An Attempt for Early Detection of Bark Beetle Infestations in Germany using Deep Learning and Sentinel-2 Time Series

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Outline

Norway Spruce (*Picea abies* L.) is among the most abundant trees in Central Europe. Due to climate change, however, these trees are increasingly threatened by the European Spruce Bark Beetle (*Ips typographus* L.; in the following: "bark beetle"). After the bark beetles have infested a tree, the filial generation of the parent beetles usually swarms out latest ten weeks after the initial attack to infest new trees. Mass outbreaks of bark beetles have led to severe ecological and economical damage in Central European forests in the last years. To estbalish an efficient bark beetle management, infested trees need to be detected and removed before emergence of the filial generation's beetles. Since terrestrial surveys are laborious, alternative methods for early detections of bark beetle infestations are in demand. One such alternative is remote sensing with satellites, as it can provide area-wide and cost-efficient forest monitoring. The detection of bark beetle infestations using remote sensing remains challenging, however, as many trees show no visible signs of the infestation within the detection period. Here, we adjust a state-of-the-art Deep Learning model to be able to cope with irregular Sentinel-2 satellite time series for reconstruction-based anomaly detection. We train the model on more than 300 000 time series of healthy coniferous forest across Central Europe and derive a threshold denoting an anomaly without prior knowledge of the time series used for testing. We test the model on a geographically distant dataset with precisely known infestation dates. The model yields moderate performance if the detection period ends 10 weeks after the infestation with Producer's Accuracy (PA) of 11.8% +/- 8.4% and User's Accuracy (UA) of 86.9% +/- 14.8%, but yields very good results when extending the detection period to 13 weeks after infestation (UA = 98.5% +/- 1.3%, PA = 81.5% +/- 1%). As the model response immediately follows an anomaly, we conclude that area-wide early bark beetle detections are likely impossible using Sentinel-2 alone. Still, our approach is suitable for near real-time monitoring of forests, can be applied on any forest disturbance detection task and might complement terrestrial surveys in future.

What challenges does the contribution address?

Currently, there is no readily applicable - let alone operational – near real-time monitoring system for early bark beetle detections in Germany. We develop a Deep Learning-based method that can be readily applied on irregular Sentinel-2 time series. Hence, it can close this gap.

How do you assess the innovation potential?

In remote sensing, we often encounter irregular time series. To the best of our knowledge, however, there is no Deep Learning-based time series anomaly detection method that has been tested on remote sensing data comprising irregular time series, yet. Consequently, the developed method/model is highly innovative, since it combines 1) a state-of-the-art Deep Learning architecture used for anomaly detection in regular time series with 2) an innovation from literature to enable Convolutional Neural Networks (CNNs) to cope with irregular time series and 3) make some additional changes to the model to work well for remote sensing time series.

In training, the model only needs healthy (in more general terms: non-anomalous) time series and does not rely on disturbed (anomalous) time series. The latter are often more difficult to acquire. Furthermore, the code of the model can be easily adjusted to work for other time series analysis tasks as well, e.g. classification and forecasting.

Which stakeholders are affected?

The main stakeholders are forest managers of any coniferous, especially Norway spruce, forest stands. As we plan to release a model version that is trained on broadleaved and mixed forest as well, the model might be interesting for any forest manager in Central Europe. Another stakeholder is the remote sensing community, since we develop a model with a broad range of applications in remote sensing.

What added value or use should be generated for the conference participants?

Upon acceptance of the paper, the code and trained models will be released for anyone to use. As stated above, we develop a deep learning model capable of anomaly detection using irregular time series, which are abundant in remote sensing. This model can be used in a multitude of applications. Besides that, our results show new directions and possibly dead ends for current research on bark beetle monitoring.

What feedback do you expect from the participants?

Since an operational roll-out of the developed model is feasible, we would like to learn if the developed model achieves sufficient performance to support the everyday work of forest practitioners.