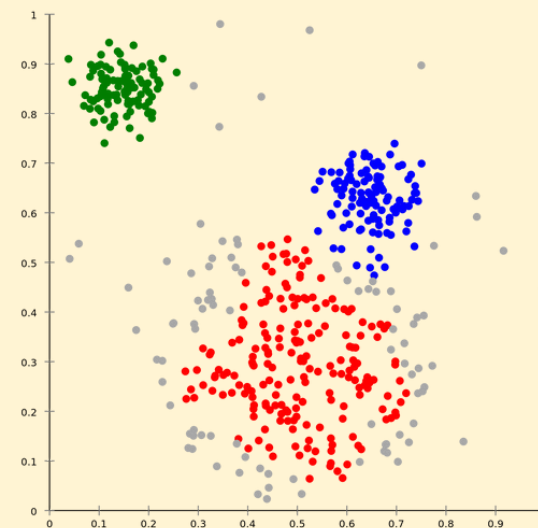


Fine-tuning

Frozen

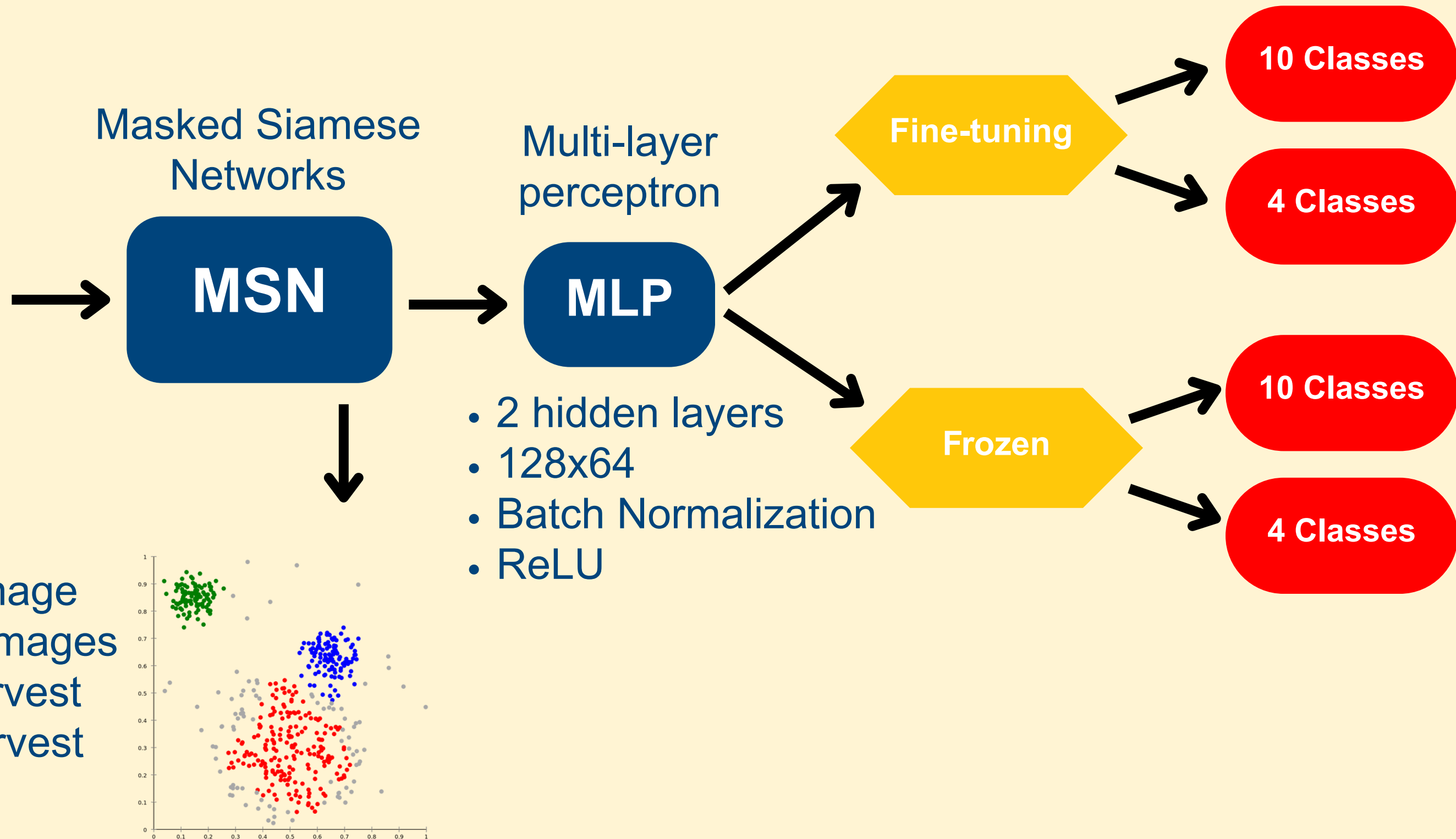
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Crop Clustering and Classification

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Crop Clustering and Classification

IRB(P&D)

