ICARDA

Science for resilient livelihoods in dry areas

VegMeasure® software: user report

2019

Prepared by: Mounir Louhaichi (ICARDA – Tunisia) and Sawsan Hassan (ICARDA – Jordan)

OSU Oregon State UNIVERSITY

CGIAR RESEARCH PROGRAM ON Livestock

USER REPORT

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About ICARDA
Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is a non-profit, CGIAR Research Center that focusses on delivering innovative solutions for sustainable agricultural development in the non-tropical dry areas of the developing world.

We provide innovative, science-based solutions to improve the livelihoods and resilience of resource-poor smallholder farmers. We do this through strategic partnerships, linking research to development, and capacity development, and by taking into account gender equality and the role of youth in transforming the non-tropical dry areas.

Address
Dalia Building, Second Floor, Bashir El Kasser St, Verdun, Beirut, Lebanon 1108–2010.

www.icarda.org

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1. Introduction

Plant vegetation cover plays an important role in ecosystem stability by reducing soil loss in the form of soil erosion. At the same time, vegetation cover is an indicator which can be used in a nondestructive manner as a basis for biomass estimation (Sala and Austin, 2000; Montes et al., 2000). This indicator can be used to measure the percentage of ground surface covered by vegetation in a certain area. Visual plant cover estimates are often used in the basic and applied plant ecological research because they are more rapid, easier and cheaper than other cover methods (Sykes et al., 1983).

Plant biomass is an important indicator of ecosystem productivity as well as for defining the potential of carbon sequestration and the carbon stock estimation for climate change mitigation. A plant's biomass includes the above ground plant parts i.e., stems, branches, seeds and other vegetative parts. Measurement of these parts is essential to evaluate and estimate the terrestrial carbon pools of other species in the ecosystem.

The estimation of plant biomass can be measured using destructive or non-destructive methods. The destructive methods are usually not ideal as they cannot be repeated and are expensive, time-consuming and limited in terms of spatial distribution. Non-destructive methods based on modeling and other technologies to assess vegetation characteristics are becoming more widely used, especially with the recent advances in geoinformatics.

Advanced research indicates the importance of biomass estimation using high resolution satellite imagery, and physical measurements of phytomass of different plant types/species at the reference sites. Remote-sensing methodologies can provide new opportunities to estimate plant biomass through plant cover measurement. Given their potential to provide accurate information, satellite imagery is a common tool used for monitoring above ground plant biomass and generating biomass prediction maps. Satellite images vary in resolution, coverage, security procedures and cost. These variations make these images sometimes difficult to obtain, which can prohibit/reduce their use. High resolution imagery is required to map species and to define land cover classifications, but often such imagery is expensive. But, compared with field surveys and manual measurements, these methodologies are cost effective.

Digital camera images can be classified and interpolated to give overall plant cover maps for the site(s) of interest. The Digital Vegetative Charting Technique (DVCT), for example, involves the use of digital cameras to classify and measure vegetation on the ground, requiring specialized software to process the digital images. This process is considered as rapid, cheap and reliable for measuring plant vegetation cover. More recently however, Geographic Information System (GIS) and image analysis software have offered the possibility of using digital images to objectively measure the ground cover and composition of vegetation.

VegMeasure® is one such software that processes images that are collected in a standardized manner to provide classification of imagery and measure changes over time (Louhaichi et al., 2010). This software has been developed by the VegMeasure project.

Variability in plant biomass estimates using DVCT was less than that of the data provided by personnel using traditional methods (Booth et al., 2005). The technique also provided greater accuracy than visual estimates (Olmstead et al., 2004). The information provided through high resolution, detailed imagery at local scale – when coupled with wide scale satellite remote-sensing – can be used as reference data to produce detailed classification maps that have greater accuracy than those generated from low resolution remote-sensing technologies.

DVCT requires a digital camera with built in GPS that can be mounted to a stand. The pictures should be taken from a fixed height with the lens pointing vertically downward. A scale should be provided on at least one of the field photos to indicate the size of each photographic pixel on the ground. Before collecting any images, enabling GPS recording on the camera is required to receive GPS satellite data and synchronize these signals with the data and the time of the camera's internal clock. The same camera and picture settings, height and orientation of photos should be kept constant throughout the sampling period.

