# Calculation and Interpretation of Fractional Green Canopy Cover in the Southwest of Buenos Aires through an Open-Source Mobile Application

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**Abstract.** Within the province of Buenos Aires, there is a region known as the semi-arid southwest, integrated by Bahía Blanca, Coronel Rosales, Tornquist, Puan, and Coronel Pringles. In this area, it is possible to find not only bare soil but also soils with dry or alive plant material. It is in the interest of both INTA and the landowners in this area to study soil cover to achieve better decision-making on environmental and productive impact and take advantage of resources in the most efficient way possible. For example, bare soil runs great risks of wind and water erosion. Through proper analysis and estimation, these problems could be prevented. Our proposal is a mobile application, open-source and freely available, that that speeds up the coverage calculation, supports data interpretation and decision-making regarding the coverage and management of soils through photographs taken from mobile devices and synchronized with the cloud. Unlike other existing solutions, our development distinguishes between bare soil, soils covered with alive plant material, and soil covered with dry plant material.

**Keywords:** Fractional Green Canopy Cover · FGCC · Open-Source · Image processing.

## 1 Introduction

Since the information on soil cover is essential for the conservation of the resource, the improvement in infiltration, the reduction of erosion, the cycling of

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nutrients, and other processes; is of vital importance in the planning and management of agricultural establishments and plays a key role for INTA professionals Given the considerable improvement of accessibility and the enormous increase in the processing capacity of mobile devices, it is possible and convenient to introduce tools for soil-cover calculation based on such platforms. Such tools must be adapted to the needs of their users, maximizing capacity and usability.

The existing applications in the agricultural field are diverse. These applications may be available for different platforms and help solve a specific aspect, such as monitoring agricultural and livestock production, predicting phenomena, or comparing alternatives. However, it is not always easy to find a product tailored to the needs of a particular workgroup. One of the main motivations for developing this project is, precisely, the lack of an application that allows the INTA's working group to control and monitor soil cover as required for their region of interest.

The tools that this team had been working with did not fully meet their needs. In particular, in terms of soil cover, such tools did not allow them to easily distinguish different types of soil coverage (green pastures and dry pastures, for example). For this reason, they contacted the Department of Computer Science and Engineering (DCIC) of the Universidad Nacional del Sur, which took up this challenge and generated a solution thanks to the joint work of DCIC teachers/researchers and students together with INTA professionals.

The definition, design, and implementation of the application and its interactions with the user were conceived under a User-Centered Design strategy [4] and with consideration of the work done by Jones et. al [7]. This solution was created as the thesis of two student from the Information Systems Engineering degree at the DCIC under the direction of two research professors and the collaboration of the staff at Instituto Nacional de Tecnología Agropecuaria, Estación Experimental Agropecuaria Bordenave, Gr. Extensión Establecimientos Rurales Extensivos, Agencia de Extensión Bahía Blanca.

In this work, we present CGS, a free and open-source application for Android that allows the user to calculate soil cover by differentiating between live cover, dry cover, and bare soil. The application also allows the management of the derived data through a website. The rest of the paper is structured as follows. In Section 2 we detail how the INTA workgroup has been calculating soil cover so far. Then, we present our work in Sections 3 and 4 with all its features. We later introduce two test cases. Finally, in Section 6 we conclude with a brief discussion on the limitations and advantages of our approach and the future work.

## 2   Previous Work

Among the main current tools, one that stands out and has been used extensively by INTA members is an application called *Canopeo* [8] which is mainly used for agriculture, where the importance lies in the live forage. While in livestock it is also important the presence of forage in other conditions of maturity, which vary in color, and the general coverage due to erosion. Even though this application

has interesting characteristics, one of its drawbacks is that it does not mark certain sectors that are of interest to the professionals since it only focuses on the green-colors coverage. As mentioned, it is useful to differentiate bare soils from green grasses, but it does not consider dry grasses in its classification. This section presents a detailed analysis of *Canopeo* and a more general description of other existing alternatives that focus, at least in part, on vegetation cover.

## 2.1   Canopeo

This mobile application was developed at Oklahoma State University, United States, in 2015. It has a version for both Android and iOS and a web page for the user to access previously created sessions. The main functionality of *Canopeo* is determining the percentage of green canopy cover (GCC) in an image. The application was developed using Matlab [6]; the color system it uses is RGB and operates based on calorimetry. It also should be noted that this application is the most downloaded in the Google Play Store within the alternatives that offer analysis of green vegetation coverage.