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Masked Siamese Networks

MSN

Multi-layer perceptron

MLP

- 2 hidden layers
- 128x64
- Batch Normalization
- ReLU

Fine-tuning

Frozen

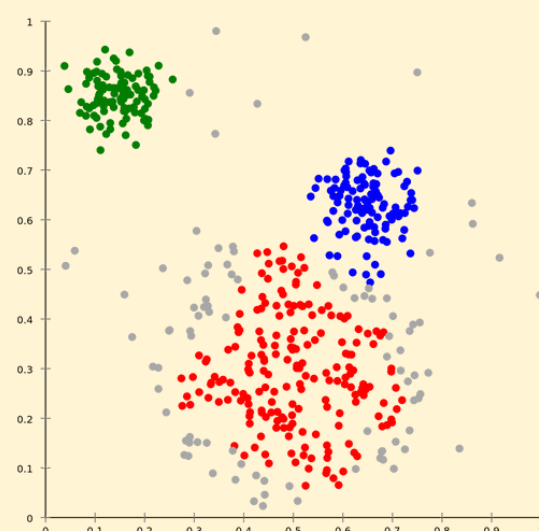
10 Classes

4 Classes

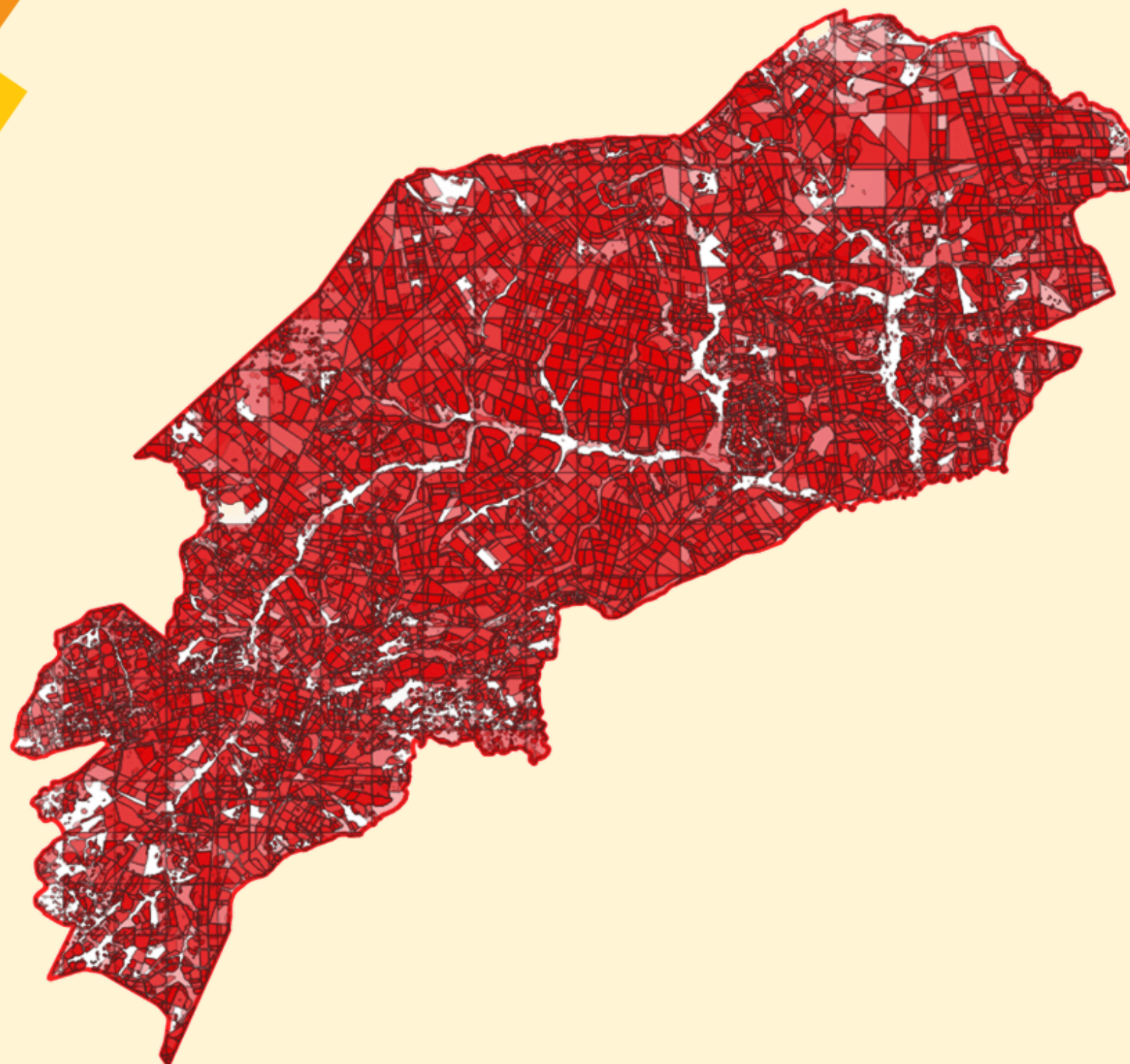
10 Classes

4 Classes

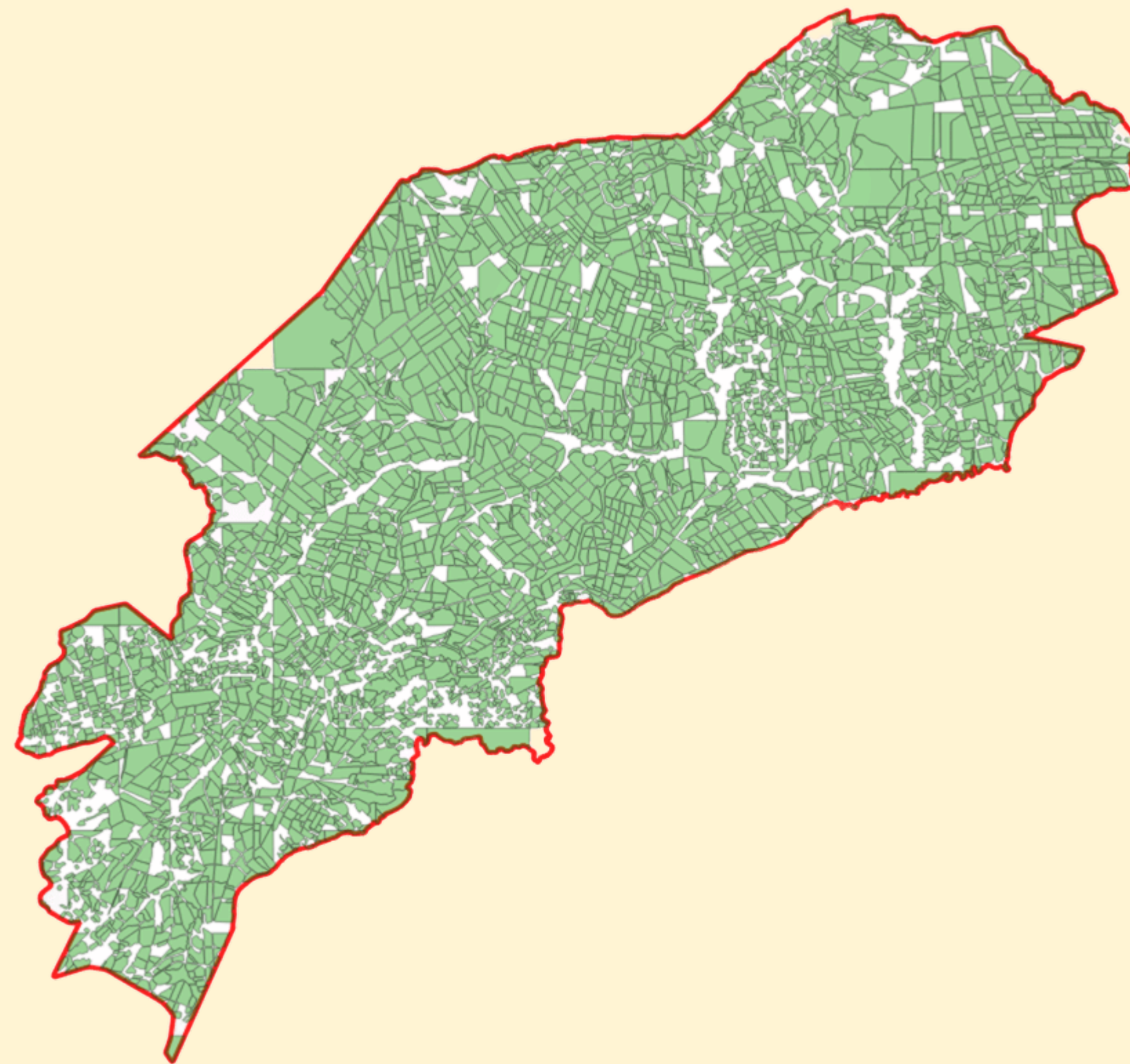
- Soybean
- Maize
- Cotton
- Others



Application and Results



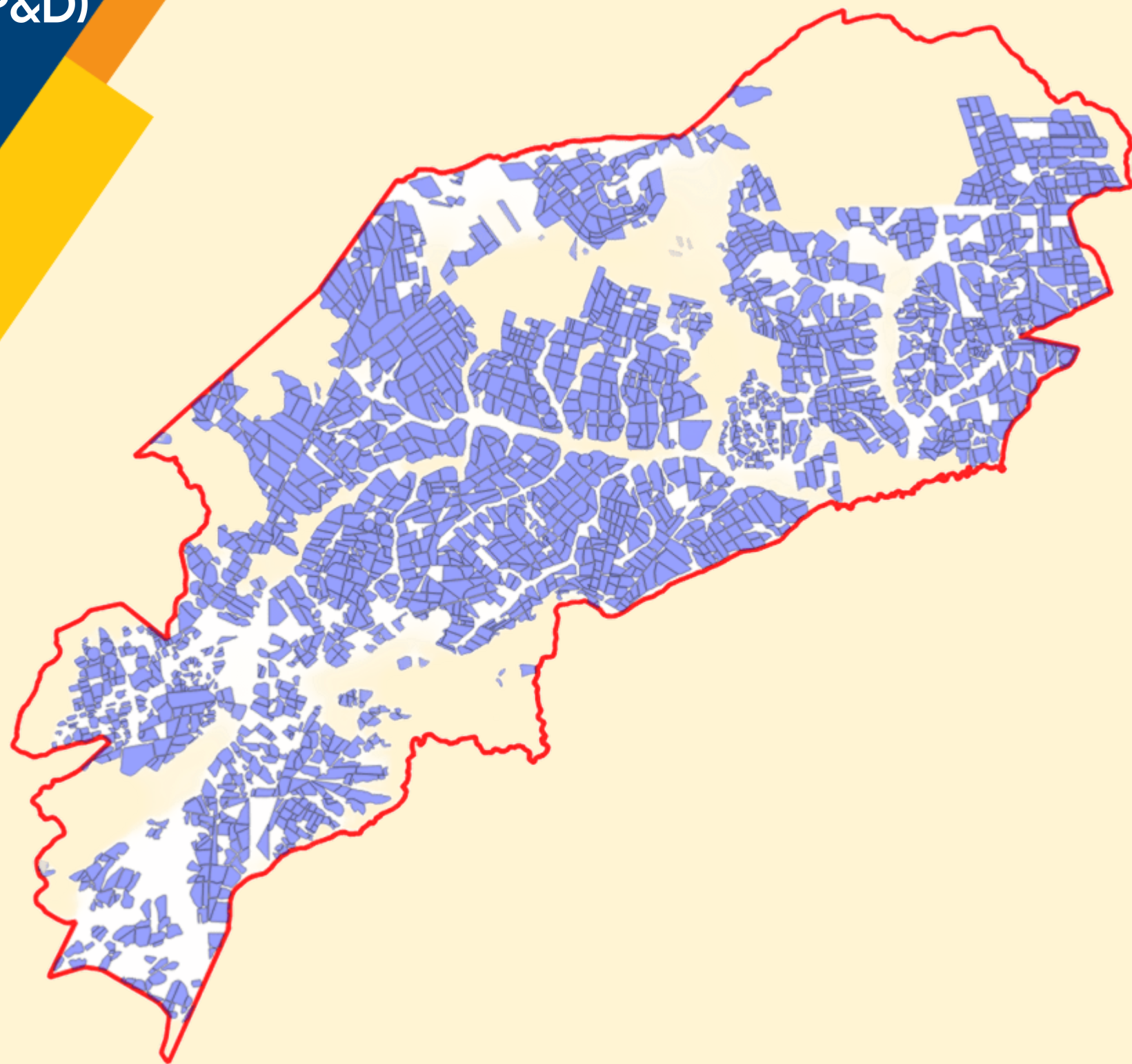
Raw Masks



Filtro size e overlap

Segmentation

IRB(P&D)



MapBiomas Filter

- 2189.73 km²
- 4014 labeled field plots



Zoom

Confusion Matrix

		Predicted Values	
		Positive	Negative
Actual Values	Positive	TP	FN
	Negative	FP	TN

$$\text{Accuracy} = \text{acc} = \frac{TP + TN}{TP + TN + FP + FN}$$

Confusion Matrix

		Predicted Values	
		Positive	Negative
Actual Values	Positive	TP	FN
	Negative	FP	TN

		Predicted Class		
		A	B	C
Actual Class	A	TP ₁	E ₁₂	E ₁₃
	B	E ₂₁	TP ₂	E ₂₃
	C	E ₃₁	E ₃₂	TP ₃

$$acc = \frac{TP + TN}{TP + TN + FP + FN}$$

$$total\ acc = \frac{\sum_i^N TP_i}{\sum_i^N (TP_i + \sum_j^N E_{ij})}$$

$$acc_i = \frac{TP_i}{TP_i + \sum_j^N E_{ij}}$$

$$mean\ acc = \frac{\sum_i^N acc_i}{N}$$

Classification - 10 classes

IRB(P&D)

Model	Fine-tuning	Frozen
N# de classes	10	10
Total Acc	88.05	87.41
Mean Acc	77.32	69.49
Epochs	7341	40000
Patience	200	200
Learning Rate	5,00E-07	5,00E-07

Crop	Train		Test	
	N#	%	N#	%
Soybean	2357	38,55	1931	35,44
Maize	1124	18,38	952	17,47
Cotton	1481	24,22	1213	22,27
Sorghum	28	0,46	19	0,35
Beans	7	0,11	3	0,06
NCC	303	4,96	280	5,14
Pasture	348	5,69	506	9,29
Eucalyptus	130	2,13	154	2,83
Soil	222	3,63	220	4,04
Cerrado	114	1,86	170	3,12
Total	6114	100,00	5448	100,00

Classification - 10 classes

IRB(P&D)

	Soybean	Maize	Cotton	Sorghum	Beans	NCC	Pasture	Eucalyptus	Soil	Cerrado
Actual Soybean	94.0%	2.2%	0.1%	0.0%	0.1%	1.5%	1.0%	0.1%	0.9%	0.1%
Actual Maize	1.4%	88.9%	5.9%	0.0%	0.0%	2.0%	1.2%	0.2%	0.3%	0.2%
Actual Cotton	0.2%	2.4%	96.3%	0.0%	0.0%	0.6%	0.5%	0.0%	0.1%	0.0%
Actual Sorghum	0.0%	68.4%	0.0%	31.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Actual Beans	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Actual NCC	2.9%	0.7%	7.5%	0.0%	0.0%	78.9%	3.6%	0.4%	4.6%	1.4%
Actual Pasture	0.2%	3.4%	2.2%	0.4%	0.0%	1.0%	70.9%	9.1%	2.4%	10.5%
Actual Eucalyptus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	96.1%	0.0%	0.0%
Actual Soil	5.5%	0.0%	3.6%	0.5%	0.0%	24.5%	0.9%	0.9%	64.1%	0.0%
Actual Cerrado	0.0%	7.1%	0.0%	0.0%	0.0%	1.2%	27.6%	11.2%	0.6%	52.4%
	Prediction									

Fine-Tuning Model

	Soybean	Maize	Cotton	Sorghum	Beans	NCC	Pasture	Eucalyptus	Soil	Cerrado
Actual Soybean	96.4%	1.8%	0.3%	0.0%	0.0%	0.8%	0.4%	0.0%	0.3%	0.0%
Actual Maize	2.0%	88.8%	6.2%	0.0%	0.0%	1.9%	0.9%	0.1%	0.1%	0.0%
Actual Cotton	0.2%	2.6%	96.3%	0.0%	0.0%	0.2%	0.6%	0.0%	0.0%	0.0%
Actual Sorghum	0.0%	52.6%	15.8%	21.1%	0.0%	5.3%	5.3%	0.0%	0.0%	0.0%
Actual Beans	33.3%	0.0%	0.0%	0.0%	66.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Actual NCC	9.3%	1.1%	13.6%	0.0%	0.0%	73.6%	1.4%	0.0%	1.1%	0.0%
Actual Pasture	0.8%	6.7%	4.0%	0.0%	0.0%	0.6%	68.6%	8.3%	0.4%	10.7%
Actual Eucalyptus	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	4.5%	92.2%	0.0%	2.6%
Actual Soil	12.3%	0.9%	5.5%	0.0%	0.0%	18.6%	0.5%	0.9%	61.4%	0.0%
Actual Cerrado	7.1%	18.2%	0.0%	0.0%	0.0%	0.6%	32.4%	11.8%	0.0%	30.0%
	Prediction									

Frozen Model

Classification - 10 classes

Confusion Matrix - Absolute

	Soybean	Maize	Cotton	Sorghum	Beans	NCC	Pasture	Eucalyptus	Soil	Cerrado
Soybean	1816	42	2	0	2	29	20	1	18	1
Maize	13	846	56	0	0	19	11	2	3	2
Cotton	2	29	1168	0	0	7	6	0	1	0
Sorghum	0	13	0	6	0	0	0	0	0	0
Beans	0	0	0	0	3	0	0	0	0	0
NCC	8	2	21	0	0	221	10	1	13	4
Pasture	1	17	11	2	0	5	359	46	12	53
Eucalyptus	0	0	0	0	0	0	6	148	0	0
Soil	12	0	8	1	0	54	2	2	141	0
Cerrado	0	12	0	0	0	2	47	19	1	89
Actual	Prediction									

Fine-Tuning Model

Confusion Matrix - Absolute

	Soybean	Maize	Cotton	Sorghum	Beans	NCC	Pasture	Eucalyptus	Soil	Cerrado
Soybean	1862	35	5	0	0	16	8	0	5	0
Maize	19	845	59	0	0	18	9	1	1	0
Cotton	3	32	1168	0	0	3	7	0	0	0
Sorghum	0	10	3	4	0	1	1	0	0	0
Beans	1	0	0	0	2	0	0	0	0	0
NCC	26	3	38	0	0	206	4	0	3	0
Pasture	4	34	20	0	0	3	347	42	2	54
Eucalyptus	0	0	1	0	0	0	7	142	0	4
Soil	27	2	12	0	0	41	1	2	135	0
Cerrado	12	31	0	0	0	1	55	20	0	51
Actual	Prediction									