After collecting the data, GPS recorded images should be transferred to a computer in order to be analyzed using the VegMeasure® software, which interprets the colours in the digital camera to create meaningful classes. More specifically, the software enables: hue extraction, calibrating a threshold, K-means classification, brightness algorithms, and green leaf algorithms. The software operates by using a mathematical formula (ratio) to identify the pixel values that correspond to green living vegetation and where blue light is low (i.e., the spectrum of light used by leaves in photosynthesis). The resulting ratioed image had pixel values from -1 to +1 using the following formula:

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$$[(G - R)+(G - B)] / [G + R + G + B]$$

Additionally, classification accuracy could be assessed using the Accuracy Assessment tool of the VegMeasure® software, which works by computing the error matrix and the Kappa Index of Agreement. The latter is commonly used in remote-sensing classifications to assess the degree of success of a classification technique. The error matrix permits measurement of overall accuracy, category accuracy, producer's accuracy and user's accuracy (Congalton, 1991). Large scale maps can be created using DVCT with VegMeasure®. Moreover, with repeat monitoring, changes in vegetation over time can be evaluated.

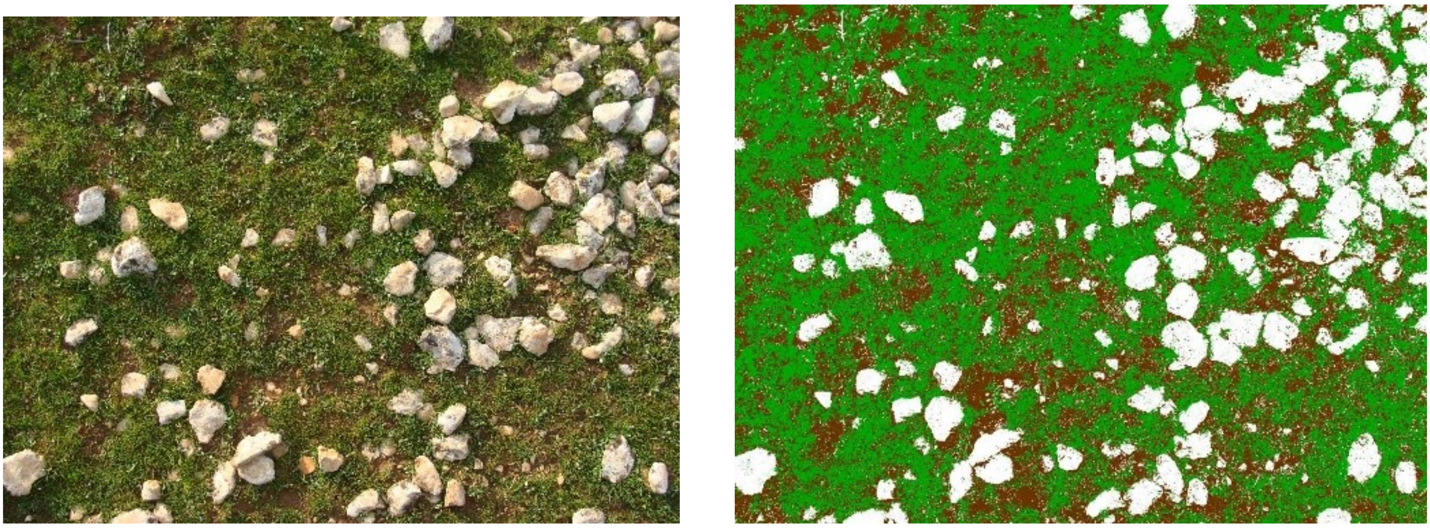
2. Software use

VegMeasure® was developed to help researchers of the VegMeasure project to estimate vegetation canopy cover in different research areas, as well as different ecosystems. The software allows the estimation of grassland vegetation parameters and the monitoring of native grassland at a minimum cost and in a non-destructive manner. The effectiveness of VegMeasure® was tested by a team of scientists in agro-ecological sites, ranging from natural ecosystems (grasslands and rangelands) to cereal-based production systems.

2.1 Grasslands

Grasslands are one of the world's most wide spread vegetation types, covering nearly 20% of the planet and playing a significant role in the livelihoods of pastoral and agro-pastoral communities. Their productivity is highly correlated to rainfall. The establishment of a good productivity estimate is crucial – not only to local communities but to decision makers, who can use this data to help put in place any necessary action to maintain productive livestock production. Figure 1 illustrates the use of VegMeasure® in the grasslands of Syria.

Figure 1. Original (left) and processed (right) images using VegMeasure® to estimate ground cover in a grassland site in Syria



2.2 Shrubland

In many arid and semi-arid ecosystems of the world, shrubs are vital for indigenous people who rely heavily on them both for food, animal feed and for their livelihoods. Traditional techniques for estimating shrubland biomass rely mainly on direct measurement which is destructive. The costs and logistics associated with field measurements limits the number of destructive samples in order to have a fair estimate.

