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# Digital Charting Technique for Monitoring Rangeland Vegetation Cover at Local Scale

MOUNIR LOUHAICHI[1], MICHAEL D. JOHNSON†, ADELE L. WOERZ‡, ABDUL WAHID JASRA¶ AND DOUGLAS E. JOHNSON‡
*International Center for Agricultural Research in the Dry Areas (ICARDA) Aleppo, Syria*
†*Department of Physics, University of California/Santa Barbara, Santa Barbara, CA, USA*
‡*Department of Rangeland Ecology and Management, Oregon State University, Corvallis, OR, USA*
¶*ICARDA, Dubai, United Arab Emirates*
[1]Corresponding author's e-mail: M.Louhaichi@cgiar.org

## ABSTRACT

Changes in agro-pastoral production systems affect the livelihoods and development of rural communities. Thus it is important for planners and policy makers to be able to document land or ecosystem conditions and trends in relation to managerial actions at specific locations. Quantification of ecosystem parameters that are used for condition and trend assessment has been difficult, time consuming and expensive resulting in very few locations worldwide with detailed records. We report monitoring techniques that can be used at local scales, to speed up the collection, processing and storage of indicators of agro-ecosystem health. By coupling digital photography, differential global positioning systems technologies, information collected with accessory devices and computer software applied in a strict monitoring protocol enabled rapid sampling and recording geographic position (latitude/longitude) of quadrates (1 to 25 m$^2$) with vegetation, litter and soil parameters. If vegetative species are visually distinctive, plants can also be identified. Repeated measurements over time at the same locations provide information regarding environmental trend and rate of change. Coupling our local scale measurements with landscape scale remote sensing data such as satellite or high altitude aerial photography, we have a complete picture of vegetation dynamics and system change, which facilitates interpretation. 

**Key Words:** Digital charting; Bare ground; Vegetation cover; Arid land; Image processing

## INTRODUCTION

Ecologists and natural resource managers are often called upon to evaluate the effects of their actions and thus are required to document changes in plant communities (Greig-Smith, 1983; Chaichi *et al*., 2005). They typically want to know whether plant communities are progressing towards a desired goal or regressing. Development of vegetation sampling protocol requires careful assessment of management goals in relation to benefits received from sampling efforts. Traditionally ecologists have employed a laborious technique of quadrates sampling for plant cover, aboveground biomass and density (Barbour *et al*., 1987; Cox, 1990; Hill *et al.*, 2005; Louhaichi *et al*., 2009). 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 (Bureau of Land Management, 1996; Magill, 1989). The Daubenmire quadrate, for example, is painted in patterns that facilitate estimates of 5%, 25%, 50%, 75%, 95% and 100% coverage (Daubenmire, 1959 & 1970). However in a statistical context credible documentation requires not only careful examination of sampled material in each quadrate but asks for large number of quadrates to be sampled. Furthermore traditional sampling techniques for monitoring changes in rangeland vegetation cover are subjective, costly and destructive.

Attempts in using photography for measuring cover through film camera or automated digital image analysis are numerous (Booth *et al*., 2004; Rico-García *et al*., 2009). Louhaichi *et al*. (2001) mounted a 35-mm film camera, pointed vertically downward 1.7 m above the ground, on a lightweight platform of polyvinyl chloride (PVC) tubing to monitor forbs' dynamics in dry areas. A 1 m$^2$ frame was central in the photograph, which provided an estimate of scale. In recent years, digital photography is becoming a common and affordable means for the scientific community to document and present images. High-resolution digital images are useful for several types of data gathering and have proven to be a quick and accurate means for vegetation classification (Bennett *et al.*, 2000; Luscier *et al*., 2006). Remote sensing data, in conjunction with image analysis software, are being used to quantify vegetation canopy cover in rangelands (Louhaichi *et al.* 2006a). Recently, digital image analysis was used to map slick spot dynamics

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with increased precision over more traditional evaluation methods (Louhaichi *et al.*, 2006b; 2007; Blanco *et al*., 2008; Kennedy *et al*., 2009; Lisandro *et al*., 2009).

For several years digital cameras are being assessed to quantify vegetation by continuously recorded differential global positioning station (DGPS) positions and computer analysis, because photographic records of plots or experimental sites can be a simple, rapid and cost effective alternative to aerial photos. Photo points are obtained with a hand held camera from an elevated position (Hacker *et al*., 1990; Borman, 1995; Booth *et al*., 2006). Digital cameras record the date and time when photographs are taken to the nearest second. DGPS receivers record the location of the antenna and time with great accuracy and if a continuously recording DGPS is coupled with a digital camera, thus we can know the time, position and camera settings of photograph. The image can be rotated and geographically registered to make it a map and colors in the image can be interpreted by humans or a computer algorithm to make meaningful classes. With this registered digital image, measurements of objects in the photo can be quantified and information can be stored in digital format.