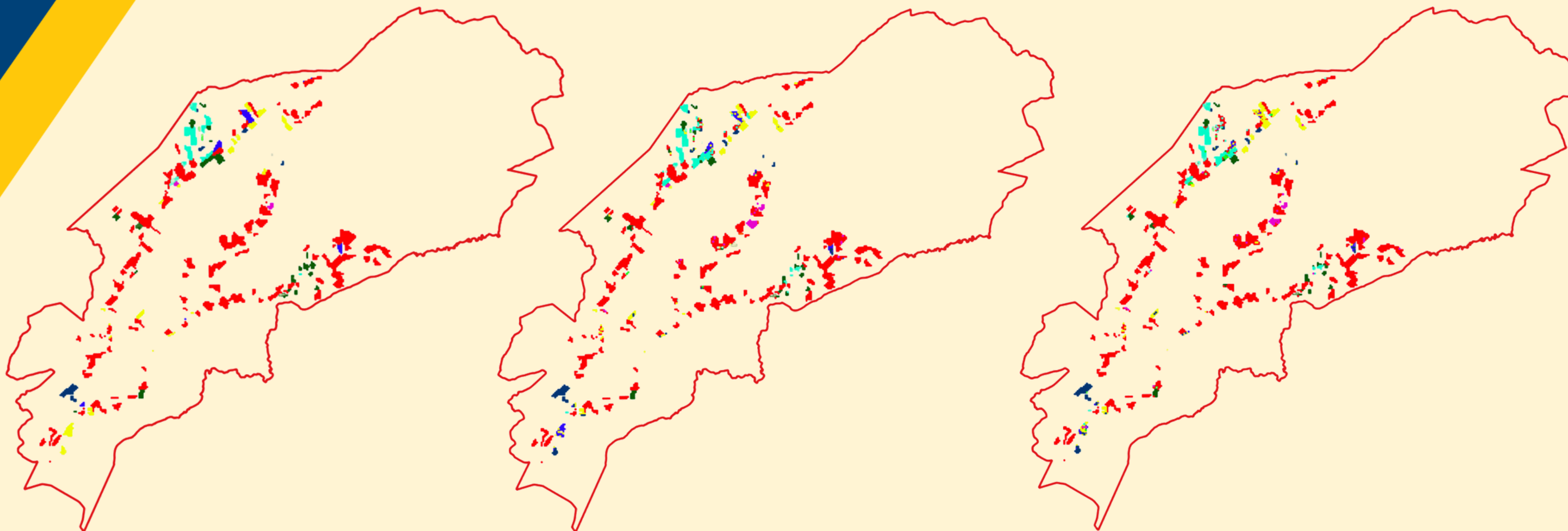
Frozen Model

Classification - 10 classes

December - Test Dataset

- Soybean
- Cotton
- Beans
- Pasture
- Soil
- Maize
- Sorghum
- NCC
- Eucalyptus
- Cerrado

IRB(P&D)



Labeled Data

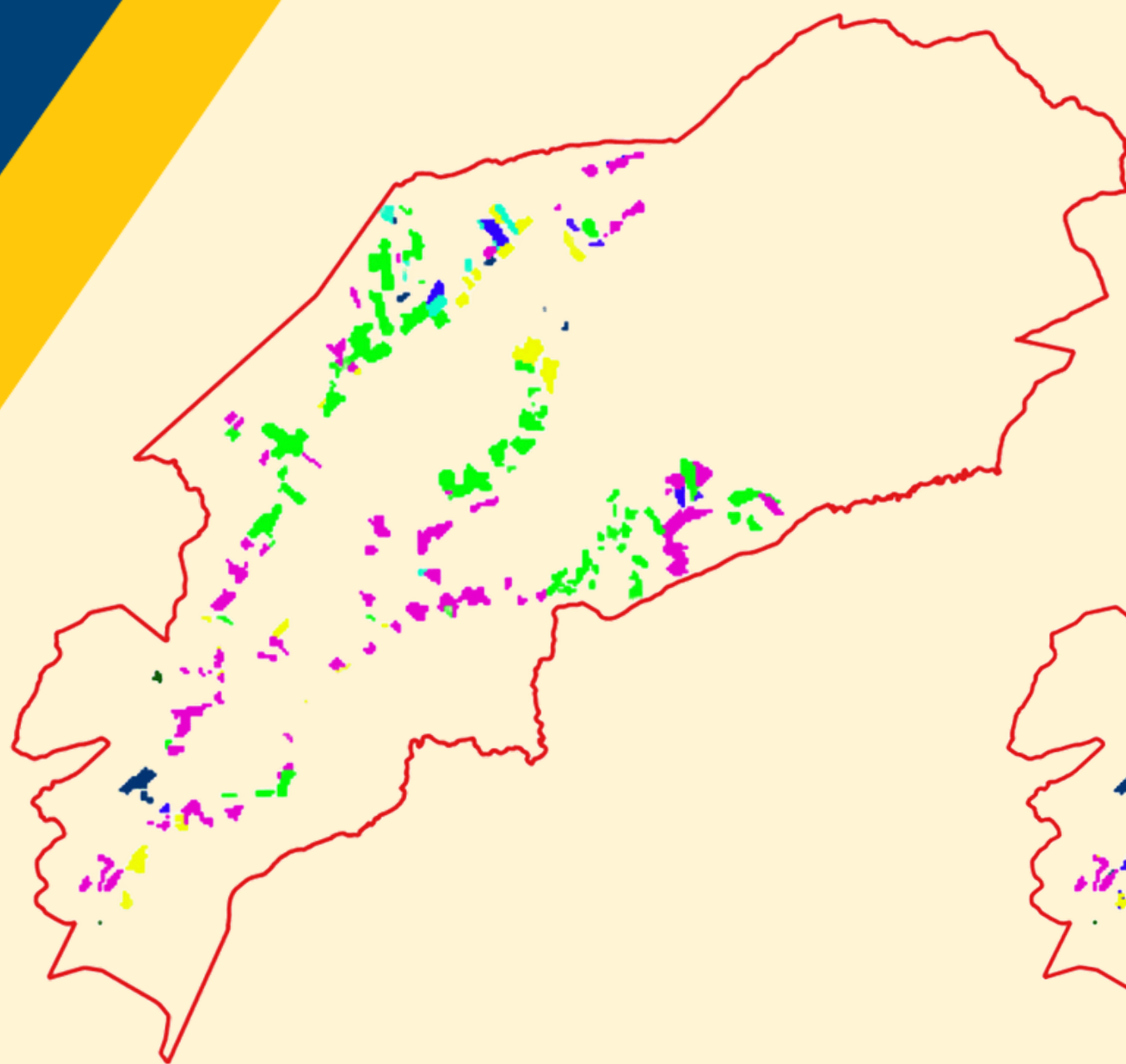
Fine-Tuning Model

Frozen Model

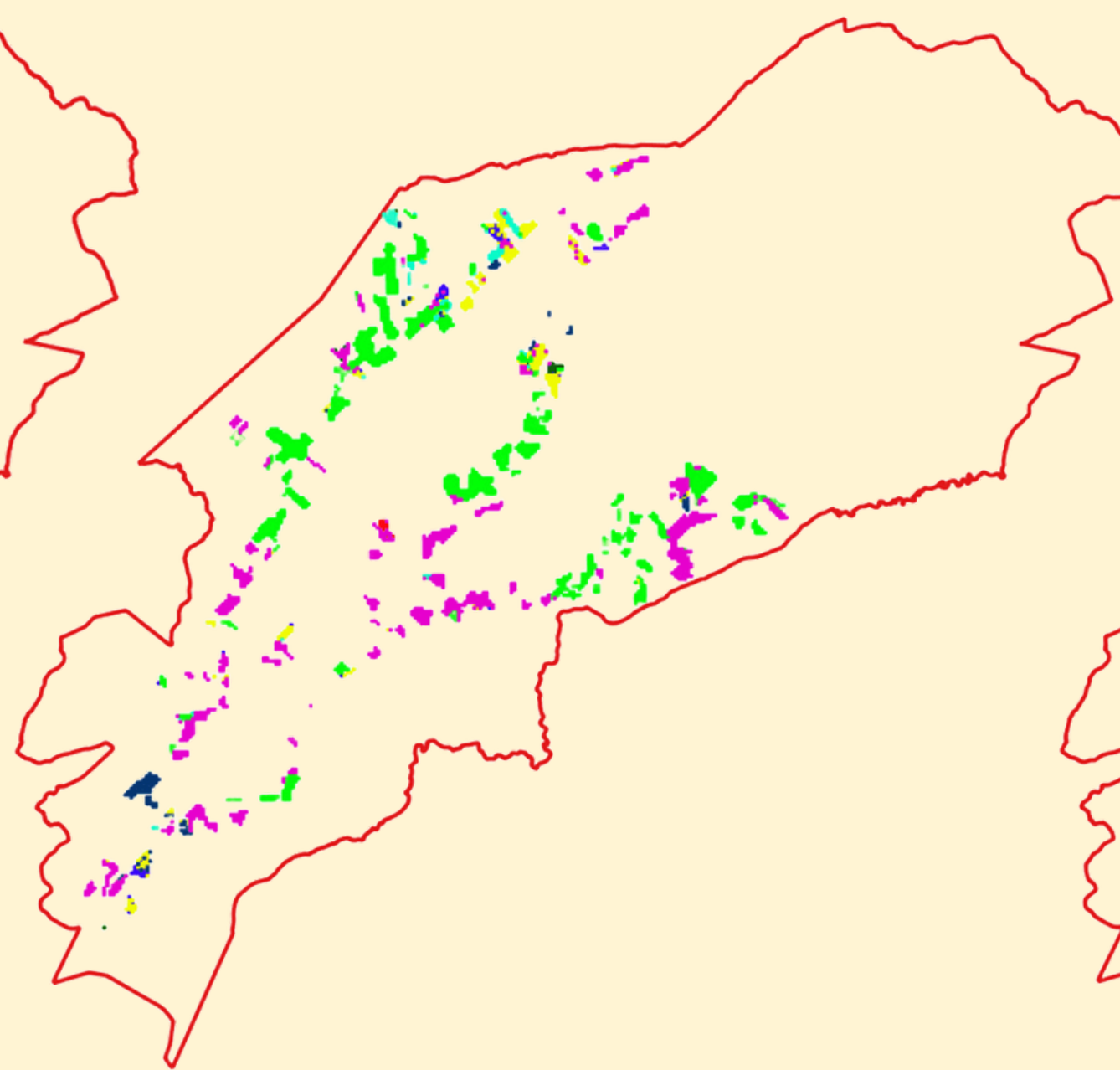
Classification - 10 classes

May - Test Dataset

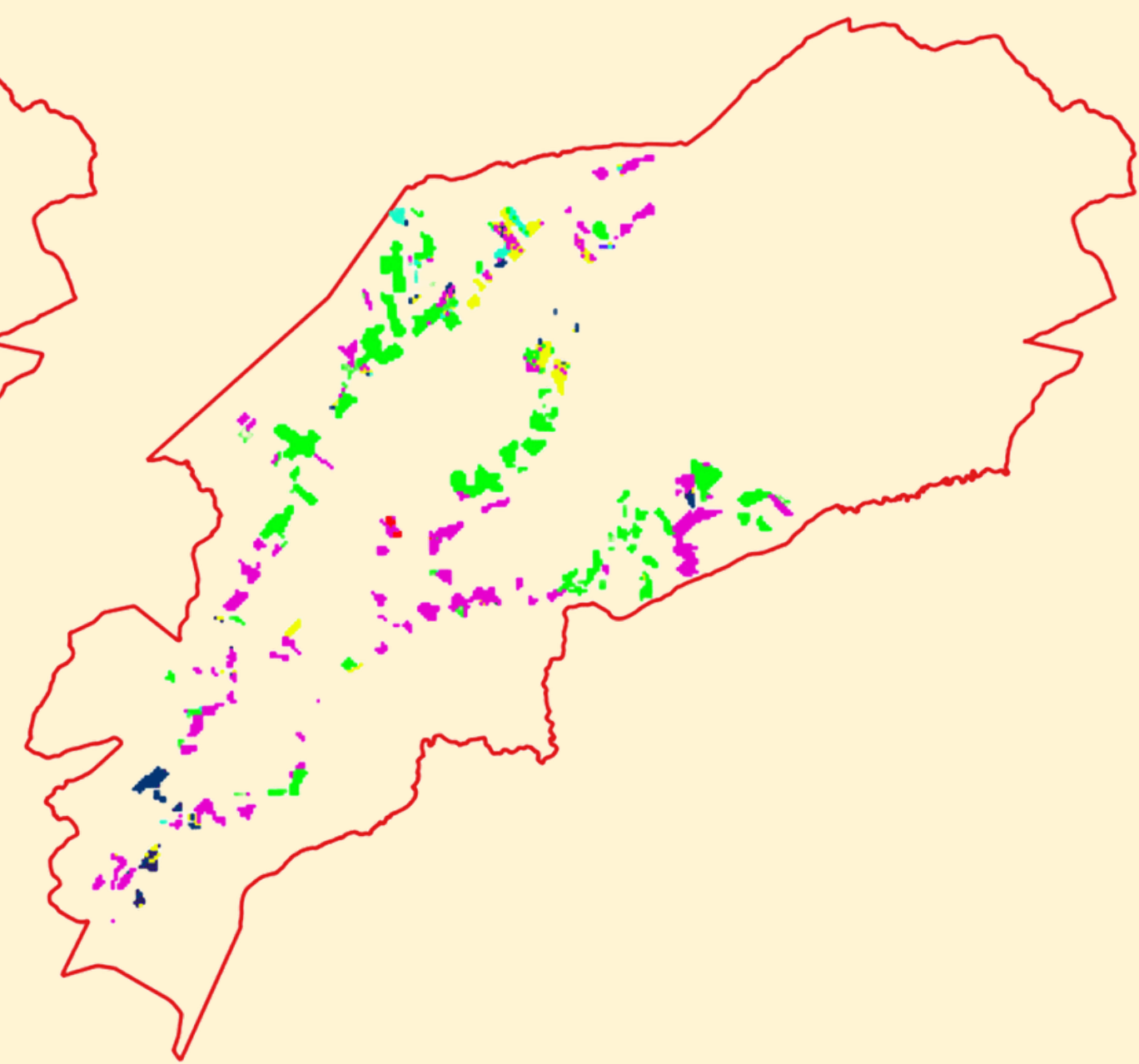
- | | | | | |
|--|---|---|--|---|
| ● Soybean | ● Cotton | ● Beans | ● Pasture | ● Soil |
| ● Maize | ● Sorghum | ● NCC | ● Eucalyptus | ● Cerrado |



