Explainable Deep Learning for Detection of Fairy Circles

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Large barren soil circles (so-called fairy circles), up to 12 meters in diameter and visible in satellite images, are a prominent feature of semiarid landscapes around the world, including the Namib Desert, the outback of Australia, and the southwestern US. Such fairy circles are ecologically important, because fairy circles created by insects are a sensitive climate indicator. Moreover, they are global with confirmed occurrences in the Namibian grassland, Australia's desert outback, and the semiarid southwestern United States. To take advantage of this climate indicator, our long-term goal is to create a global database of fairy circles for monitoring their changes over time. Ground survey is not an option, as many of these places are hard or impossible to access. In this study, we propose a deep learning model to efficiently detect fairy circles without strongly labeled data. To tackle the current limitation that most state-of-the-art methods heavily relies on a large set of images with pixel-level labels of interest (i.e., strongly supervised data), which is time-consuming and labor-intensive, we developed a novel attention-based deep learning approach for fairy circle detection using image-level labels (i.e., weakly supervised data). The pipeline consists of (1) extracting feature maps from the backbone convolutional neural network, (2) learning multiple self-attention (SA) modules, and (3) identifying the regions associated with the target class. We enhanced the SA modules of multiple layers by using bilinear interpolation and stacked them up. We yielded significant results in localizing objects of interest. The experimental results show that fairy circles could be effectively detected by the attention-based deep learning model without strongly supervised data. We validated our model using fairy circles in Nevada and Australia's desert outback. Expressive employment of this approach in satellite imagery can improve the interpretation in various ecology applications in accordance with NASA's strategic goals.