The current research builds on the preliminary work by the department of Rangeland Ecology and Management at Oregon State University, OR, USA (Louhaichi *et al.*, 2001; Borman *et al.*, 2002), who developed new methodology for assessing the impact of grazing on crops by integrating high spatial-temporal resolution remote sensing (platform photography) and GIS combined with a rigorous, repeated ground-truthing data collection (Johnson *et al*., 2008; 2009).

The objectives of the study were to (a) design and build a photographic staff that holds a digital camera, compass and level so raw images can be obtained with the proper ancillary information, (b) develop software to position, rotate and register the images and save them in a global bitmap format and (c) design and program software to rapidly classify the images into green leaves, litter and soil or into other meaningful classes.

## MATERIALS AND METHODS

**Digital vegetation charting:** A digital charting apparatus was assembled together, which consisted of a Bogen-Manfrotto 681B Professional Aluminum Monopod and B3025 3D Junior Head, camera capable of obtaining RAW format digital imagery and a platform fixed parallel to the image sensor containing a continuously recording DGPS, compass and level (Fig. 1). Both digital color and digital infrared cameras can be used. The DGPS receiver's clock is extremely accurate since it synchronizes with the atomic clocks embedded within the satellites. Thus camera's clock needs to be synchronized with the DGPS clocks. The camera clock is usually set to local time and the DGPS clock is set to universal time. The camera time offset from universal time is determined by photographing a computer screen showing the official Greenwich Mean Time (GMT; accessible at http://wwp.greenwichmeantime.com). Having known offset from camera time, the position of camera during the photo shoot can be determined. Depending on the canopy vegetation cover including herbaceous, dwarf and tall shrubs, the monopod height above the ground can be adjusted. Depending on the height of the camera above ground, the zoom function (wide angle) and the focal length of the camera, the surface area covered can extend from 1 to 25 $m^2$. Taller vegetation required higher camera position to reduce distortion in the image and we used pole-mounted cameras that were triggered using radio-controlled servos. During field data collection, we routinely switched between oblique images (beginning transect line) and vertically downward images (Fig. 2).

**Image synchronization:** Synchronization between image data and location information was accomplished using GeoAlbum®, a software developed by Global Geomatic Solutions (Johnson *et al.*, 2007). For each separate project or field assignment, it is best to store all the images and the GPS data in the same directory. DGPS data was loaded into the program as either comma delineated value (CSV) files with a text header in each column, a shape-file, or as native National Marine Electronics Association (NMEA) data string text files. In order to geo-position the images, several steps were involved in the process: (1) determination of the global position of the camera when the photograph was taken, (2) conversion of RAW images into a standard 24-bit BMP format, (3) rotation of the image so that north was to the top, (4) scale the image, (5) generation of projection and world files so the image was viewed correctly in a GIS program, (6) tagging the image with important information in an associated information file and (7) storage of the original image, processed image and associated information in digital format (Fig. 3).

## RESULTS AND DISCUSSION

Output from the program was either a single database or associated information files with the same name as the photo but with an info file extension. The information files were in American Standard Code for Information Interchange (ASCII) text and contained latitude, longitude, elevation, date and time of the camera when the photo was taken. New images can also be output in a referenced global bitmap format. A collar was created above and below the image with pertinent information such as project name, position, date, time etc. (Fig. 4). World files are not generated for oblique or landscape photos but they can still be accompanied with information files or positioned information burned into a collar. Output photographs with world and projection files were successfully opened in most GIS programs and maintained spatial fidelity.

Output from the program also included a point map superimposed on a blank background, a digital ortho-photographic quadrangle map or a USGS digital raster

**Fig. 1: The camera-staff setup used to collect spatially explicit digital photographs of vegetation, It consists of a digital camera, GPS tracker, compass and level, all attached to a monopod**