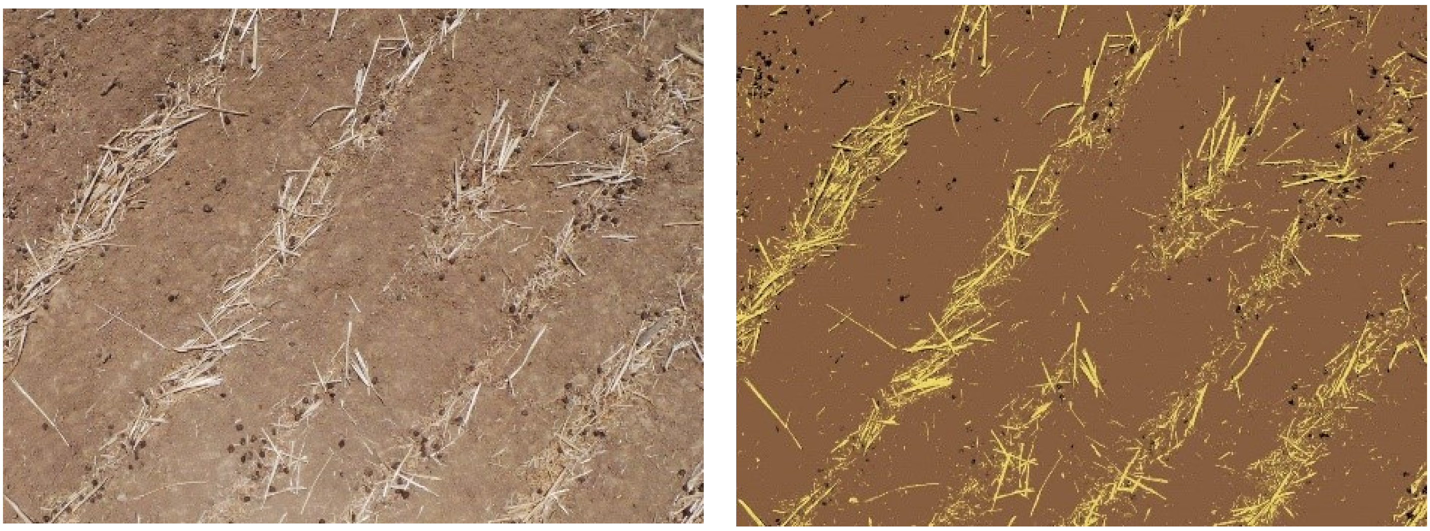
As an alternative to destructive techniques, shrub biomass can be estimated using variables that are correlated with it, such as canopy cover (Tarhouni et al., 2016; Louhaichi et al., 2018).
Figure 2 illustrates an example of *Salsola vermiculata*, an important shrub species for the arid areas of the Mediterranean region. Allometric equations have been developed using canopy cover and plant height estimates as surrogates for biomass measurements.

Figure 2. Original (left) and processed (right) images using VegMeasure® software to estimate shrub cover in a rangeland site in Jordan

2.3 Cropland

While VegMeasure® has primarily been used for rangelands to monitor and measure changes over time, it can also be used in monocrop environments. Determining early vigour between genetic varieties is important to estimate a crop's productivity, water use efficiency, as well as its ability to crowd out weeds (Preuss et al., 2012).
Under a conservation agriculture system, the management of crop residues can play a decisive role in soil water conservation by reducing evaporation losses, leading to higher water availability. The images of Figure 3 demonstrate how VegMeasure® can be used in conservation agriculture practices by estimating the amount of remaining crop residue to inform pastoralists on when to stop their livestock from grazing.