The application offers three options as image inputs. The user can analyze the soil cover from a newly captured image, from one from the gallery, or from a video; however, the latter option is only an Android functionality and is limited to 15-second videos. For images, it calculates the percentage of green coverage and shows both the original and the processed image. The latter displays the vegetation coverage as white pixels. Moreover, the application allows modifying the analysis precision-level, and thus, changing the number of pixels considered green. In the case of video analysis, the user can record it at the moment, and the application divides it into frames to show the green percentage for each frame. Finally, if the user has an account and is logged into the application, he/she is able to save the result for later access.

Among the advantages offered by *Canopeo*, it is worth mentioning that it is free, has a version for Android, and allows saving sessions for later access, using both the same mobile application and the website. It offers the possibility of frame-by-frame video analysis and has the functionality of adding notes to the sessions. The main disadvantage is that it only focuses on the coverage of greens and does not allow to make a difference in soils, green pastures, and dry pastures. On the other hand, it does not have support for the Spanish language, does not allow retouching the image, and only allows increasing or decreasing the tolerance level when calculating the coverage, without zooming to detect areas that may not be fully visible given light conditions. The web version allows the user to view the information of the sessions with their corresponding images, both the original and the one that shows the coverage, edit the information, download it in CSV format and delete the desired sessions. As part of Section 5, we will show a comparison between the results obtained by *Canopeo* and our application.

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## 2.2   ImageJ

*ImageJ* [2] is a desktop application dedicated to image processing, developed by Wayne Rasband in the U.S. National Institutes of Health (NIH) and in continuous development since 1997. It was designed as an open architecture, where users can write custom plugins to solve different problems related to image analysis and processing. For this reason, it includes a wide variety of tools for more advanced measurements, such as 3-D live-cell imaging, radiological image processing, data comparisons from multiple imaging systems, and automated hematology systems. Although the fact that *ImageJ* is open and has a wide variety of plugins can be beneficial in many cases, it is also true that since it is not an application exclusively dedicated to covering floors, its use is somewhat complex.

To perform an alive-vegetation cover analysis, it is necessary to perform various manual adjustments that can be very cumbersome. To get started, the image to analyze must be converted to grayscale. Then, the color scale and the area of interest must be selected. Finally, the brightness, saturation, and contrast values are adjusted. These tasks must be performed each time the user wants to analyze an image, making it impractical for analyzing many images.

## 2.3   Cobcal

*Cobcal* [5] is based on colorimetry and uses digital photos of the sampled area as input, calculating the percentage and area covered by crop, stubble, weeds, or disease patches. According to its authors, *CobCal* is a fast and efficient method that seeks to improve current methods for calculating vegetation cover that is very demanding and must be performed by qualified personnel. The idea is that the tool is useful when making decisions in the agricultural mechanization sector. The program is a desktop-only application for the Windows operating system. When uploading an image, the user must select the area to analyze, the colors include, and those to exclude from the detection. Finally, it displays the percentage covered by the chosen color range and the total covered area. Worth noting that an attempt was made to download the application from the official website, but the link did not work.

## 2.4   Sigma Scan Pro

*SigmaScan Pro* [1] was originally developed by Jandel Scientific Software in the late 1980s and was later acquired by SPSS Inc. in October 1996. From then on, it has been available for commercial use. The software can achieve a green coverage analysis through a macro called *Turf Analysis*. One of the advantages of his tool, over other alternatives, is that it can analyze multiple images simultaneously. However, it should be noted that of all the mentioned tools this is the only one that requires the payment of a license to be able to process the images.

# 3    Our Proposal

Our proposal seeks to satisfy the needs of the professionals at INTA who contacted us and solve the problems they observed in *Canopeo*. Specifically, Canopeo does not allow to differentiate green from dry pastures. Since having a mobile application was convenient for the work team, one was developed. However, due to the existing restrictions on developing mobile applications for iOS and no one in the INTA work team owning an iPhone, it was decided to implement only the Android application and postpone the development for iPhone for a future version.

The proposed application organizes the image information in different levels, where each level is a subdivision of the next:

- The simplest level of organization is *Pasture*. This level can contain several images, organized as "before" and "after" versions to compare the coverage percentages after applying some change in the vegetation. This list of images can be viewed, as well as the average of the different coverage percentages. Each Pasture has an identifying name and the creation date.
- The second level is the *Lot*, which represents a geographic portion of a field. It can contain Pastures or individual images.
- Finally, the third level is the *Session*, which represents a photo session in a certain field. It can be subdivided into Lots to group images or contain individual images. Each Session has a description, a creation date, and the name of the person who created it; it can also contain notes with additional information.

