Temporal Analysis of Regional Sustainability Using CNNs and Satellite Data

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Motivation

We utilized public satellite data to build a deep learning classification model that describes the land use for a geographic region. Our model architecture is Resnet50 and achieves a 96% test set accuracy.

Additionally, we built a pipeline for downloading new satellite data, and introduce a methodology to quantify the biocapacity and energy footprint of a geographic region.

Dataset

We used the EuroSat dataset provided by [Helber et al](). This dataset includes 27,000 64x64 images with 10 classes that describe land use. There is an RGB version of each image, as well as version containing 13 spectral bands.

The ten classes can be split into two broad categories: Natural (forest, river, sea/lake, herbaceous vegetation) and man made (annual crop, residential, highway, industrial, pasture, permanent crop).

Models

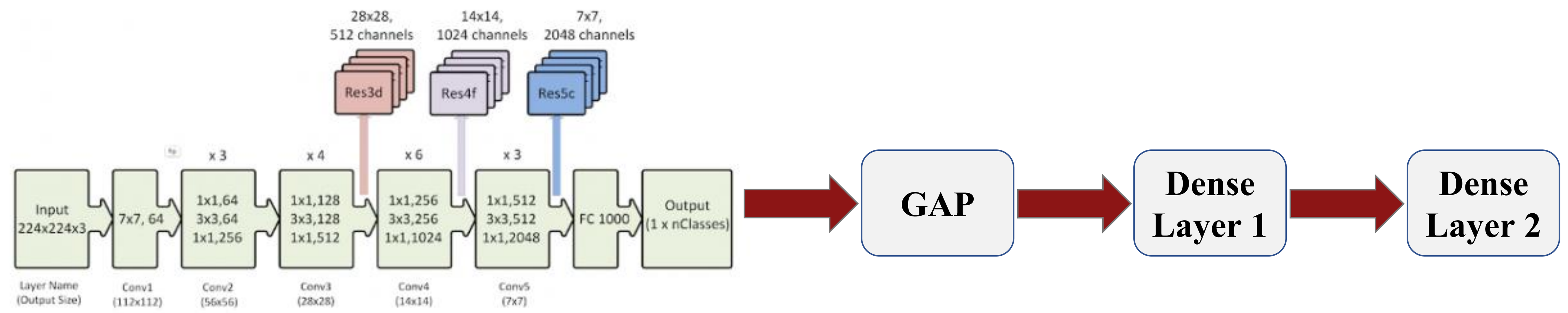
Primary Model:

- We used the **Resnet50** architecture, trained in batches of size 64 on an Nvidia Tesla v100.
- We appended the Resnet50 architecture an additional **Global Average Pooling layer**, **a Dense layer** with 1024 units, **Relu activation** and **L2 regularization**, and then final Dense layer with **softmax activation** for 10 classes.
- The model was trained with the **Adam optimizer** and learning rate of 0.0001 with the **standard categorical CrossEntropy loss**.
- **Tensorboard** was utilized for model evaluation, and **the Keras ReduceLROnPlateau callback** used to tune the optimize the learning rate.

Other Architectures:

- Using the Keras Applications module, we tried out several architectures, including VGG and DeepNet