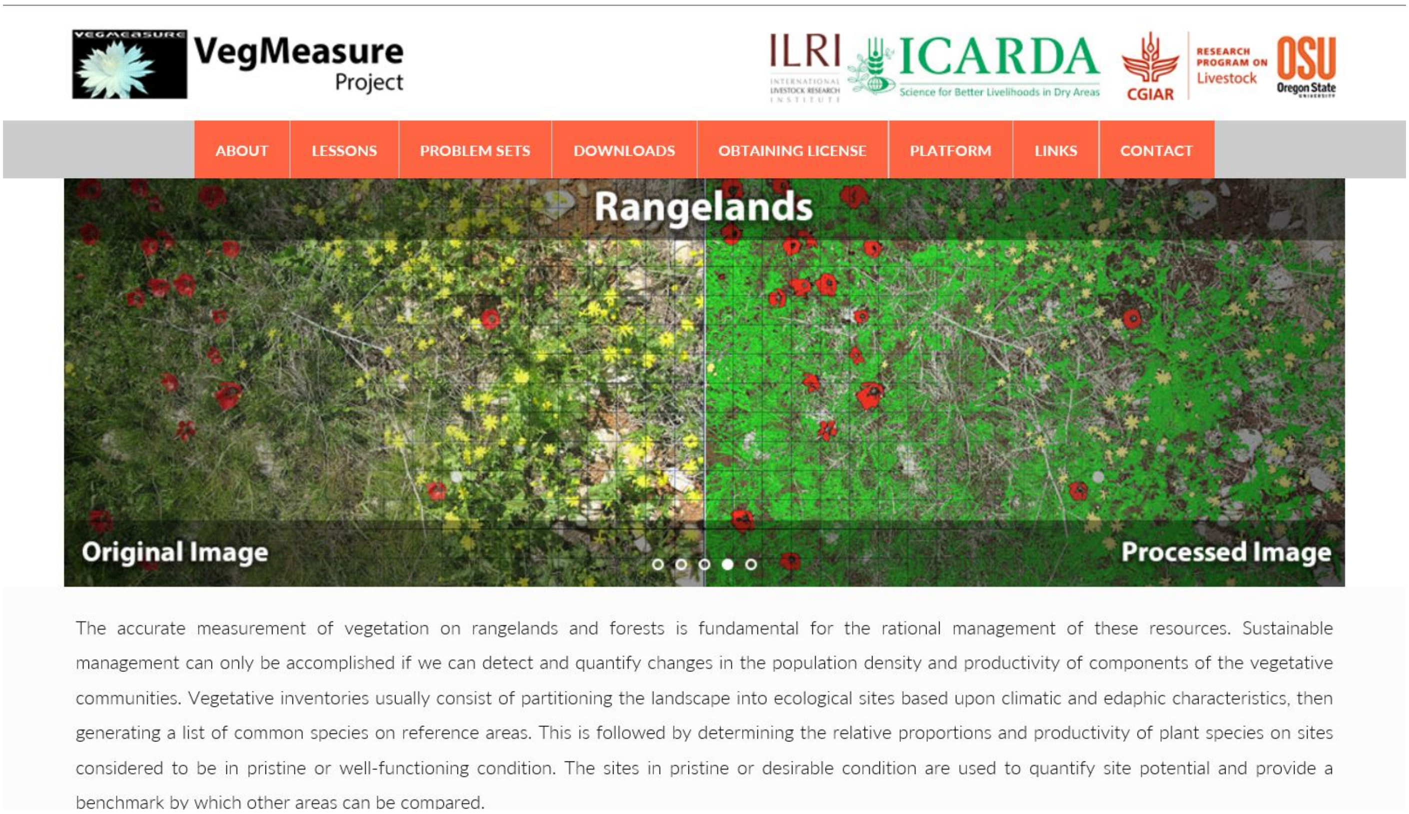
Figure 3. Original (left) and processed (right) images using VegMeasure® software to estimate residue cover on an Algerian wheat field managed under conservation agriculture.



3. VegMeasure website

This website has been developed to promote the VegMeasure® tool and engage with partners and stakeholders (Figure 4). The software has been developed by scientists at The International Center for Agricultural Research in the Dry Areas (ICARDA) and Oregon State University (OSU). VegMeasure® is free of charge and can be easily downloaded from the VegMeasure website (www.Vegmeasure.com).

Figure 4. A screenshot of the home page of the VegMeasure website



3.1 Target users

This website is targeting different users who is working in Research and Developments including International, national research institutes, universities, NGOs and private companies.

3.2 Software and Website objectives

It is important to adopt new technologies which are easy to use, cost and time effective, and also non-destructive to the vegetation. One potential alternative uses image processing software to determine vegetative cover from color digital images. Vegmeasure quantifies areas of defined classes such as bare ground and vegetation using built-in algorithms. The website has been developed to enhance the use of free Vegmeasure software. The specific objectives of this software:

1. Rapidly classify ground level photographs into meaningful groups based on colour.

2. Save classification parameters so they can be applied to other images taken under similar conditions.

3. Automatically classify all photographs selected or all photographs in a directory folder.

4. Export images as either classified ASCII Raster maps or bitmaps with word files and projection information so they can be saved as GIS data layers.