Labeled Data



Fine-Tuning Model

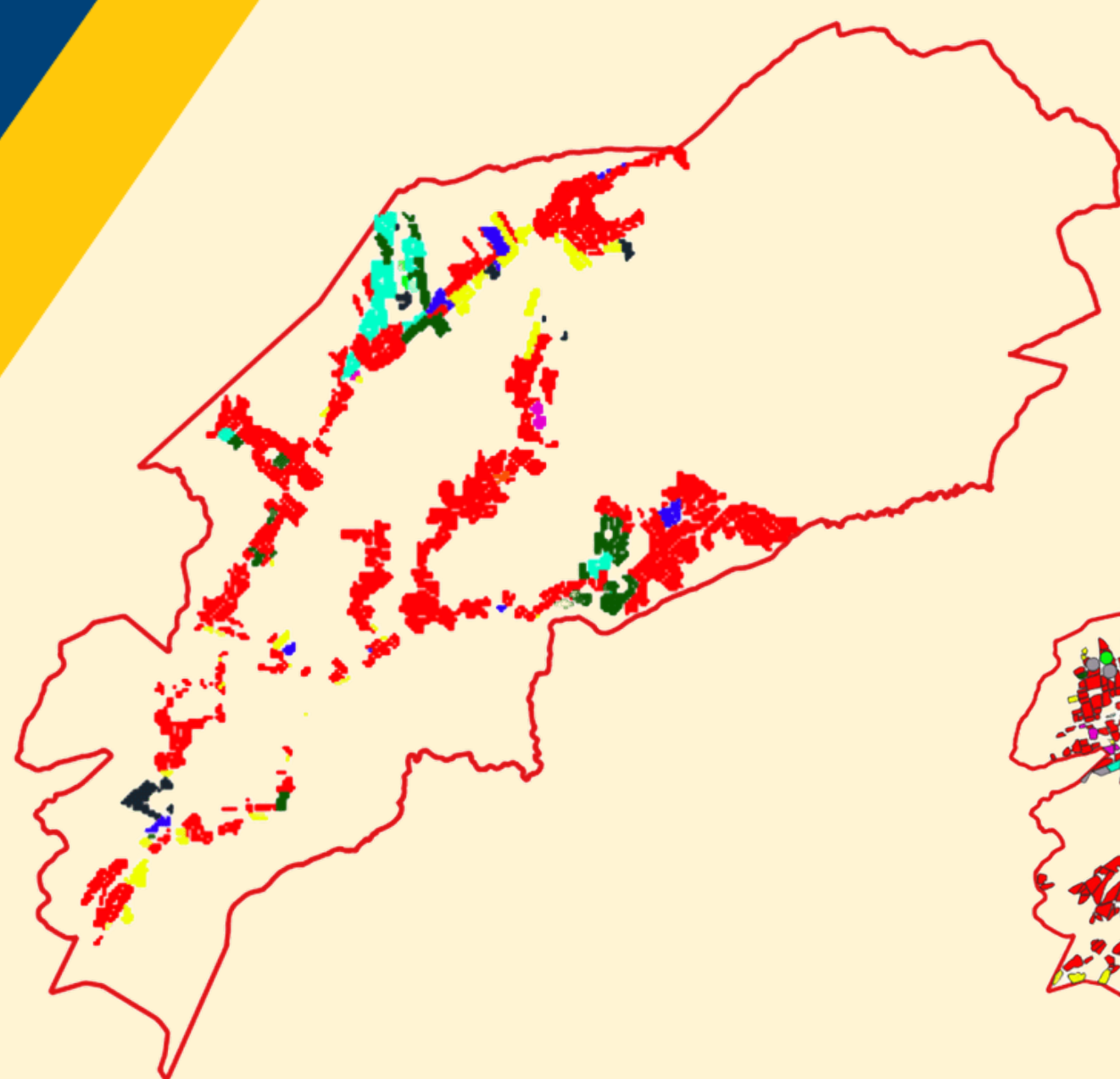


Frozen Model

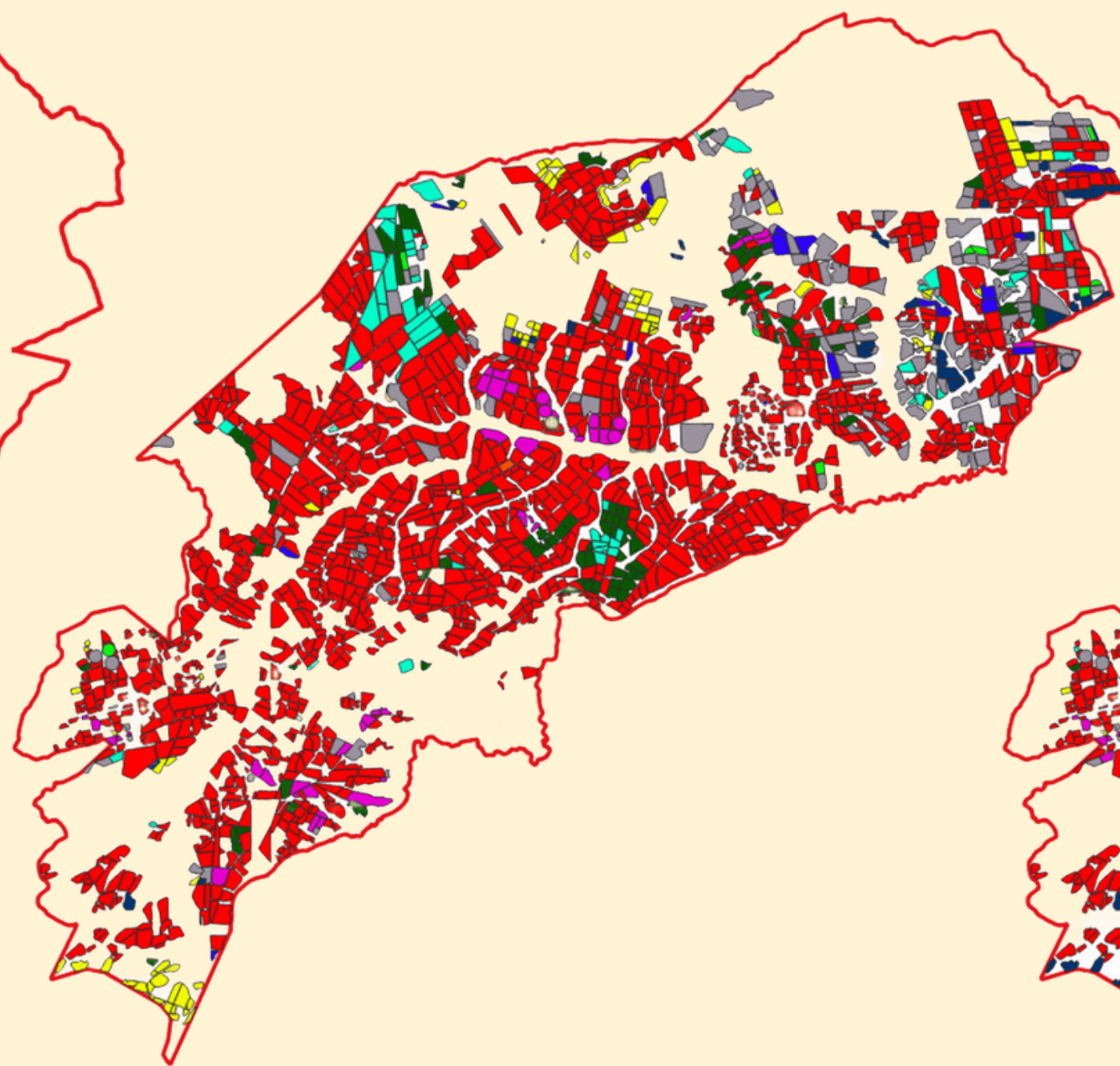
Classification - 10 classes

December - Generated Masks

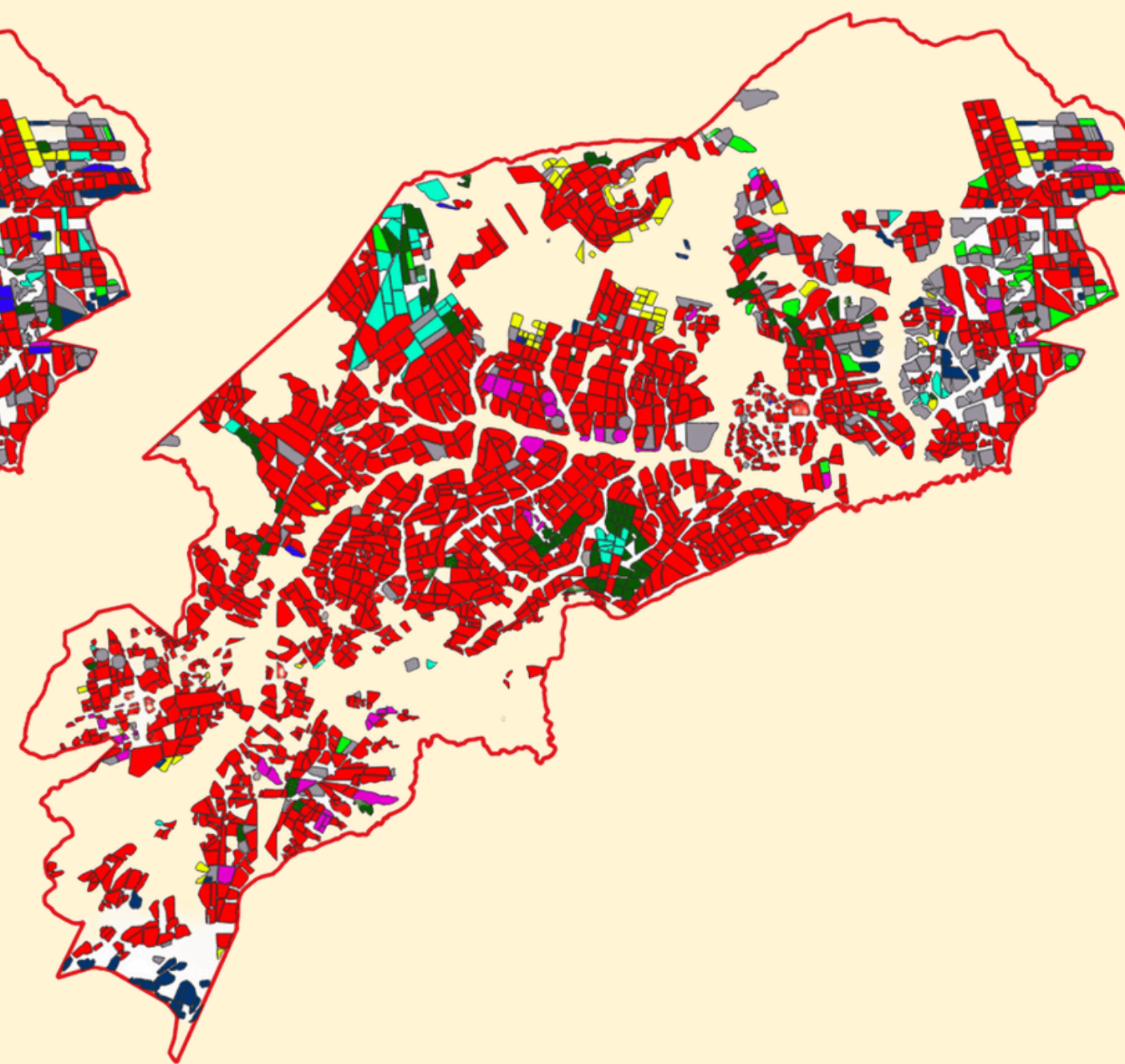
- Soybean
- Cotton
- Beans
- Pasture
- Soil
- Maize
- Sorghum
- NCC
- Eucalyptus
- Cerrado
- Not Classified



