Soil erosion detection

Solution Report

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Introduction

Soil erosion is a geological process in which the top layer of dirt (topsoil) is eroded due to strong winds, rains and flowing water. Usually it ends up in rivers or seas, and if the land was used for agriculture, it pollutes the water with the chemicals used for improving it's fertility. Topsoil is the most fertile layer of soil, so it's erosion also leaves less fertile land for food production. It is a major ecological problem.

Half of all topsoil loss has occurred in the last 50 years due to it's intensification by human activity. Farming and land clearing, overgrazing of farm animals and deforestation can leave large areas of land devoid of ground-covering plants that would otherwise hold the soil in place [1].

So, soil erosion is a major ecological problem, but it can be significantly reduced by people if the soil is taken proper care of. This task has as it's aim creating a model for identifying where soil erosion is happening using satellite imagery, which can be used to focus on the problematic areas and try to stop this harmful process before it's too late.

Analysis

We have been provided with a 10980x10980 satellite image of land, a shapefile with masks that indicate where soil erosion is happening, and files with additional specifications about the data. In order to prevent overfitting, the data was split into 128x128 images and augmented by randomly flipping some of them horizontally.

The most used and efficient models for image segmentation are fully convolutional networks. They were improved upon later by U-Net, which was developed for biomedical image segmentation. U-Net is what we'll use in this solution.

FCNs are composed of an encoder network and a decoder network. The encoder network is a CNN that takes an input and produces a feature map. The decoder network then takes it and generates a segmentation map that assigns a class label to each pixel in the input image [2].

U-Net incorporates skip connections between the decoder and the encoder networks of the FCN, which allows the network to preserve information from earlier layers and use it to make more accurate predictions, among other improvements [3].

After doing data preparation [4], including normalization and augmentation, and constructing a simple U-Net model [5], we can start training it. But there is a very important feature of our data that we have to take into account: the class distribution is highly imbalanced. The number of pixels that are masked is around 500 times smaller than the number of unmasked pixels. This is important, because a lot of common loss functions will have very low values even if the model just assigns all pixels as unmasked. That's why we have to use a loss function that assigns a much larger weight to incorrect classification of minority-class instances. In our case the classification is binary, so we can use tensorflow's tf.keras.losses.BinaryFocalCrossEntropy.

Results

We didn't have enough time to further adjust and train the model to achieve a useful state. Currently it predicts 10x less soil to erode than is actually eroding, but the model was consistently improving during the training process. With a bit more hyperparameter-tuning and data augmentation, we probably could achieve a working result. The accuracy is 99.15%, but in this case it doesn't give any useful information, because the data is so unbalanced towards non-eroding land. More details on the actual numbers and visualizations can be found in the Jupyter Notebook analysis.ipynb.

Conclusion

Soil erosion is an important ecological problem that has to be addressed. In order to address it, we have to create good models for predicting where it is happening based on satellite imagery. As was described above, the best models to use for that currently are U-Nets, and for getting useful results training the model we have to use BinaryFocalCrossEntropy, so that the model will focus on accurately predicting the minority class (the land that's eroding).

More experimentation should be done adjusting different hyperparameters of the model itself, improving data augmentation, trying using bigger layers in the model, etc. Research should be done into possible new techniques to use that might improve image segmentation models further.

Additional data can be used to improve the model's predictions. For example, climate, slope steepness and length, the soil's type, organic content, and much more [6].

References

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