5. Produce output summary tables with results of the classification for each image.

The website was established in order to encourage and help researchers and development agencies to use the software to monitor the following agro-ecological sites:

- Rangelands
- Shrubland
- Agronomy
- Coastal vegetation
- Cropland
- Forests
- Grasslands
- Mining reclamation sites
- others

3.3 VegMeasure website structure

The website contains the following navigation structure:

- **Home**

- **Lessons**
  - Range Analysis Intro
  - Review of Statistics
  - Lesson 1
  - Lesson 2
  - Lesson 3

- **Problem Sets**
  - Exercise 01
  - Exercise 02
  - Exercise 03
  - Exercise 04

- **Downloads**
  - VegMeasure Software
  - VegMeasure Image Positioning Tool
  - VegMeasure Accuracy Assessment
  - KRESS (Multi-Criteria Decision-Making Tool)

- **Obtaining license**
  - Obtaining a VegMeasure 2 License
  - Obtention d'une licence VegMeasure 2
  - VegMeasure 2 كيف تحصل على ملف تشغيل برنامج

- **Platform**

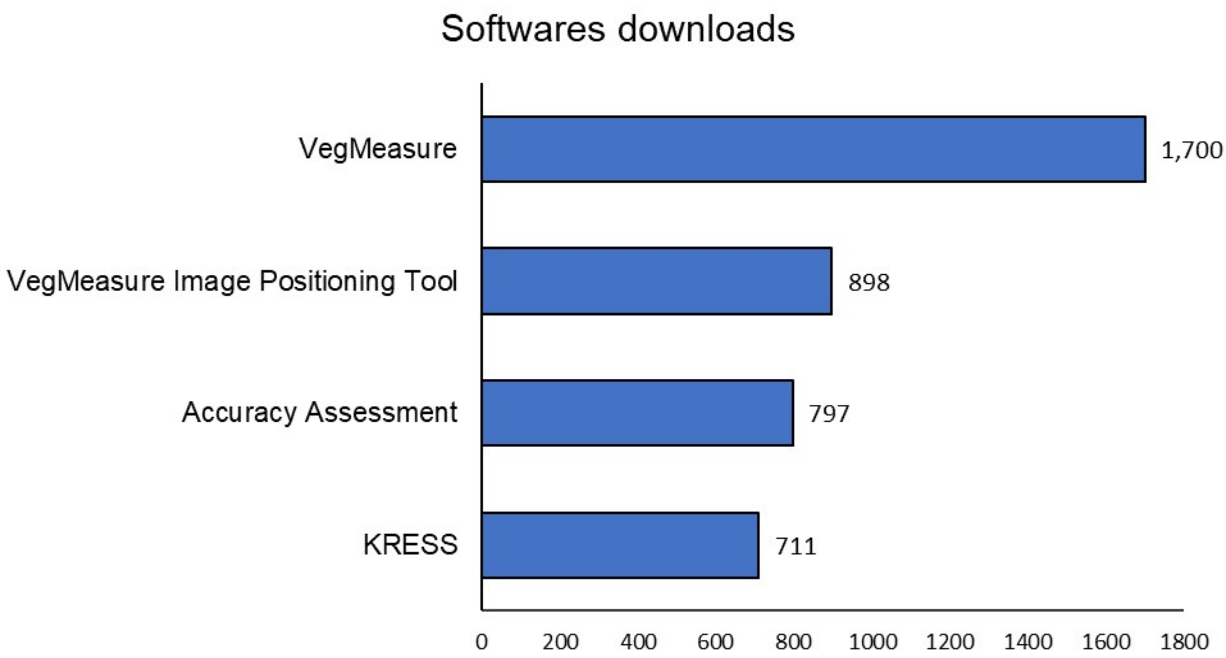
- **Links**

- **Contact us**

4. VegMeasure® use

Individuals wishing to use the software must follow the instructions. Once the software is downloaded, a "license prep" (license preparation) is created to generate a license key for each user (IP address). There is no limit to how many licenses a person may request but in order to keep track of who is using the software – and for what purpose – this step was required. At the end of November 2019, VegMeasure® had been downloaded from the VegMeasure website 4,106 times (Figure 5).

Figure 5. Number of downloads of VegMeasure®, VegMeasure® Image Positioning Tool, Accuracy Assessment Tool and KRESS through the VegMeasure website