Labeled Data



Fine-Tuning Model

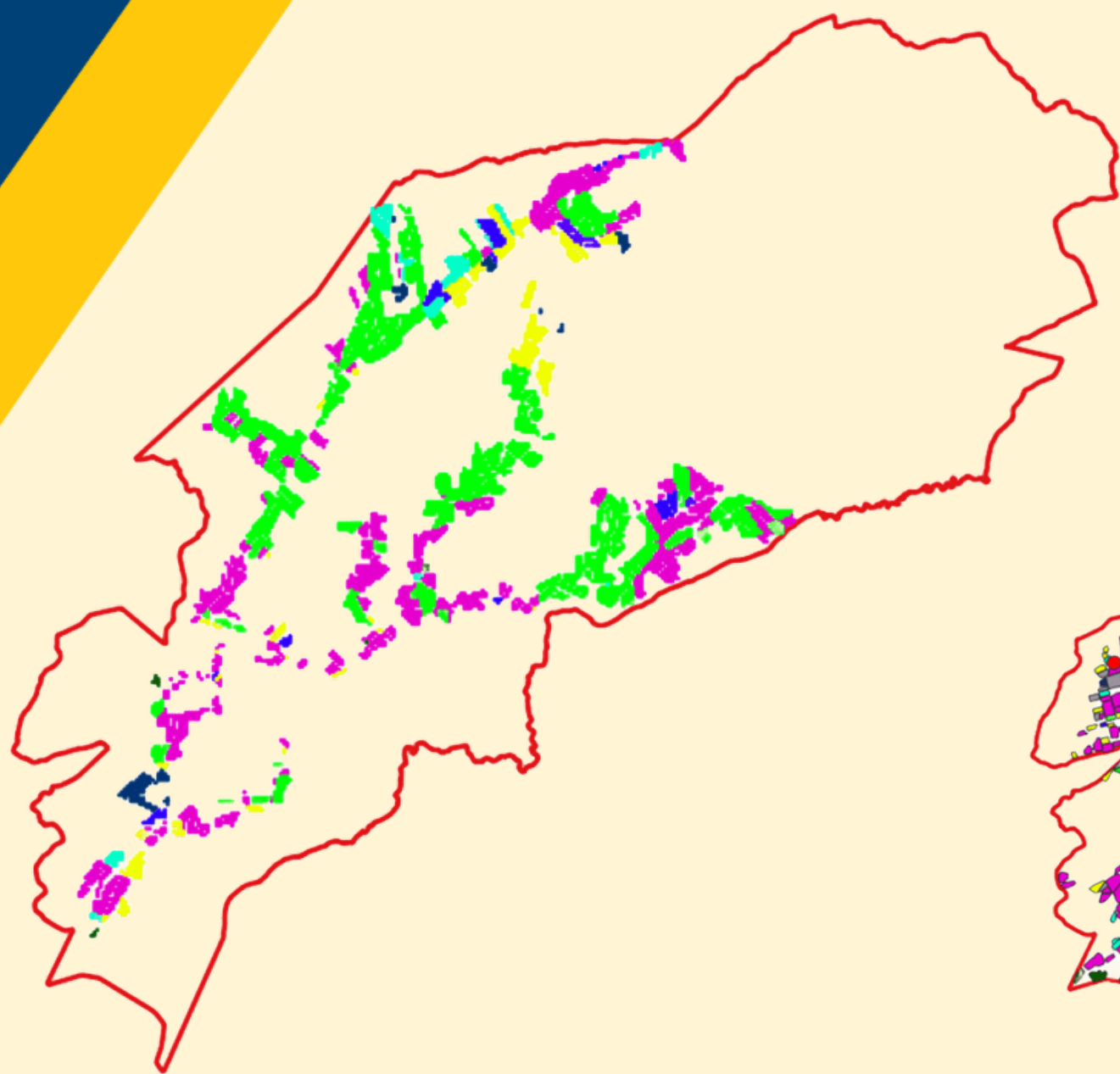


Frozen Model

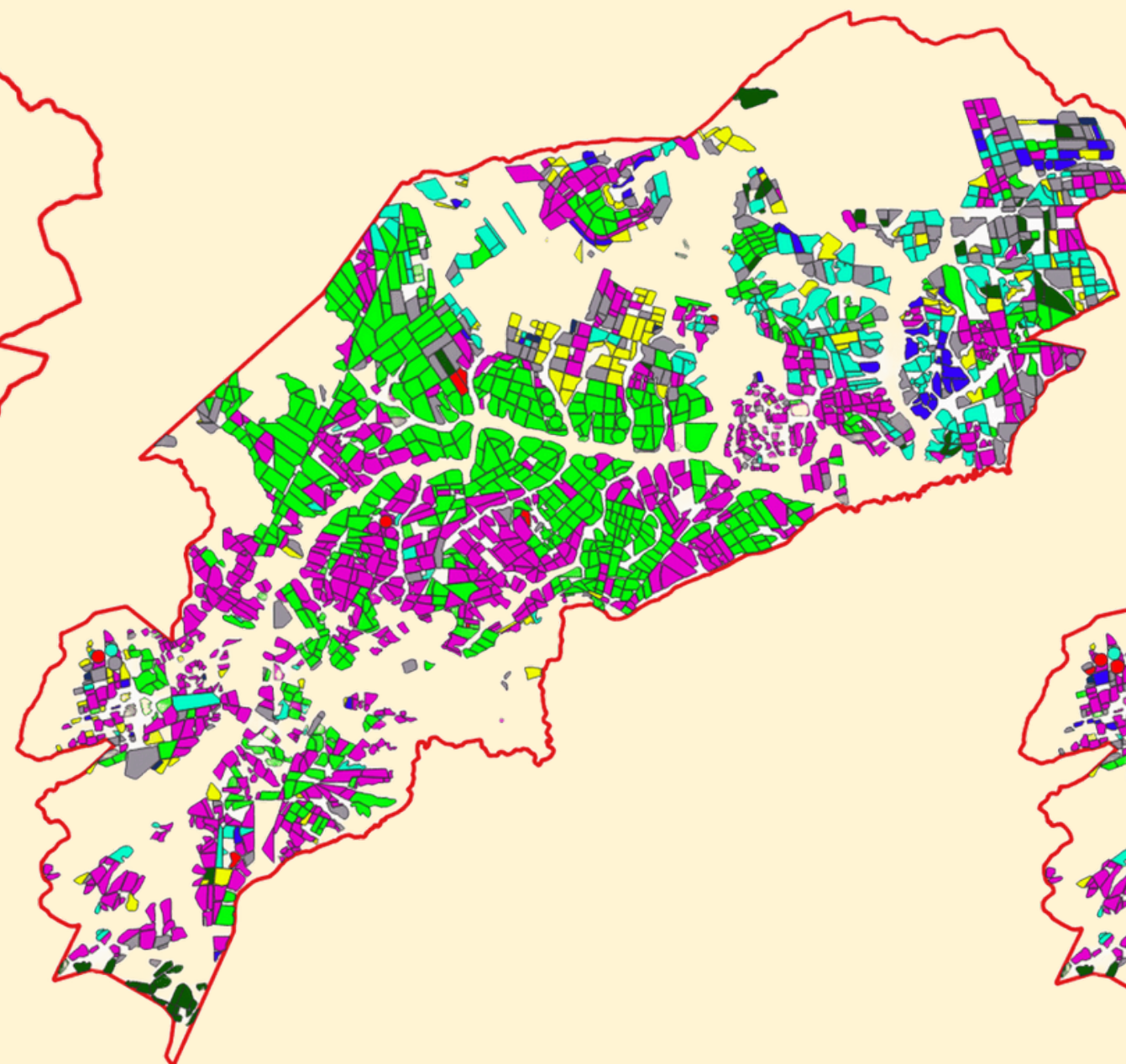
Classification - 10 classes

May - Generated Masks

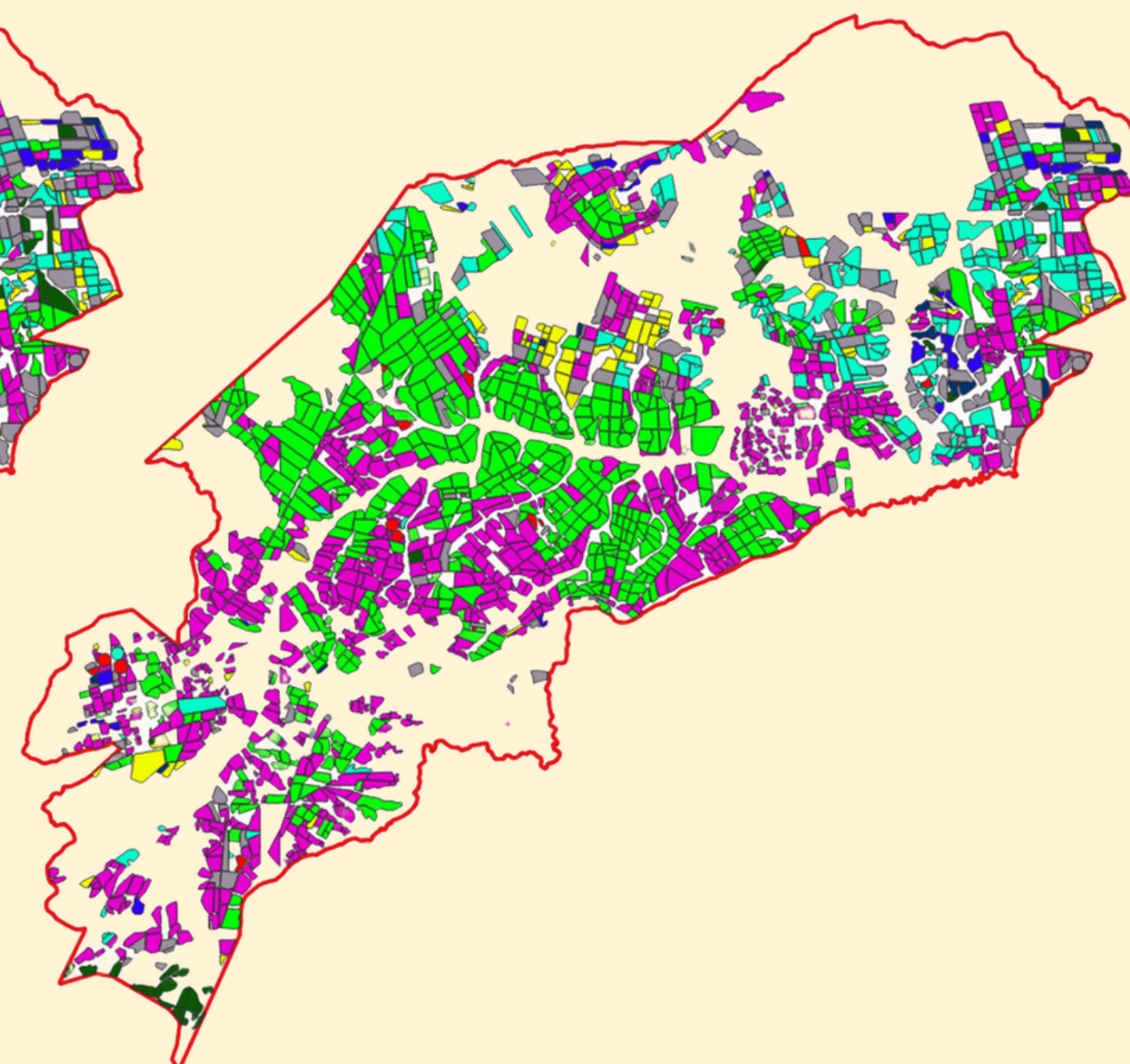
- | | | | | |
|--|---|---|--|--|
| ● Soybean | ● Cotton | ● Beans | ● Pasture | ● Soil |
| ● Maize | ● Sorghum | ● NCC | ● Eucalyptus | ● Cerrado |
| | | | | ● Not Classified |