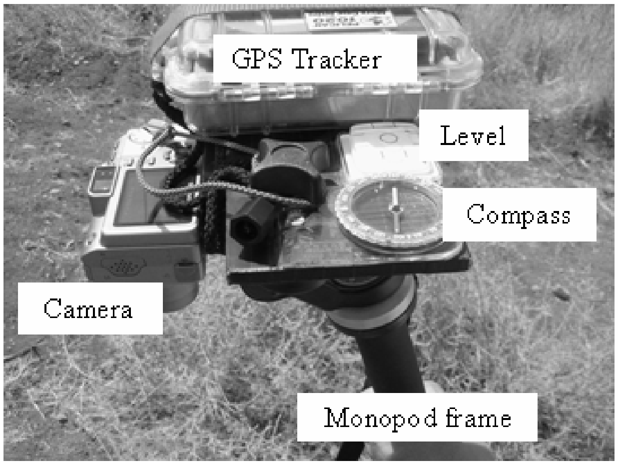



**Fig. 2: Both oblique (top) and vertically downward (bottom) images are taken in the field with the staff mounted digital cameras**

graphics map downloaded from the TerraServer website http://terraserver-usa.com. Images were labeled with data from the information files, marker size adjusted and resulting images exported for use in other programs. The data viewer was used for previewing images in relation to

**Fig. 3: Images were imported into Geo-Album and linked to the GPS file. The camera clock was synchronized to the DGPS clock and true time was specified. Photo locations were assigned the closest point or positions were interpolated between the closest DGPS points**

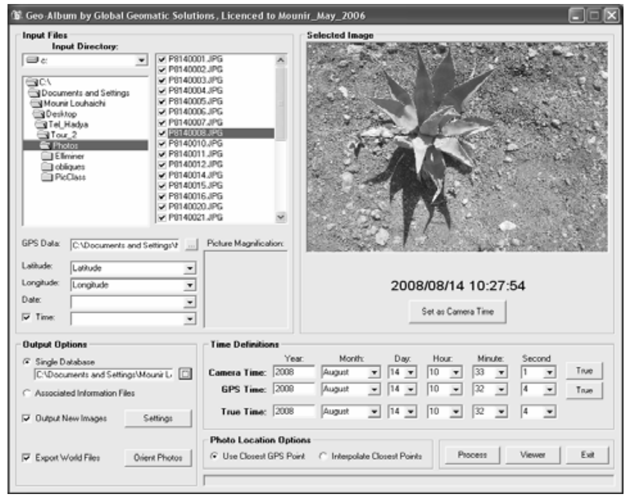



**Fig. 4: Collared image showing the date, local time and GMT of when the image was taken (top) and easting and northing coordinates of its exact location (bottom)**

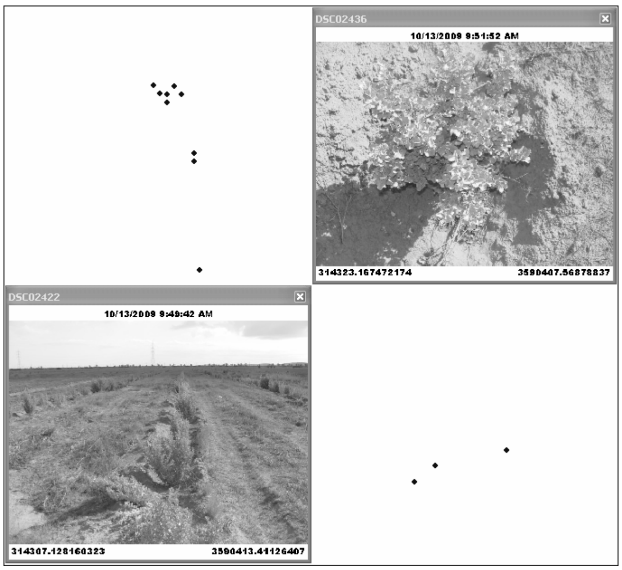

their position on the landscape and examining the distribution of the photographic samples (Fig. 5). Comparison of ground or vegetative condition was facilitated with the viewer.

Johnson *et al*. (1998) and Louhaichi *et al*. (2001) have developed an algorithm based on the red, green and blue bands of color photography. The information contained in a digital image includes the amount of red, green and blue (RGB) light emitted for each pixel in the image. Thus the digital numbers of each pixel were ratioed resulting in a Boolean image, where green leaf was classified as cover and soil as non-living. The algorithm was later automated and compiled into non-commercial software named VegMeasure® version 1.6 (Johnson *et al*., 2003) More

**Table I: Summary output of classified images along with GPS coordinates where each image was taken. The cover occupied by each class is in percent**