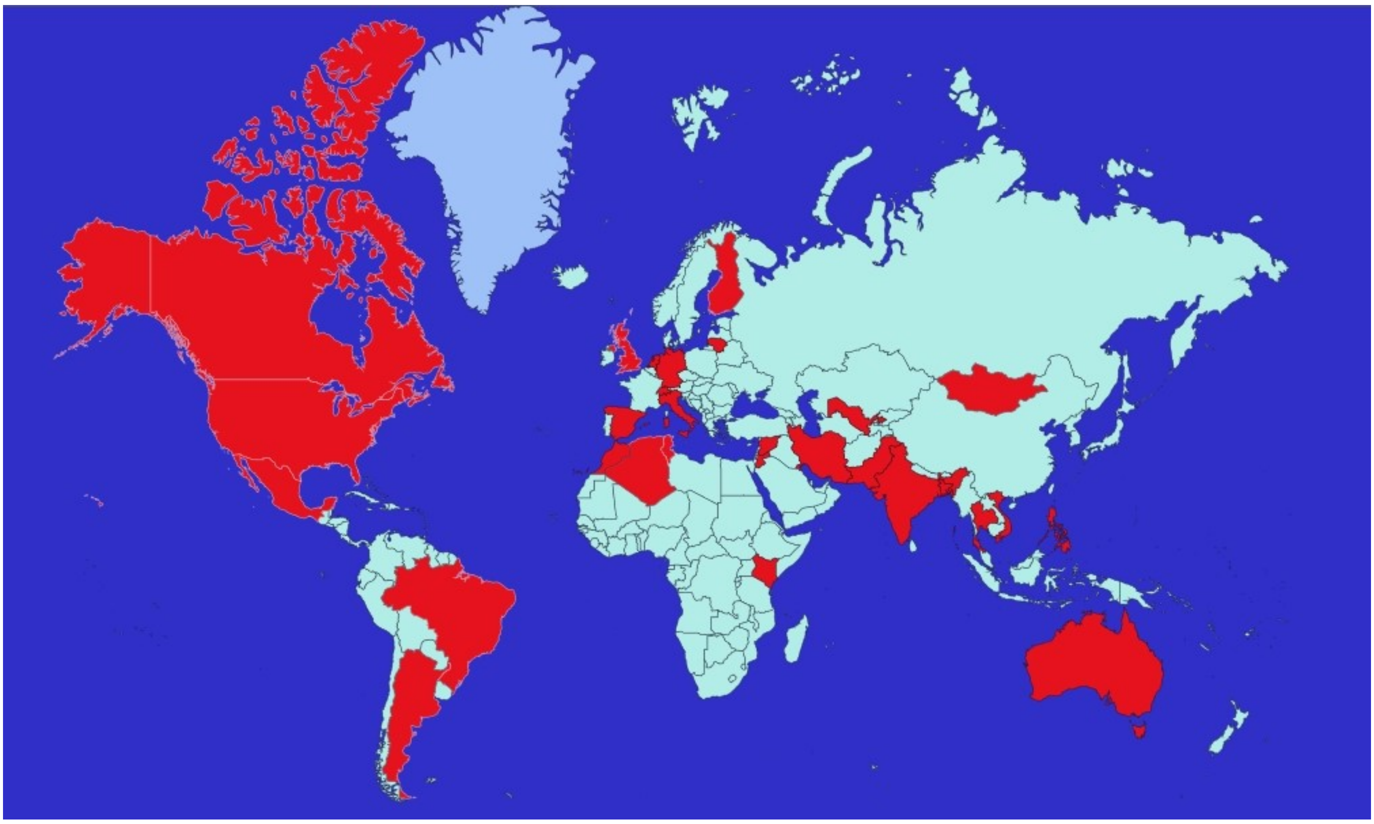


5. Who uses VegMeasure®

Data generated from the website shows that VegMeasure® has been accessed by users in 32 different countries (Figure 6). This indicates that the software is a tool that can be efficient in different environments and different research areas. More than half (60%) of VegMeasure® users are based in Australia, Jordan and Pakistan, with strong representation from Tunisia and the USA – which may be explained by the presence of the founding companies (ICARDA and OSU) in these two countries.

On the other hand, very few users are based in Finland, India, Mexico, the Philippines, Switzerland, Thailand and the UK, representing about 5% of the total combined.