Labeled Data



Fine-Tuning Model



Frozen Model

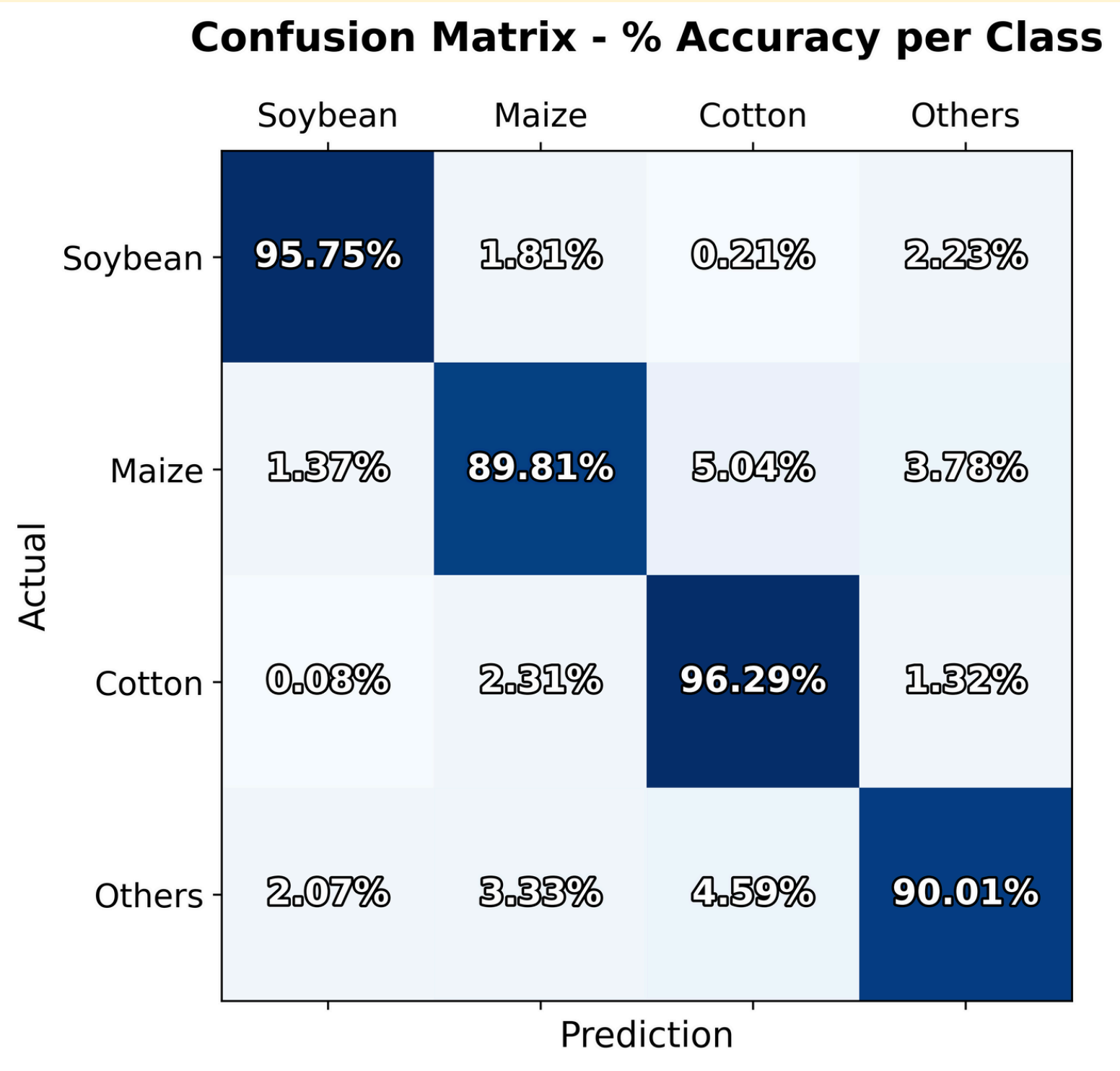
Classification - 4 classes

IRB(P&D)

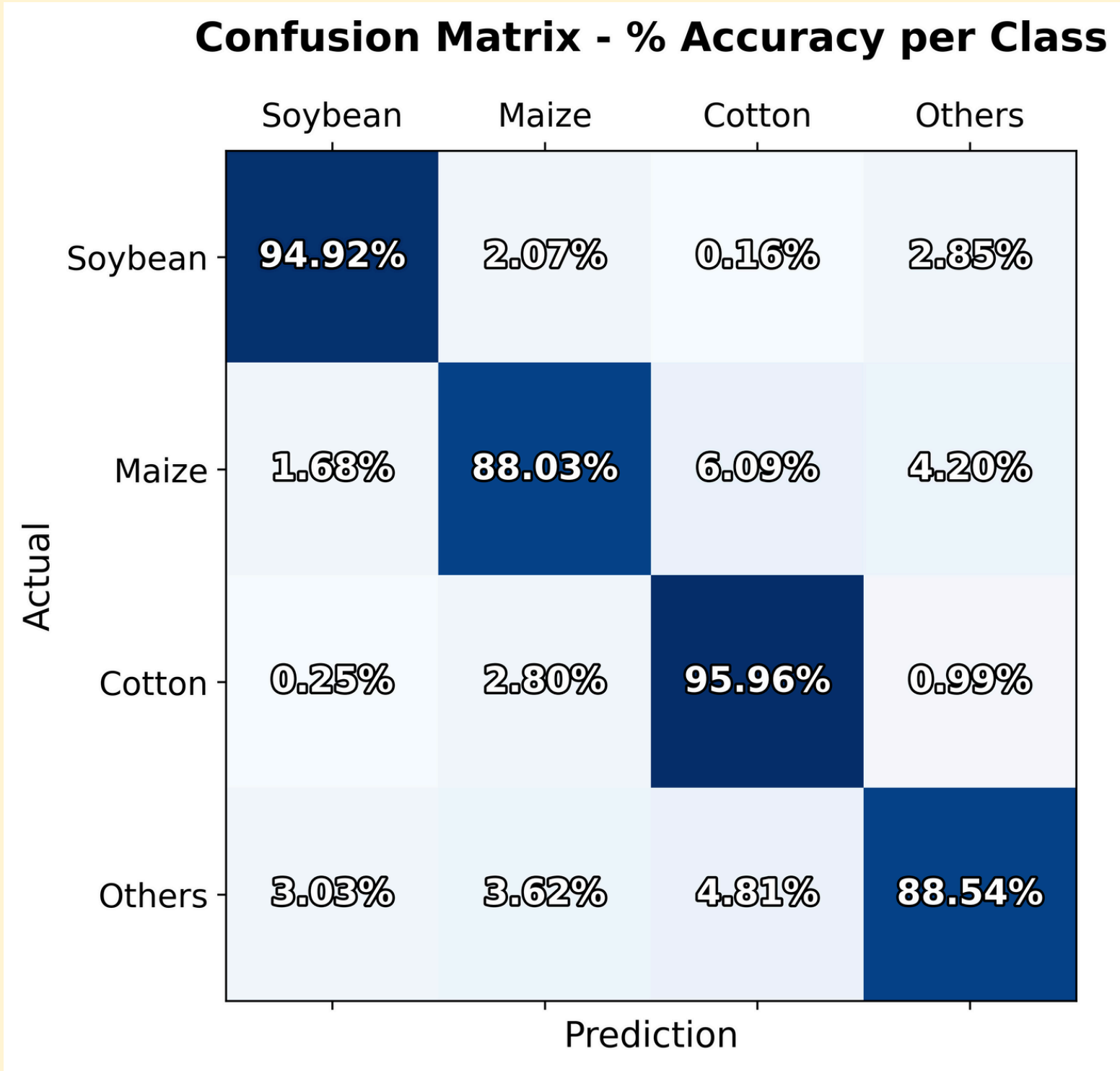
Model	Fine-tuning	Frozen
N# de classes	4	4
Total Acc	93.41	92.36
Mean Acc	92.97	91.86
Epochs	5080	40000
Patience	200	200
Learning Rate	5,00E-07	5,00E-07

Crop	Train		Test	
	N#	%	N#	%
Soybean	2357	38,55	1931	35,44
Maize	1124	18,38	952	17,47
Cotton	1481	24,22	1213	22,27
Others	1152	18,84	1352	24,82
Total	6114	100,00	5448	100,00