Models



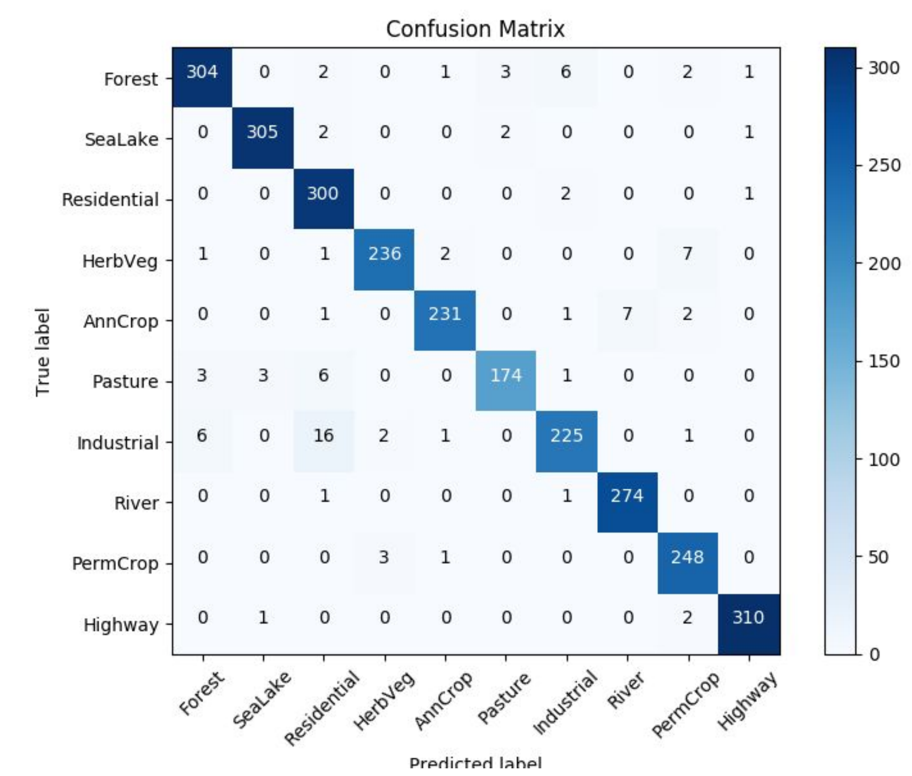
Results and Discussion

Table 1: Best Results of Different Architectures

Model Architecture	Train Accuracy	Dev Accuracy	Test Accuracy
Resnet50	0.99	0.97	0.96
VGG	0.98	0.95	0.95
DenseNet	0.99	0.96	0.97

Table 2: Precision/Recall for Dev and Test sets

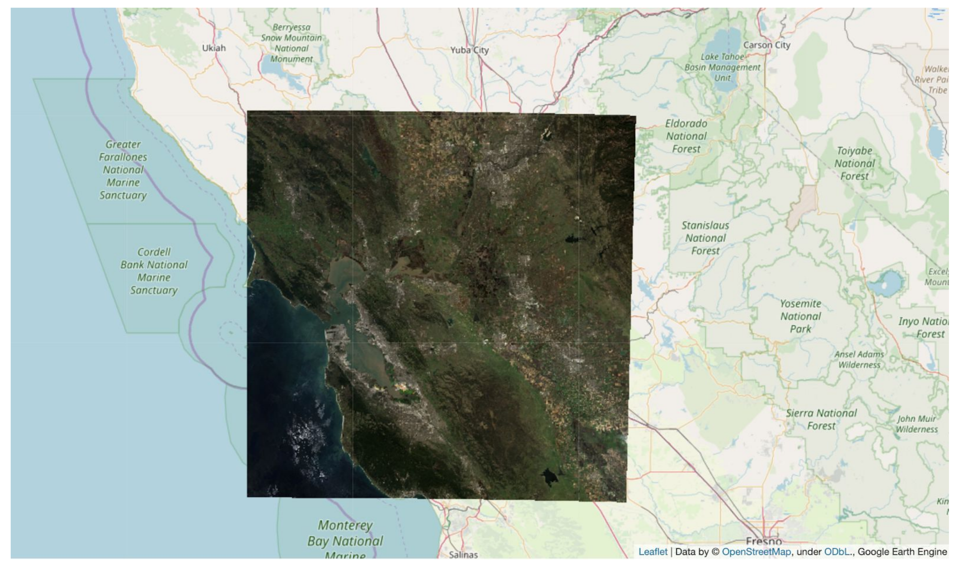
Dataset	**Macro Precision**	**Macro Recall**
Dev	0.97	0.97
Test	0.97	0.96



Application

- Sentinel has a revisit period of 2-10 days, depending on the location. That means around every week and a half, there is new imagery covering most of the world. We extracted data from two geographic regions and use our trained model to calculate their footprint.

