UAV-HiRAP: A novel method to improve landscape-level vegetation classification and coverage fraction estimation with unmanned aerial vehicle platform

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Abstract:

Lightweight unmanned aerial vehicles(UAV) are revolutionizing spatial ecology and environment monitoring due to their ability to acquire high-resolution imagery and flexibility of flying time. Development of image-analyzing tools is currently challenging to extract efficiently and effectively vegetation structural and functional attributes at landscape-level in the local ecosystems with UAV platform.

In this study, we proposed a novel method with machine learning algorithm to classify vegetation and calculate the vegetation coverage fraction(VCF) on the high spatial-resolution orthomosaic generated from thousands of images acquired by UAV with structure-from-motion (SfM) computer vision technique. We validated this method with detailed ground measured datasets, including 3953 trees and 19677 shrubs in the 100 ha (1000 m×1000 m) long-term monitoring plot (115.95E, 42.96N) in Elm (*Ulmus pumila*) Sparse FOrest Grassland Ecosystem(ESFOGE-Plot), which is located in Otindag Sandy land, Inner Mongolia, China. The new method was incorporated into a user-friendly software "Unmanned Aerial Vehicles - High Resolution imagery Analysis Platform" (UAV-HiRAP), which integrated color space transformation function, classification and regression tree (CART) algorithm and parallel computing. Finally, we developed a model to optimize the workload of vegetation survey by Monte Carlo stochastic simulation based on the classified vegetation map.

Using this new method, bare sandy land, perennial plants and herbaceous plants were classified successfully on the high-resolution orthomosaic (10 cm/pixel) of ESFOGE-Plot. The VCF calculated from UAV imagery agreed well with the results estimated from the crown diameters of all individuals measured in the ground survey. The validated results showed that the coverage fractions of perennial plants calculated from UAV imagery and that estimated from ground survey have a stable linear relationship over different spatial scale (slope = 0.76, 0.77, 0.80, and 0.77, R^2 = 0.62, 0.25, 0.12 and 0.20, at 100 m×100 m, 50 m×50 m, 25 m×25 m and 12.5 m×12.5 m plot-levels, respectively; P < 0.001). Furthermore, we found the relationship between investigated quadrats number n and side length l can be described as n=727 / (l + 7) (R^2= 0.996, P<0.0001) at desired confidence level of 95%. The number and area of quadrats can be estimated from this function, which reduces workload in the field survey while preserving the accuracy and reliability required.

Our results suggest that UAV-HIRAP can be a powerful tool to classify vegetation and calculate VCF at the landscape-level with UAV platform, and demonstrate the potential of UAV to monitor vegetation in ecology and environment management.

Keywords: dryland vegetation, machine learning, sparse forest grassland, orthoimages