Classification - 4 classes



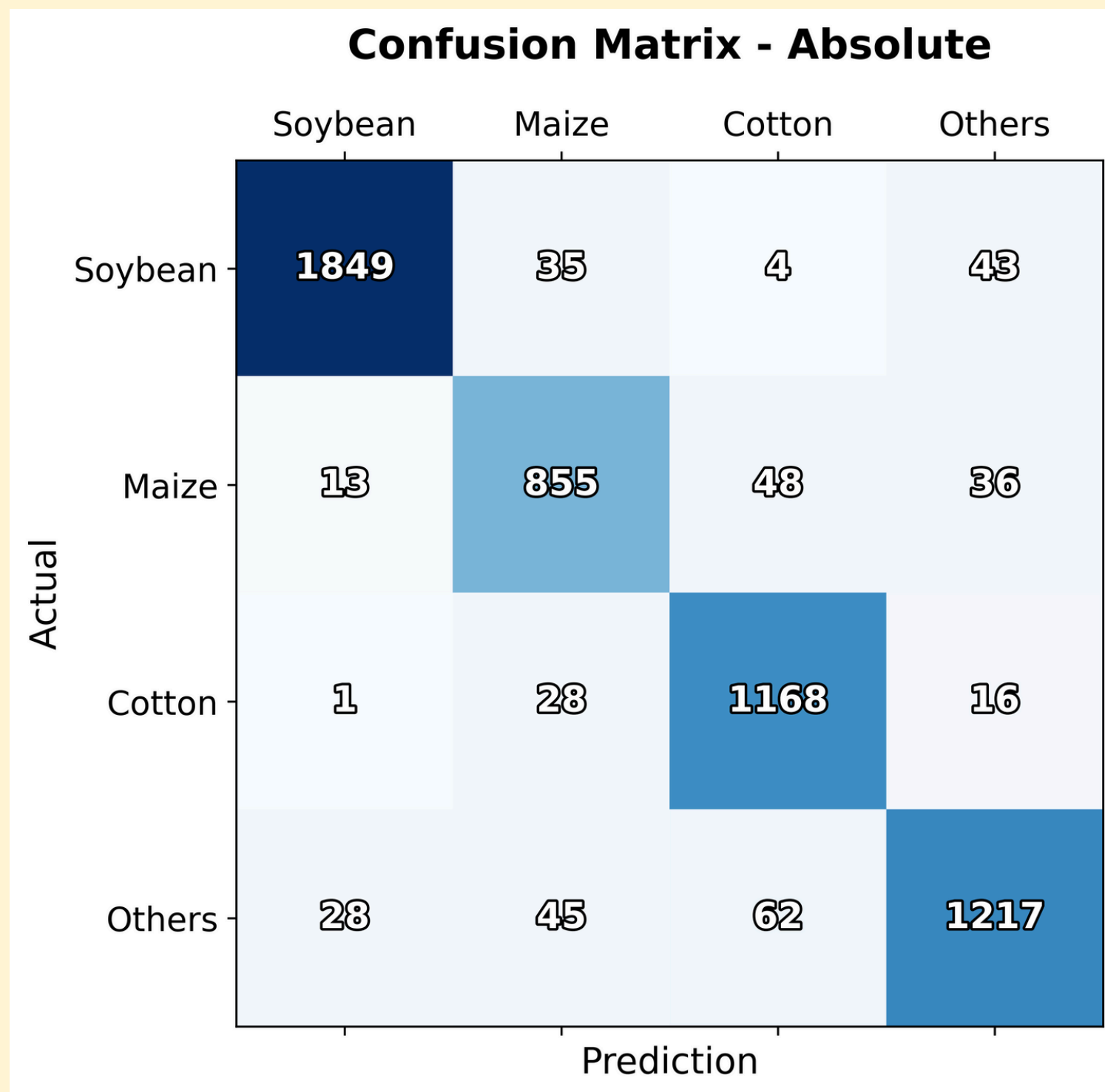
Fine-Tuning Model



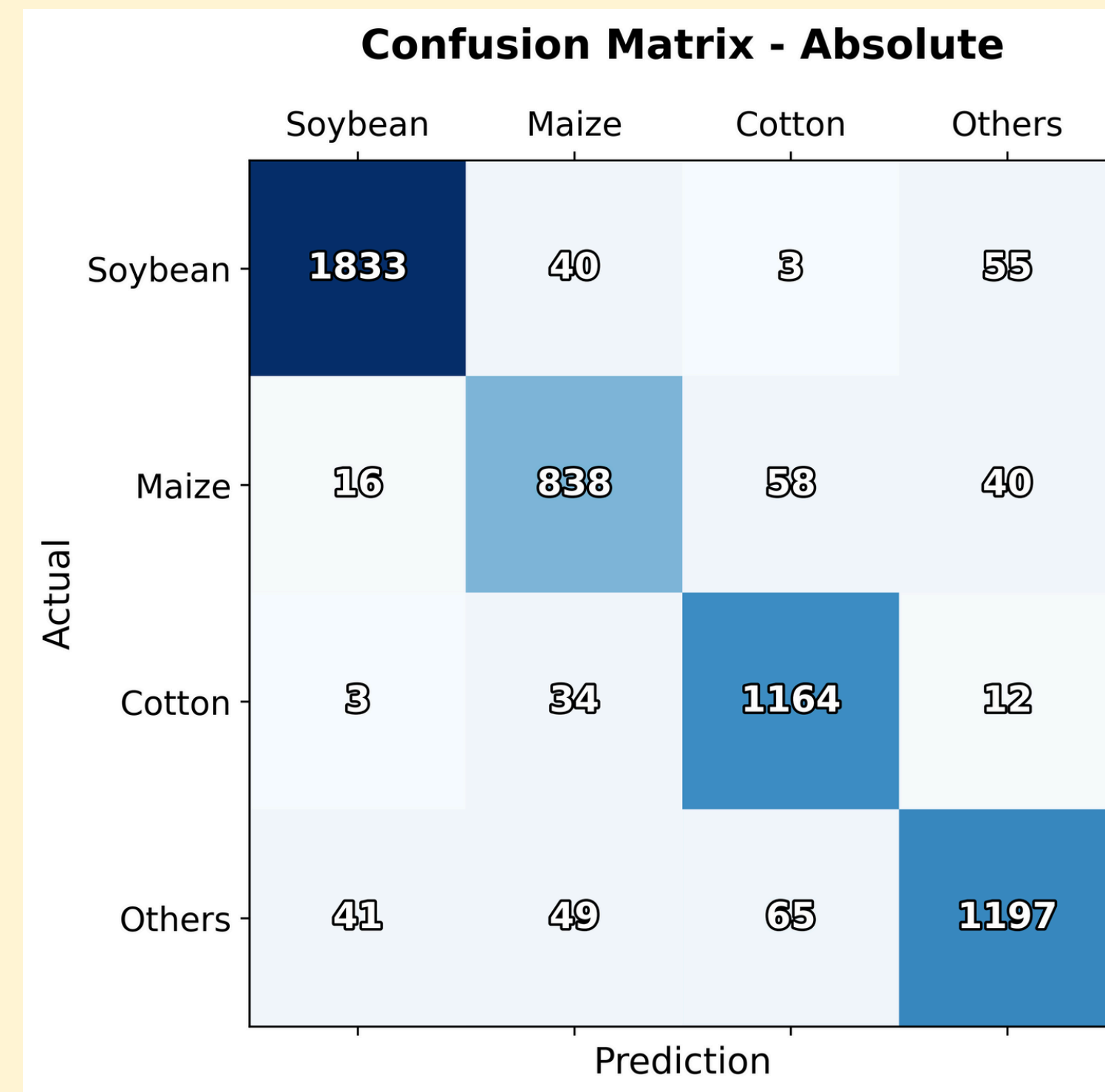
Frozen Model

Classification - 4 classes

IRB(P&D)