For each image, three coverage percentages are determined: alive vegetation, dry vegetation, and absence of vegetation. Then, color ranges were defined for each type of coverage:

- *Green range.* The part of the image that is in the green spectrum will be considered as alive vegetation.
- *Yellow/gray range.* The part of the image within this range of colors will be considered dry vegetation.
- *No range.* Parts of the image that are not in any of the above ranges are considered to be not covered by vegetation.

Each part of the image falls within only one of these cases. Therefore, the sum of these three percentages must result in 100% of the image. To make the analysis as accurate as possible, users can make color corrections to the photos by adjusting the saturation, contrast, or brightness of the image and, thus, modify in what range certain portions of the image fall.

All the information described above is synchronized with a database in the cloud so that it can be accessed by anyone. In this way, several people can work on the same session, lot, or pasture, and the information collected is shared between them all. The application will continue to work offline with full functionality, and all changes and updates will synchronize with the cloud only when connectivity

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is active again. Finally, a web page allows the users to view the information from a browser in a clearer way, filter or sort the sessions by different attributes, and download the information for backup or export to other programs.

## 4    Implementation

The mobile application was developed using the React Native framework. This technology allows defining mobile views using the Javascript language in a very similar way to defining views for web applications, and the same source code is suitable for Android and iOS. We also considered developing a native Android application or making a Progressive Web App. However, the former implies a brand new development for iOS, and the latter has not a good performance and cannot be published on App Stores.

The flow of views in the application goes from the most general to the more specific information. In other words, the first view that the user will have contact with is the list of existing Sessions, while the last view will be a view of a Pasture together with its images. The flow is described as:

- *Session list.* The list of existing sessions.
- *Individual Session.* Information about the Session will be displayed (description, creation date, etc.), a list with the Lots assigned to the Session, and a list with the users' notes.
- *Individual Lot.* Information about the Lot will be displayed here, as well as a list with the loaded images and a grid with the Pastures of the lot.
- *Individual Pasture.* Information related to Pasture and the list of images belonging to it will be displayed.

Besides the session list, the user can access two additional views: "Recents" and "Quick processing". The first one shows the batches recently accesses by the user to save user interactions. The second view allows the user to quickly process an image without entering a Lot or a Pasture. This information will not be stored, so it is lost once the processing view is exited. To carry out this implementation, we use the react-navigation library, which allows the definition of different views and the navigation between them programmatically.

### 4.1    Image Processing

The image processing was carried out in a particular module implemented in Java using the computer vision library OpenCV [3]. It allows to define ranges of colors and then identify which parts of an image fall within those ranges. Colors were represented using the HSV model since it supports defining a contiguous range of colors. This model represents colors by three components:

- *Hue (H).* Represents the color gamut and takes values from the range $[0°, 360°)$.
- *Saturation (S).* Defines the intensity of the color and takes values from the range $[0, 1]$.
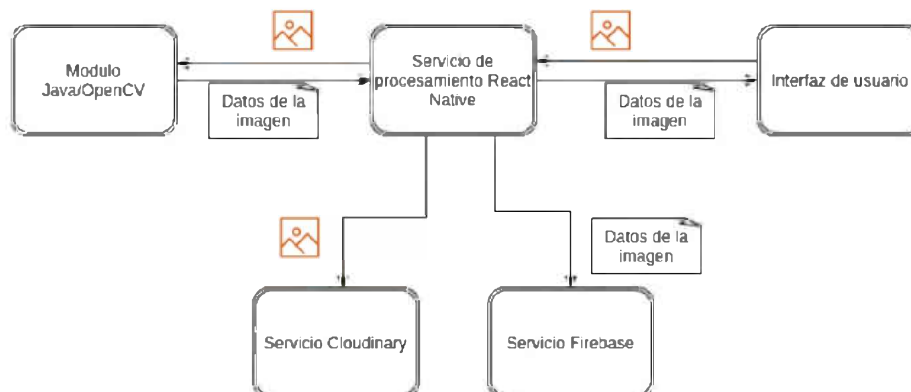
Fig. 1: Interaction of the different components in the application.

– *Value (V)*. Defines the amount of light that is reflected in the color, that is, the brightness. It also takes values from the range $[0, 1]$.