Figure 6. Map showing the countries (in red) where VegMeasure® is being used

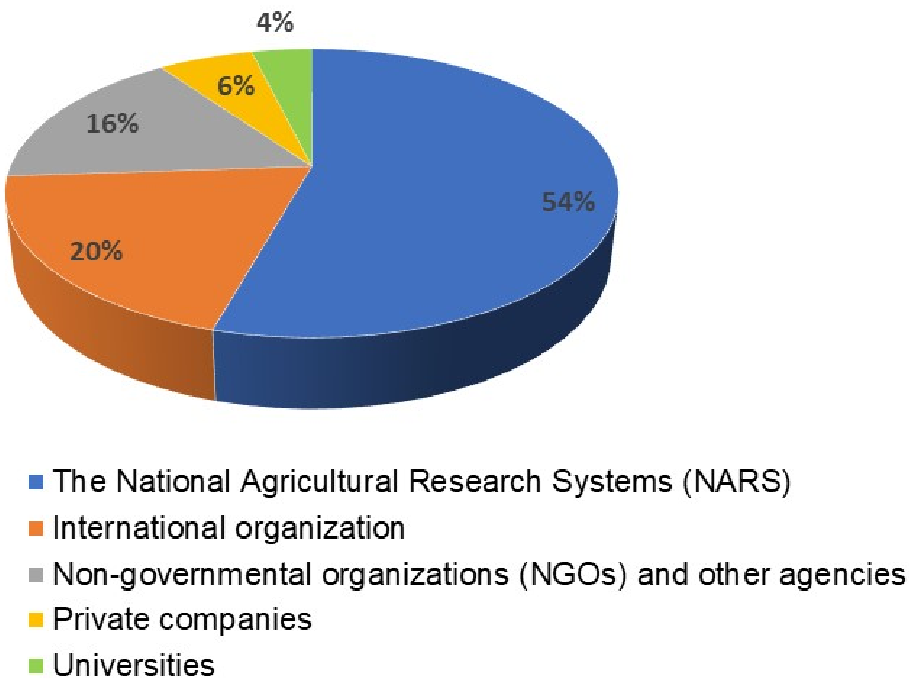


6. Type of institutions using VegMeasure®

Data on the users of VegMeasure® indicate that they do not predominantly come from one type of institution. In fact, five different institutions were recorded. More than 50% of users work at National Agricultural Research Institutes (NARS), whilst international research organizations (mainly CGIAR) make up 20% of users.

Following this are Non-governmental organizations (NGOs), which constitute 16% of users (Figure 7).