Fine-Tuning Model

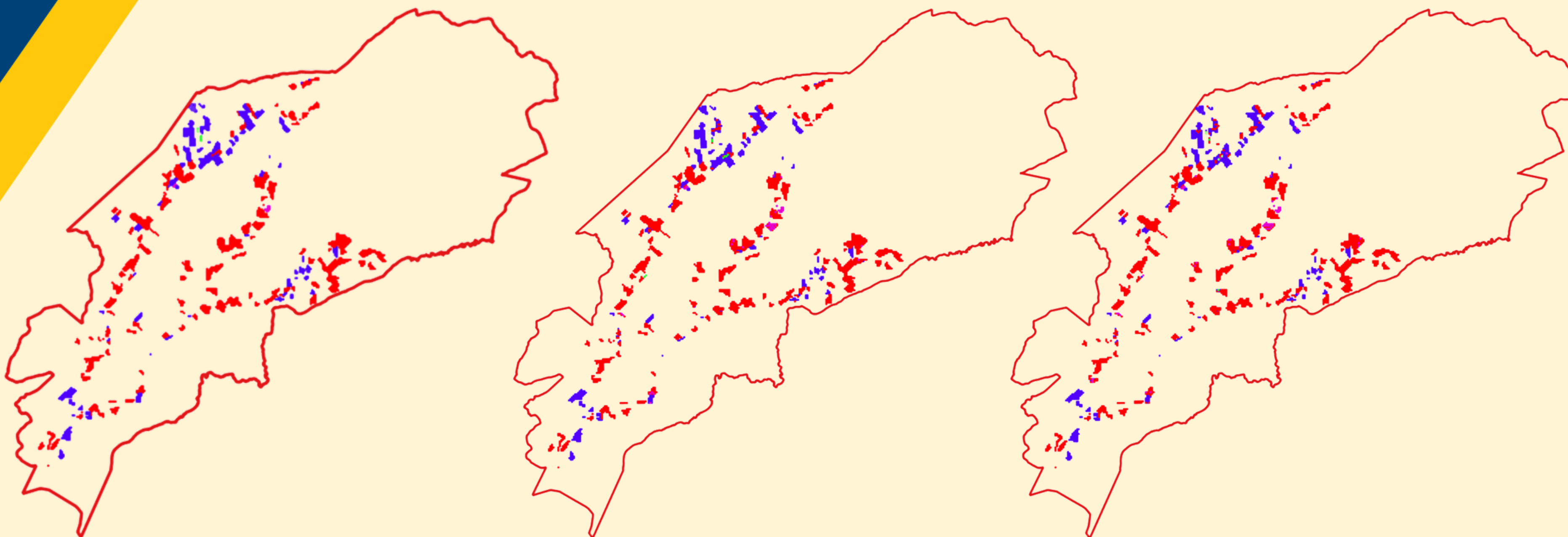


Frozen Model

Classification - 4 classes

December - Test Dataset

● Soybean ● Cotton
● Maize ● Others



Labeled Data

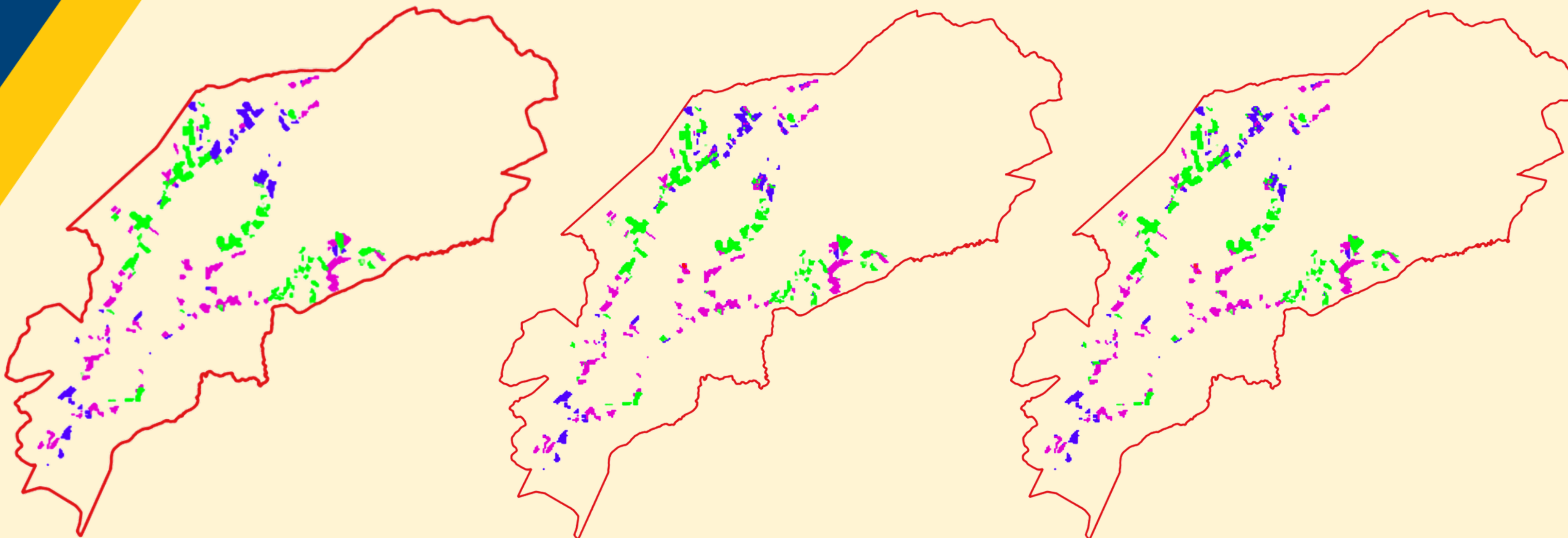
Fine-Tuning Model

Frozen Model

Classification - 4 classes

May - Test Dataset

● Soybean ● Cotton
● Maize ● Others



Labeled Data

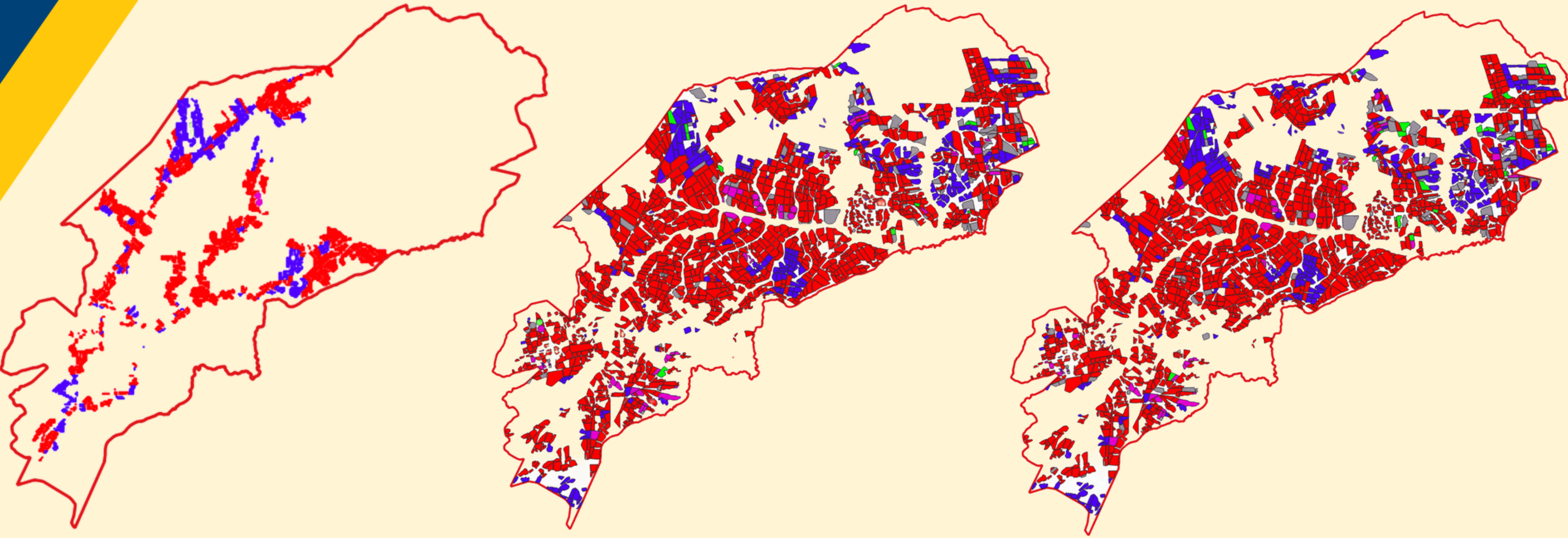
Fine-Tuning Model

Frozen Model

Classification - 4 classes

December - Generated Masks

- Soybean
- Cotton
- Maize
- Others
- Not Classified



Labeled Data

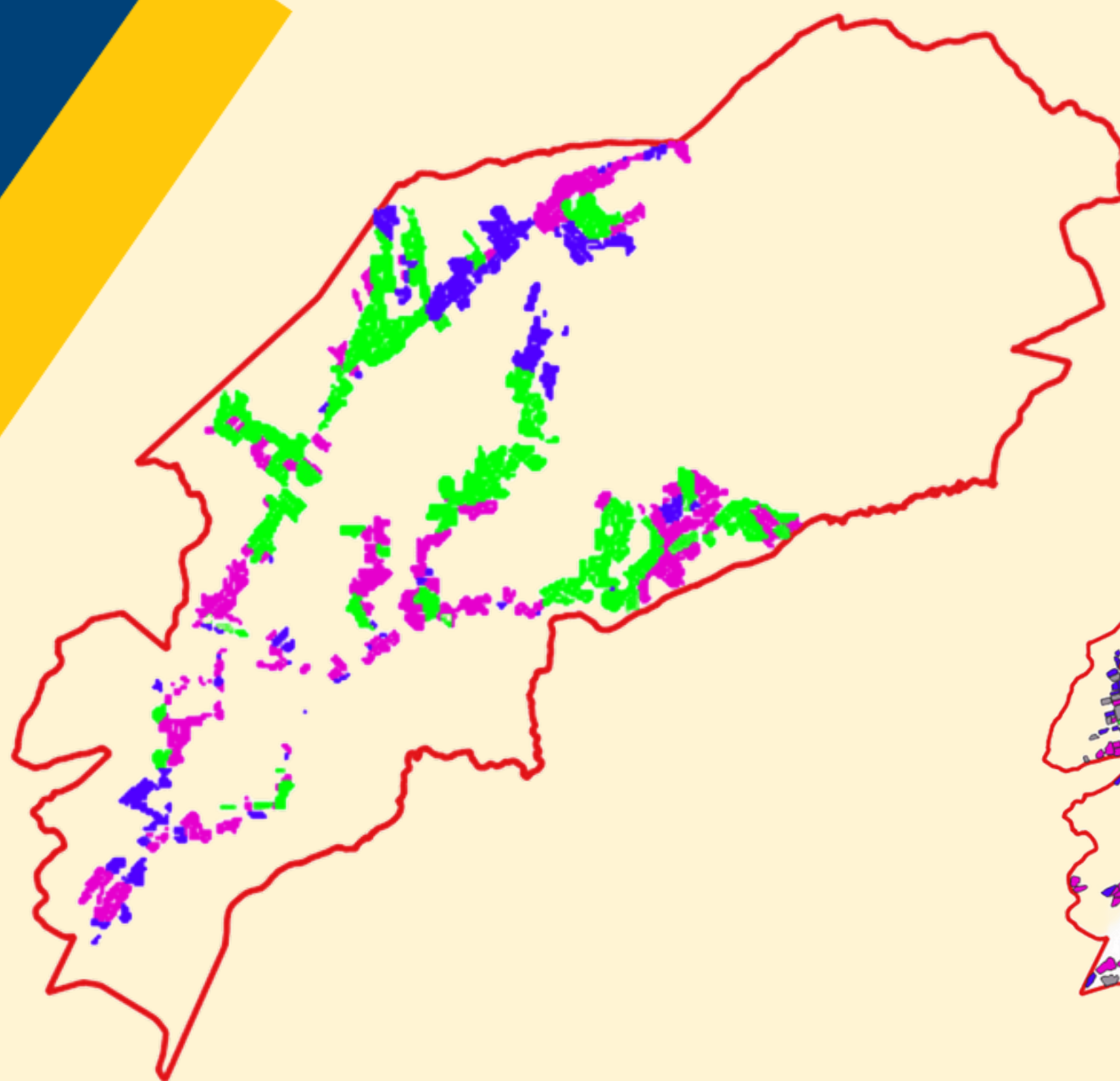
Fine-Tuning Model

Frozen Model

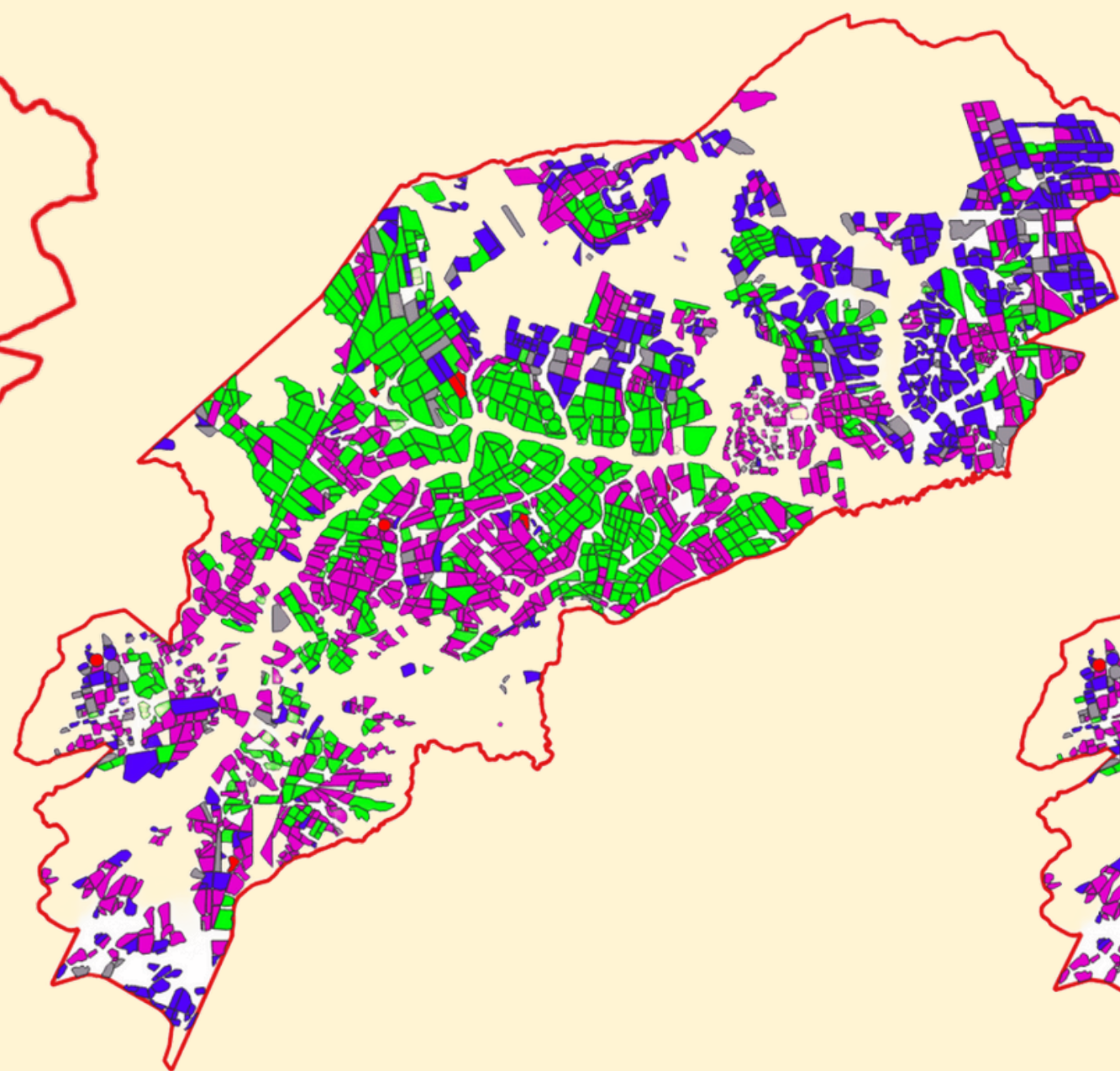
Classification - 4 classes

May - Generated Masks

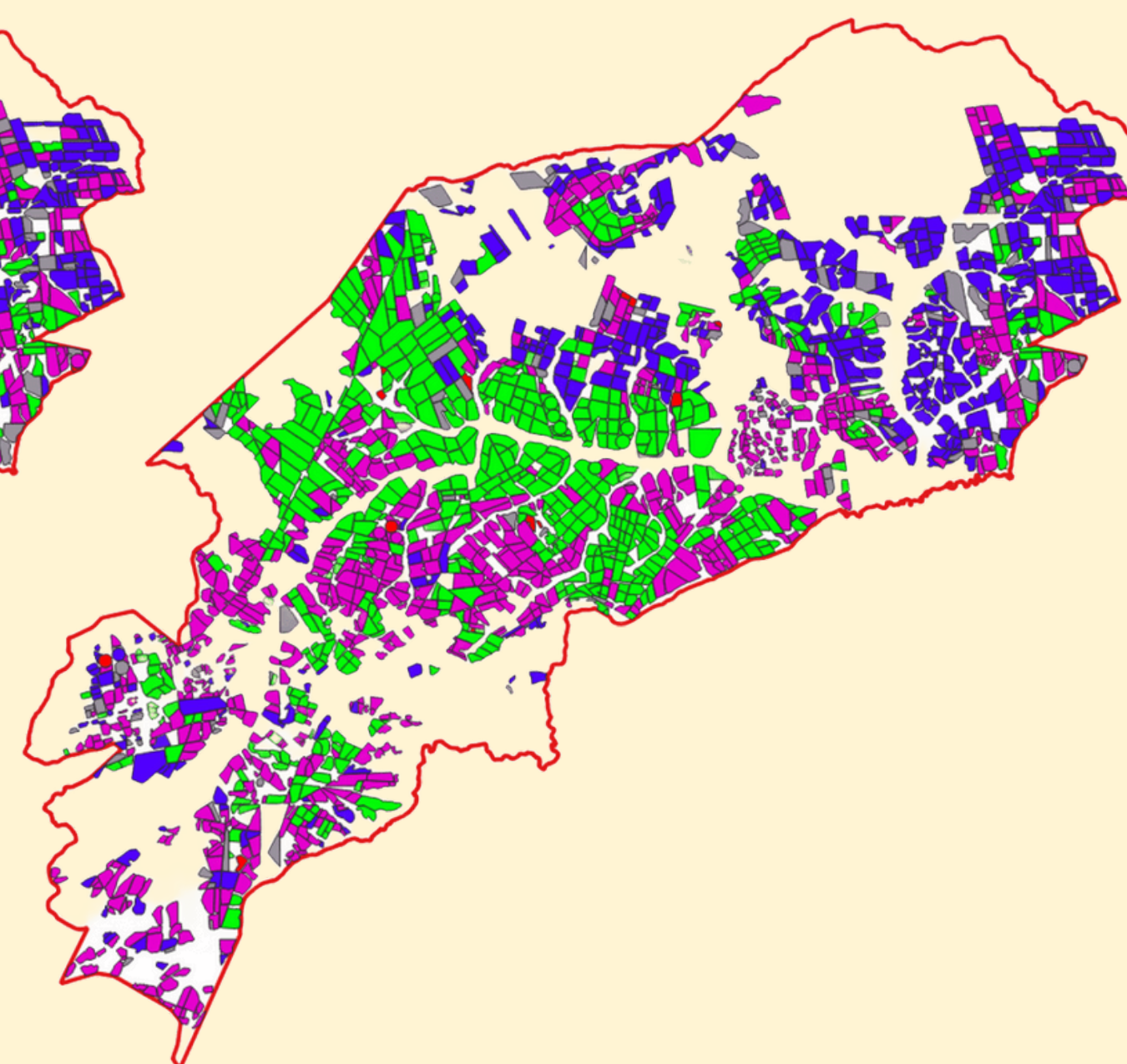
● Soybean
 ● Cotton
 ● Not Classified
● Maize
 ● Others



Labeled Data



Fine-Tuning Model



Frozen Model

Conclusion

Conclusion

- We developed a scalable algorithm for field plot segmentation
- We achieved good organization of the latent space
- We successfully addressed the problem caused by cloud coverage during harvest periods
- We reached 93.41% total accuracy in crop classification
- We classified 2189.73 km² with only 520.29 km² of labeled data
- In total, we classified 4014 crop field plots, starting with only 513 labeled field plots

Thank you! Obrigado!

Questions?



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