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Mapping and Monitoring of Biomass and Grazing in Pasture with an Unmanned Aerial System

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ANNOTATION: The tools available to farmers to manage grazed pastures and adjust forage demand to grass growth are generally rather static. Unmanned aerial systems (UASs) are interesting versatile tools that can provide relevant 3D information, such as sward height (3D structure), or even describe the physical condition of pastures through the use of spectral information. This study aimed to evaluate the potential of UAS to characterize a pasture's sward height and above-ground biomass at a very fine spatial scale. The pasture height provided by UAS products showed good agreement (R2 = 0.62) with a reference terrestrial light detection and ranging (LiDAR) dataset. We tested the ability of UAS imagery to model pasture biomass based on three different combinations: UAS sward height, UAS sward multispectral reflectance/vegetation indices, and a combination of both UAS data types.

KEY WORDS: unmanned aerial vehicles; unmanned aerial systems; drone; precision grazing; pasture biomass modeling.

INTRODUCTION: Grasslands cover 26% of the world's total land area and 69% of the agricultural area and are the least expensive way to feed ruminants, such as cattle reared for milk or meat production [1]. In the European Union, permanent pastures and meadows occupy 34% of the utilized agricultural area. A significant share of the cultivated fields include temporary pastures in their rotation [2]. Grazed pastures benefit the sustainability of dairy production in multiple ways, such as lower feeding costs [3], higher animal welfare and a lower occurrence of lameness and mastitis, good public image, and increased milk quality [4]. In addition, grasslands have an important role in the provision of social and environmental services [5].

The selection of an adequate choice of diverse grass and legume species and varieties with adequate management could also support the growth of a wider range of micro-fauna and crop auxiliaries. Finally, pastures could play a significant role in trapping atmospheric CO2 through soil carbon sequestration [6].

Managing pastures through direct grazing is not an easy task, as it requires combining actions to allow the dynamic growth of multispecies grassland vegetation while managing animals that consume it selectively and non-homogeneously. The plant and the animal components of the grazed pasture system have mutual influences in addition to the influences of environmental factors. Both components also have different biological dynamics. Unfortunately, the tools available to farmers to manage grazed pastures and adjust forage demand to grass growth are generally rather static, for example, the use of stocking rates, fences, grazing pressure, resting times, locations of water troughs, locations of salt licks, fertilization, and irrigation [7]. The application of precision livestock farming to grazing has the potential to promote more dynamic management of ruminants on grasslands by switching from management at the herd level to the management of each individual on the pasture. In the past decade, several works have demonstrated how the development in sensors and information technology can be used to improve the monitoring of grazing animals, especially cattle [8–11]. Monitoring the grazing process to the finest scale, namely at the consumption level, in space and time is now possible [8], and the development of such technology as a research tool is likely to enter farms progressively as a complement to virtual fences [12]. In

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addition to the monitoring of individual grazing animals, improvements in the monitoring of the grazed vegetation are also called for. French et al. [12] presented a rising plate meter that automatically communicates the pasture height and biomass data to a geographic information system (GIS). Other techniques, such as satellite-based remote-sensing [13] and on-field 2-D and 3D-cameras, have been used to measure photosynthetic activity and forage height [14] or to identify weeds in grasslands [15]. Handcock et al. [16] proposed combining satellite remote sensing and collar-based georeferenced information to characterize animal behavior and environmental interactions. Even though the accessibility and the spatial resolution of satellite imagery are continuously improving, generally, they are too coarse to describe pastures at the scale of individual animals on the pasture. On the other hand, field-based remote sensing methods, such as terrestrial light detection and ranging (LiDAR), allow for the fine 3D characterization of vegetation structure [17].

LiDAR technology was also successfully combined with a vegetation index (normalized difference vegetation index, NDVI) by Schaeffer and Lamb [18] to estimate the standing biomass on tall fescue pastures. Nevertheless, terrestrial remote sensing remains spatially limited. At the interface of satellite-based remote sensing and on-field approaches, unmanned aerial systems (UASs) can cover substantial areas (>10 ha in a single flight), providing imagery at a very high spatial resolution (data (digital surface model in case of aerial survey) to be derived from overlapping images acquired with consumer-grade digital cameras. In the agricultural field, SFM photogrammetry can be used to derive the crop surface/height model (CSM/CHM) from UAS imagery at very low cost compared to LiDAR. In the context of precision grazing, pioneer studies [29,30] have demonstrated the quality of height and biomass information derived from the UAS.

However, these previous studies have mostly focused on ungrazed, experimental pastures while leaving open the question of monitoring grazing through the use of a multi-temporal approach. Such approaches are needed to develop innovative tools to provide quick responses to allow the adaptation of grazing schedules or other decision-making tools for farmers. Pastures should be consumed by animals when they display a specific structure that is principally defined by height and density, ensuring the removal of only grass leaves during bites [31]. Pasture height information is very important for farmers to maximize the intake rate of animals.

However, such measurements are still taken using low frequency and time-consuming instruments, notably sward-sticks or rising plate meters [14]. The use of UAS imagery could be a solution to provide higher frequency, higher spatial resolution, and more precise information about the biomass productivity of a pasture. In this context, this study aimed to evaluate the potential of UAS as a tool for the characterization of pasture 3D structure (sward height) and above-ground biomass at a very fine spatial scale. More specifically, it evaluated the suitability of UAS for monitoring sward height differences and pasture biomass. Based on the hypothesis that UAS products (e.g., sward height model and orthophotos mosaic) can reflect the pasture biomass and sward height multi-temporal differences, this approach investigated the potential of UASs to monitor grazing at the feeding station level.

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