Figure 7. Type of institutions using VegMeasure®

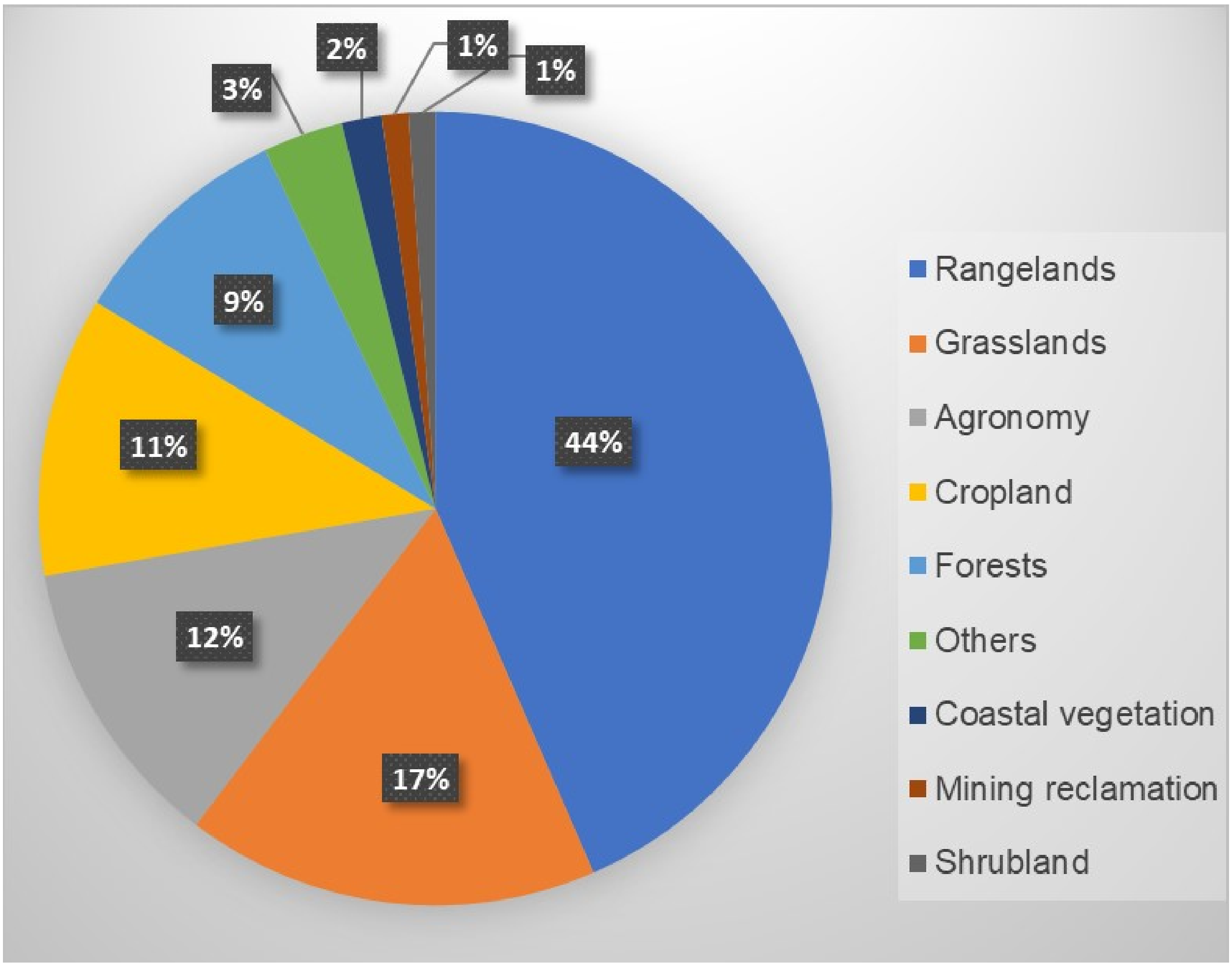


6. Level of interest among users to apply VegMeasure® to their area of study

The majority of VegMeasure® users indicated their interest to apply this software in monitoring rangelands ecosystem (44%), followed by grasslands (17%). With approximately the same level of interest are the fields of agronomy (12%), cropland (11%) and forestry (9%). The other four fields of use totaled just 7% (Figure 8).

These results indicate that VegMeasure® is most effective in monitoring and assessing rangelands over any other type of ecosystem.

Figure 7. Type of institutions using VegMeasure®



Conclusion

The use of VegMeasure® software to classify digital images of ground plots provides a repeatable, minimally disruptive, and relatively non-subjective method for estimating percentage ground cover with estimates of classification accuracy.
The VegMeasure website provides easy access to download and learn how to use the VegMeasure® software. The majority of VegMeasure® users are professionals in agricultural research systems and effort should thus be made in attracting more users from universities. This can be done by offering training at selected universities.
It would be constructive to get feedback from users in order to improve this free service. Last but not least, a great effort is dedicated to providing the software and manuals for various users, at least these users should acknowledge the developers and service offered to them.

Sample publications involving the use of VegMeasure software

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Johnson, D.E., Louhaichi, M., Pearson, A. 2018. VegMeasure Image Positioning Tool. Version 1.2. ICARDA, Amman, 11195, Jordan

Louhaichi M., Hassan S., Johnson D.E. 2019. VegMeasure: Image Processing Software for Grassland Vegetation Monitoring. In: El-Askary H., Lee S., Heggy E., Pradhan B. (eds) Advances in Remote Sensing and Geo Informatics Applications. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham

Louhaichi, M., Hassan, S., Clifton, K., Johnson, D. E. 2018. A reliable and non-destructive method for estimating forage shrub cover and biomass in arid environments using digital vegetation charting technique. Agroforest Syst 92:1341–1352

Louhaichi, M. 2018. Digital Vegetation Charting: a robust and cost-effective technique for estimating plant cover, leaf litter, and bare ground in grassland areas. R4D INITIATIVES, ICARDA publications, https://hdl.handle.net/20.500.11766/9136

Louhaichi, M., Hassan, S., Johnson, D.E. 2018. VegMeasure. Volume 1: Field Manual. ICARDA, Amman, 11195, Jordan. 16 pages

Louhaichi, M., Hassan, S., Johnson, D.E. 2018. VegMeasure. Volume 2: Image Processing Manual. ICARDA, Amman, 11195, Jordan. 28 pages

Louhaichi, M., Johnson, M.D., Woerz, A.L., Jasra, A,W., Johnson, D.E. 2010. Digital charting technique for monitoring rangeland vegetation cover at local scale. Int J Agric Biol 12:406–410

Preuss, C.P., Louhaichi, M., Huang, C.Y., Ogbonnaya, F.C. 2012. Genetic variation in the early vigor of twenty elite spring wheat under phosphate stress as characterized through digital charting. Field Crops Res. 127:71–78

Tarhouni, M., Ben Salem, F., Tlili, A., Ouled Belgacem, A., Neffati, M., Louhaichi, M. 2016. Measurement of the aboveground biomass of some rangeland species using a digital non-destructive technique. Bot Lett. 163(3):281–287

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Olmstead, M.A., Wample, R., Greene, S., Tarara, J. 2004. Nondestructive measurement of vegetative cover using digital image analysis. HortScience 39(1):55–59

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Tarhouni, M., Ben Salem, F., Tlili, A., Ouled Belgacem, A., Neffati, M., Louhaichi, M. 2016. Measurement of the aboveground biomass of some rangeland species using a digital non-destructive technique. Bot Lett. 163(3):281–287

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