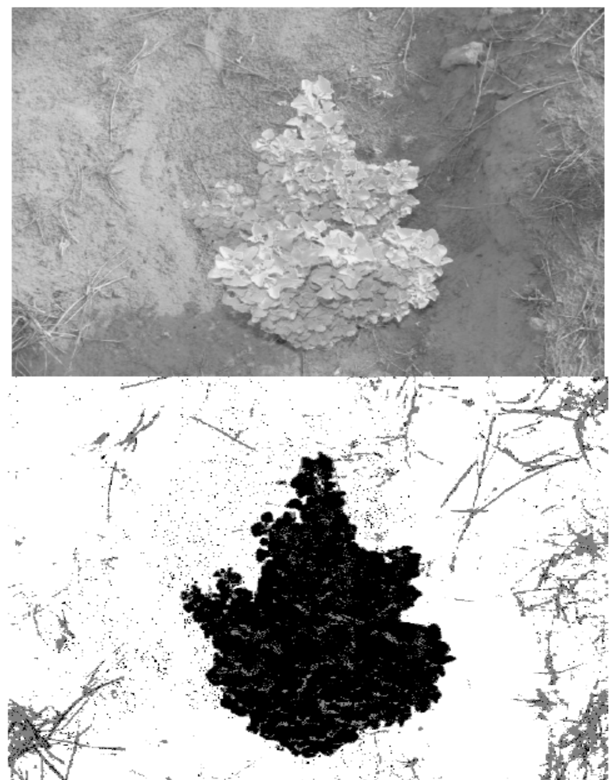
| Longitude | Latitude | Image Name | *Atriples nummularia* | Soil | Litter | Unclassified |
|---|---|---|---|---|---|---|
| 36.9412 | 36.0227 | DSC02423.JPG | 32 | 57.7 | 7.2 | 3.1 |
| 36.9417 | 36.0227 | DSC02424.JPG | 12.9 | 78 | 6.6 | 2.5 |
| 36.9550 | 36.0249 | DSC02425.JPG | 8.5 | 86.3 | 4.3 | 0.9 |
| 36.9449 | 36.0230 | DSC02426.JPG | 65 | 27.8 | 5.1 | 2.1 |
| 36.9423 | 36.0227 | DSC02427.JPG | 17.6 | 74.8 | 6.4 | 1.2 |

**Fig. 5: Position of each photograph can be plotted on the screen, If a point is selected by clicking it, the image will open in a new window**




recently a new version of VegMeasure® (version 2.0) has been developed. This version allows users to define meaningful categories for an image and select pixels on the screen that represented each classification (Fig. 5). As pixels were selected and added to the category, the color space of the class was defined. The user can also set the threshold distance from the defined colors in each class that will be assigned to that category. If the Digital Picture Info box is selected, the pixel under the cursor will be classified and the group and the distance to the color will be identified on the lower right side of the control panel. Once the Analyst is satisfied with the categories the image is classified, classification parameters (settings) can be saved and applied to other images taken in similar vegetation under similar light conditions. Using this setup, we were able to rapidly record the geographic position (latitude/longitude) of quadrates and to classify bare ground, litter and green foliage, where three distinct classes were identified (Table I; Fig. 6). The percent cover of *Atriplex nummularia* (black), soil or bare ground (white) and litter (gray) was estimated based on the number of pixels each class occupy. In addition to characterizing spatial distribution of vegetation, the approach described here has utility for monitoring short and long-term change in plant communities (Crimmins & Crimmins, 2008).

**Fig. 6: Original image of *Capparis spinosa* L. (top) taken using the digital vegetation charting apparatus. The image was imported into VegMeasure to be analyzed and interpreted for green leaves, litter and soil (bottom)**



| Class name | Color |
|---|---|
| *Atriplex nummularia* | (black) |
| Soil | (white) |
| Litter | (gray) |

Output from the program consists of: (1) a classified digital bitmap image with colors assigned to each class by the Analyst, (2) an ASCII raster classification map with class numbers as cell values, an information file with the number of pixels in each classification and if desired, the settings used for the classification and (3) a summary table with results of the classification for each image (Fig. 6). Up to 60 photo quadrates per hour can be taken. Processing time to rotate and assign coordinates takes about 20 min and time for image classification is variable and dependent upon the contrast between classes of interest.

## CONCLUSION

The components described in this paper can be efficiently used to gather spatially registered quantitative data on rangeland vegetation in the dry areas. Without having to leave a permanent mark on the ground, this technique allow land managers to establish long term monitoring sites. Monitored areas can be revisited each season or year to assess the spatial and temporal effect of natural and human induced factors. The original images, geo-referenced images and classified images become a valuable data set that records and characterizes the condition of the range at a specified location and time. These data sets are extremely valuable to document change and range trend.

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