The HSV thresholds used to detect each type of coverage were:

– *Green*. Between $(70°, 14\%, 20\%)$ and $(140°, 100\%, 100\%)$
– *Yellow*. Between $(30°, 25\%, 20\%)$ and $(70°, 100\%, 100\%)$

This module includes hooks to use from the module implemented in React Native. When the user chooses an image to load from the interface, it is sent to the Java module for processing, which returns the result of the analysis. As Figure 1 shows, once the image processing is finished, it is saved in the Cloudinary service, which is the provider chosen for image storage in the cloud. At the same time, the collected data is sent to the Firebase service, which is the chosen backend for the application.

### 4.2 Backend

In any software, the backend is the data access layer that is not directly accessible by users and contains the application logic that handles such data. In a traditional architecture, the backend runs on a server, which, in simple terms, is a specialized application capable of understanding the requests made by the client. In recent years, different variations and techniques have emerged when it comes to backend development. A model that has been gaining strength is 'Backend as a Service' (BaaS). This model offers developers a unified API to access all the services that constitute a backend, such as cloud storage, authentication, real-time, or push notifications. It simplifies the development and reduces working time.

Between the different BaaS providers (Amazon, Google Cloud, Azure, etc.), we chose Firebase as a backend. Firebase provides the most common services

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when creating a mobile or web application, such as user creation and authentication, database, storage, analytics, notifications, among others. Regarding data storage, we use Cloud Firestore to store the sessions, batches, and pastures information. The database is non-relational, document-based, and organized in collections. These documents can contain nested objects of varying complexity, as well as sub-collections. Firebase also supports real-time operations, useful to keep data updated from any connected device, and offers functionalities to work offline, a must-have functionality since in the field may not be an Internet connection.

### 4.3   Web page

Another requirement of the project was a website that serves as a dashboard or control panel for displaying all the information created in the mobile application. This website provides a way to control and access data visually from any device. Specifically, on the website, the user can see all the information of the sessions in an organized and graphic way (coverage percentages, the difference between before and after vegetation cuttings, averages, etc.). The user can search, filter, and sort sessions by description, username, and date. Also, the user can download reports in CSV or PDF format with the information associated with all sessions or someone in particular. It is also possible to edit the sessions, batches, and pastures description and notes.

## 5   Test Cases

The application testing was performed using two test cases. The first one evaluates the detection capacity of our applications versus the one most used so far, *Canopeo*. The second one tests the whole CGS usage cycle.

### 5.1   Detection Capacity Comparison

The first experiment uses a bank of 14 images; some of the images were obtained by the DCIC students and others from stock databases online. Each image was analyzed using both tools, and Table 1 shows the results. In general terms, the results on living pastures are very similar. However, on bare soil, they present a greater difference. We consider this occurs because our application considers a third possibility in the data analysis, dry vegetation. A clear example of this can be seen in images 3 and 4 (Figure 2), where Canopeo identified a high percentage of bare soil, when in fact there was a high presence of dry grass. The images are available at the URL `shorturl.at/ouCMU`.

### 5.2   CGS Usage Cycle

Figures 3 to 8 show what we consider a complete cycle of CGS use, from the start of the application and the loading of information to the retrieval of that same information from the web. The process was able to run smoothly. Currently, INTA staff is testing the application in the field.

Fig. 2: Two of the images used for the comparison between Canopeo and CGS. In both it can be observed, when analyzing the results, that Canopeo interpreted as bare soil what actually contained both bare soil and dry grass.

# 6    Conclusions and future work

Today there are numerous software applications in the agricultural field based on image analysis. These applications may be available for different platforms and help solve a specific sector aspect, such as monitoring agricultural and live-stock production, predicting phenomena, comparing alternatives, etc. Although satellite images and other tools exist today, they are not as accurate as having data at the field level. In this way, it is possible to infer, using a real sample, the current situation of the resource. However, it is not always easy to find a product tailored to the needs of a workgroup, and the specific characteristics of the crops at the regional scale. One of the main motivations for the development of this project was the lack of an application that allows the INTA workgroup to control and monitor the land cover in the way they need it, due to the importance of the vegetation cover in the face of the high susceptibility of soil erosion characteristic of the semiarid southwest of Buenos Aires. Until now, they did not have a suitable tool to satisfy all their needs when recording the range of colors present in certain soil in a certain field. Although they have been using software that helped them in this analysis, they encountered certain limitations that they had to solve by other means, often manually, leading to confusion, errors, or omissions.