Region 1. Bay Area, US.



Region 2. Northern Italy (Milan and Alps).

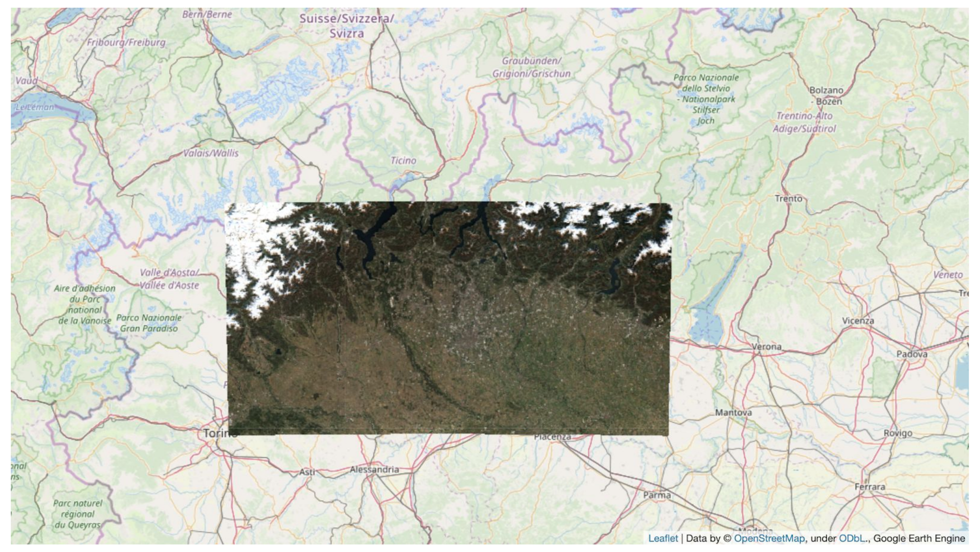


Table 3: Region 1 Label Distribution

Forest	SeaLake	Residential	HerbVeg	AnnCrop
894	4978	10024	35	1020

Pasture	Industrial	River	PermCrop	Highway
42	846	54	251	732

Table 4: Region 2 Label Distribution

Forest	SeaLake	Residential	HerbVeg	AnnCrop
2890	180	2229	74	850

Pasture	Industrial	River	PermCrop	Highway
454	3276	16	38	1

Application

- We can take the distributions from our model to apply it to Environmental Science and calculate the biocapacity of a Region as follows:

$$Biocapacity = \sum(Area(\%) * EquivalenceFactor * YieldFactor)$$

- The results of our analysis shows that the Bay Area (Region1) has a biocapacity of 2.45 g-ha/ha while Northern Italy (Region 2) has a biocapacity of 1.92 g-ha/ha.. Thus, we can conclude that the land represented by Region 1 is more biologically productive than the land in Region 2.

Future Work

- Future work would involve a more comprehensive set of evaluations including examining how the model works given different atmospheric conditions, or with cloud cover. For the application component, future work would involve a comprehensive study into the changing footprint of a city over time.

References

[1] Global Footprint Network (2019). National Footprint and Biocapacity Accounts: NFA 2019 Calculations -Equivalence Factors and Yield Factors.
[2] Kussul, N., Lavreniuk, M. , etal. (2017) Deep Learning Classification of Land Cover and Crop Types Using Remote Sensing Data, IEEE Geoscience and Remote [3] Nijhawan, R. , Joshi, D., etal. (2018) A Futuristic Deep Learning Framework Approach for Land Use-Land Cover Classification Using Remote Sensing Imagery. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE
[4] Helber, P ., (2019) EuroSAT: A Novel Dataset and Deep Learning Benchmark for Land Use and Land Cover Classification , IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing