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Developing a coherent monitoring system for Mediterranean grasslands

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Abstract. Grasslands are one of the world's most widespread vegetation types, covering nearly 20% of the land surface and represent a major source of production of agricultural products. However, grassland vegetation across the Mediterranean region is changing at an unanticipated rate. These changes are the result of climatic and socio-economic changes. Because changes in agro-ecosystems affect the livelihoods and development of rural communities, it is important that planners and policy makers be able to determine grassland condition and trend in relation to climatic and managerial factors at specific locations. Over the past decade we have been developing monitoring technologies and protocols that can be used at local scales which speed the collection, processing, and storage of indicators of grassland health. By coupling digital photography, GPS technologies, information collected with accessory devices, and computer software applied in a strict monitoring protocol, we are able to rapidly monitor grassland vegetation. Repeated measurements over time at the same locations provide information regarding environmental trend and rate of change. When we couple our local scale measurements with landscape scale remote sensing data such as satellite or high altitude aerial photography, we have a more complete picture of vegetation dynamics and system change which facilitates interpretation and development of mitigation strategies.

Keywords. Remote sensing – Vegetation dynamics – VegMeasure software – Image processing.

Développement d'un système de surveillance cohérent pour les pâturages méditerranéens

Résumé. *Couvrant environ 20% de la superficie terrestre, les formations végétales herbacées constituent le type de végétation le plus répandu dans le monde. Dans la région méditerranéenne, ce type de végétation est toutefois, en train de subir des changements quantitatifs et qualitatifs rapides résultant de facteurs d'origine climatique et anthropique. Puisque les changements dans les agro-écosystèmes influent sur les moyens de subsistance des communautés rurales, il est important que les gestionnaires et les décideurs soient en mesure de déterminer l'état des pâturages et la tendance par rapport aux facteurs climatiques et de gestion à des endroits précis. Au cours de la dernière décennie, nous avons mis au point des technologies de surveillance et des protocoles qui sont plus efficaces que les techniques traditionnelles. En combinant la photographie numérique, les technologies GPS, et les logiciels personnalisés et en suivant un protocole bien définit, nous sommes en mesure de surveiller la végétation avec une très haute précision. Ces mesures répétées aux mêmes endroits fournissent des informations utiles sur la tendance écologique ainsi que les variations inter-annuelles. Une image plus complète de la dynamique de la végétation et l'évolution du système pourrait être obtenue après association des données à l'échelle locale avec des données de télédétection par satellite telle que la photographie à haute altitude ou aérienne. Ceci facilitera l'interprétation et le développement de stratégies de mitigation.*

Mots-clés. *Télédétection – Dynamique de la végétation – Logicielle VegMeasure – Traitement des images.*

I – Introduction

Slowing grassland degradation remains an enormous challenge with concomitant social, environmental, and economic implications. Natural resource managers and ecosystem engineers are often called upon to evaluate the effects of their actions and thus are required to document changes in plant communities (Greig-Smith, 1983). Plant cover is one of the fundamental quantitative parameters measured by botanists. Cover is ecologically important because plant leaves and branches protect the soil from the damaging effects of heavy rainfall and reduce soil erosion. Agronomists, ecologists, and range scientists usually express cover as the percentage of the ground surface that is occupied by the plant crown or shoot area when it is projected vertically downward. Cover is easier to measure than biomass and if one also acquires measurements of plant height and the stratification within the vertical profile, it can be used to predict biomass. One technique that has been used in conjunction with traditional cover measurements is photographic monitoring (Bennett *et al.*, 2000).

Development of vegetation sampling protocols requires careful assessment of management goals in relation to benefits received from sampling efforts. Traditionally ecologists have employed quadrats that are sampled for plant cover, aboveground biomass, and density (Barbour *et al.*, 1987; Hill *et al.*, 2005). Also of importance is the cover of litter and percent of bare ground exposed to the erosive impact of rain. Parameters that involve cover are typically recorded by field personnel using field sampling techniques that are based on visual estimates. Advances in electronic technology have created new opportunities for vegetation and ecosystem monitoring.

II – Materials and methods

1. Apparatus

A digital charting apparatus was composed of a GPS data logger, a bubble level, and compass mounted on a wooden platform attached to a Bogen-Manfrotto 3025 3D Junior Tripod Head. The head is attached to a monopod and a digital camera as shown in Fig. 1. The camera is set at a fixed focal length and the head adjusted so the base of the monopod is just out of the field of view. The monopod is set at a fixed length so the camera is held at the same height above the ground for all photos. This setup allows the user to position the camera in a cardinal direction, in a hori-

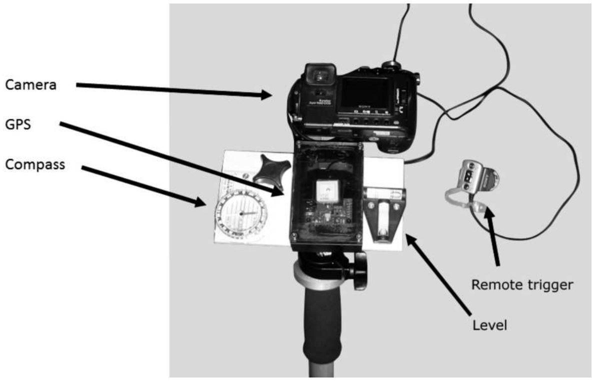

Fig. 1. This figure shows the digital charting apparatus used in this study. It consists of a digital camera mounted on a Bogen-Manfrotto 3025 3D Junior Tripod Head that positions the camera pointed vertically downward from a fixed height. The compass allows us to have the top of the camera pointed southward for each image.

zontal plane at a fixed height above the ground (Booth *et al*., 2004). We use a continuously recording GPS unit that tracks the position of the camera at 1 second intervals throughout the day.

Before we collect data in the field, we synchronize the time on the digital camera with GPS time using a hand-held GPS. Each morning before we collect data, we also take a photograph of either the hand-held GPS unit that shows the date and time or a computer screen with a master clock so any deviation of the camera time can be determined or camera time offset from GPS time corrected for. The entire apparatus allows us to know the position (latitude, longitude, and elevation) of the camera when a photograph was taken and to know the directional orientation of the image. The first photo in the field has a ruler in it so we can determine the size of each photographic pixel on the ground and scale the image.

Fig. 2. The digital charting apparatus is being used in the field. Once the height of the monopod has been set it remains at that height for the sampling session. Because we work in the northern hemisphere, we usually point the camera due south which reduces shadow in the image.

Images can be positioned and tagged with geographic coordinates with the GeoAlbum software package. This program automatically assigns coordinates, rotates the image, and sets the pixel dimensions for each image. In addition it creates a world file so they can be opened and positioned in Geographic Information Systems (GIS) programs such as ArcGIS, ERDAS, or Global Mapper (Louhaichi *et al.,* 2010). As informative as photographs are, most scientists and managers would like to be able to extract quantitative measurements from the images (Louhaichi *et al*., 2001). Once they are positioned and scaled they can be used as maps and distances between points or surface areas calculated. This has been used to determine spacing between plants in desert areas and to calculate the canopy cover of shrubs.

2. Image processing

If vegetative cover is desired, image processing programs such as ERDAS Imagine®, ENVI®, VegMeasure 2®, Sample Point®, and others. We built VegMeasure2 to rapidly calculate the cover of large numbers of images quickly (Preuss *et al.,* 2012). It was originally designed to estimate the cover of green leaves, litter, and soil in digital images (Fig. 3).

III – Results and discussion

Digital charting using the apparatus and software described in this paper can rapidly collect detailed plot-level information on grassland systems that are tagged with the location, date and time. On our sagebrush grassland studies, a team of 4 trained technicians equipped with staff-mounted cameras have taken as many as 1600 geo-referenced sample images in a day. Landscapes are therefore more intensely sampled and internal variation in the system more accurately portrayed. We often couple digital charting with traditional sampling on a subset of the sample plots so we have reference values that can be compared and errors estimated. Office time on the computer can be greater but that is generally because more samples were taken.

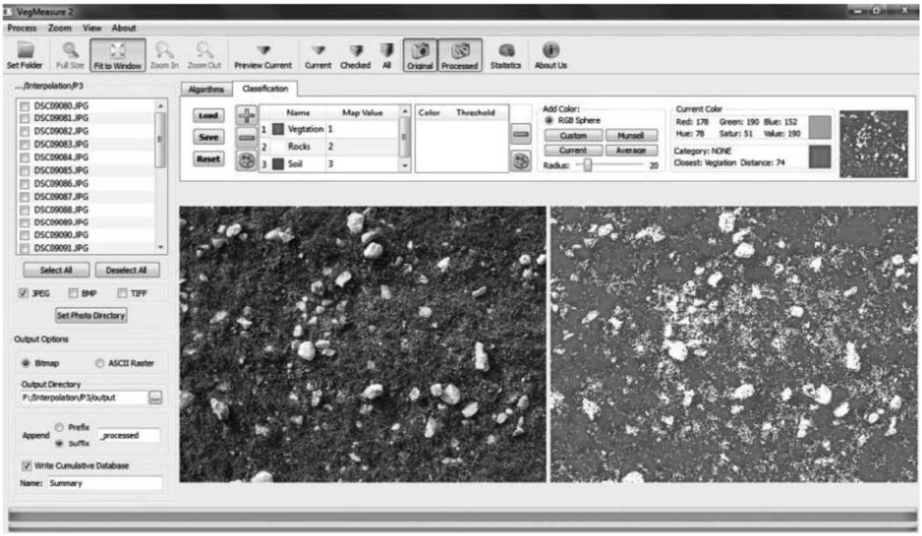

Fig. 3. This is a screen capture from VegMeasure 2 showing the classification of green leaf, rocks and soil in the digital image on the left. Each pixel in the classified image on the right has been assigned to one of these classes and colored appropriately, green for green vegetation, brown for soil, and white for rock. After the image has been classified the number of pixels in each class is counted, the surface area calculated and the relative percentage of each reported.

We suggest that with appropriately designed sampling strategies are employed using sound statistical protocols; a coherent representation of grassland ecosystem can be obtained. Because geo-referenced images can be stored on computer hard drives or optical disc storage formats (CD and DVD), storage and transfer of information is relatively easy. Once images are gathered and processed, trained botanists and vegetation ecologist find a wealth of information about conditions on the site at that point in time. Field tests of data collected using digital charting techniques compare favourably with traditional sampling.

Geo-positioned vector data (single images) would then be interpolated in GIS environment to create a raster image (Fig. 4). Repeated measurements of transects or permanent plots can be used to monitor change that results from variable weather as well as climate change. We have followed permanently positioned plots for six years and been able to document both declining and increasing plant species. It is simpler to monitor distinct, broadleaf species, but individual, perennial, bunch grasses can also be followed.

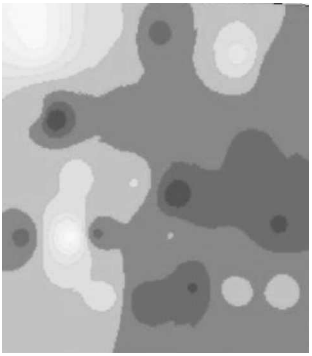

Fig. 4. Raster image generated through interpolation of vector data, greener (darker) areas have more vegetation cover.

IV – Conclusions

The overarching goal of digital charting of vegetation is to enhance our understanding of and ability to quantitative measure the condition and change in grasslands. The monitoring system evaluated in this study represents a quick and inexpensive way to obtain quantitative ground cover estimates of grasslands, while providing a temporal record of ground cover conditions. Digital photography does not require any specialized equipment and can be obtained quickly by a single person. The method also allows for the standardization of ground cover estimates between sites, something that cannot be accomplished when using visual estimates.

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