Our goal was to provide them a tool that solves these particular requirements and helps the work to require less effort and time. In essence, incorporating the knowledge and experience provided by the Department of Computer Science and Engineering to help solve a problem. Even though there is room for improvements, we consider that the implemented application can be very helpful to reduce working time and add value to the data collected. In addition, INTA researchers from other macro-regions have expressed interest in using this tool in crop cover measurements in their experiments and monitoring, given the possibility of extrapolation. Which could allow future collaborative projects with other regions.

Table 1: Results of analyzing images using Canopeo and CGS.

| Images ID | Canopeo | | CGS | | |
|---|---|---|---|---|---|
| | Green % | Bare % | Green % | Dry % | Bare % |
| 1 | 98,17 | 1,83 | 95 | 2 | 3 |
| 2 | 42,08 | 57,92 | 46 | 6 | 48 |
| 3 | 5,36 | 94,64 | 5 | 48 | 47 |
| 4 | 0,01 | 99,99 | 0 | 72 | 28 |
| 5 | 27,32 | 72,68 | 24 | 18 | 58 |
| 6 | 39,70 | 60,30 | 41 | 13 | 46 |
| 7 | 6,50 | 93,50 | 6 | 13 | 81 |
| 8 | 20,43 | 79,57 | 21 | 38 | 41 |
| 9 | 22,53 | 77,47 | 27 | 14 | 59 |
| 10 | 3,19 | 96,81 | 7 | 3 | 90 |
| 11 | 5,86 | 94,14 | 10 | 31 | 59 |
| 12 | 2,62 | 97,38 | 6 | 21 | 73 |
| 13 | 0,28 | 99,72 | 1 | 8 | 91 |
| 14 | 72,78 | 27,22 | 70 | 22 | 8 |



(a)                    (b)                    (c)

Fig. 3: Three application views related to sessions. (a) Main screen without any session created. (b) Screen to create a new session. (b) Session details screen.
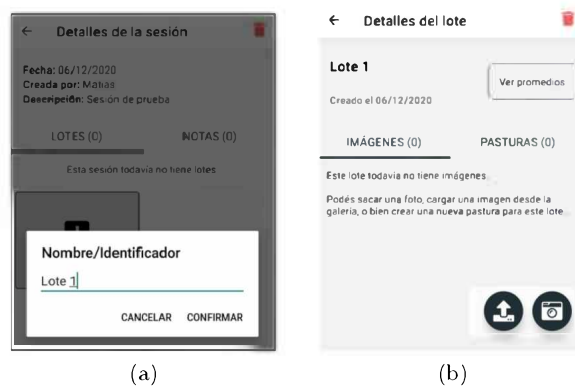
Fig. 4: Two application views related to Lot creation. (a) Creating a new Lot. (b) Detail of the recently created Lot.
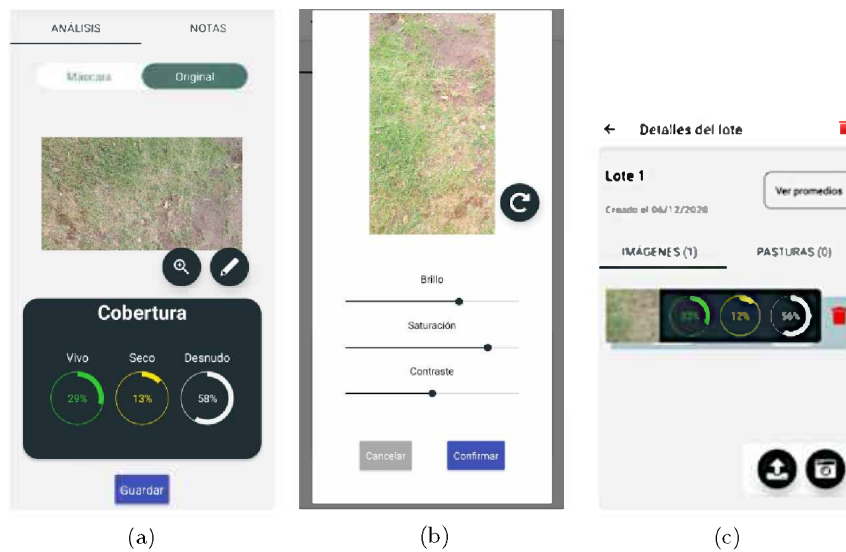


Fig. 5: Three views related to photo processing. (a) Results obtained after processing a photo. (b) One of the functionalities offered is to be able to adjust certain parameters of the image. (c) Detail of Lot 1.

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Fig. 6: Through the website the user can access the table with the list of existing sessions.



Fig. 7: Session details through the website.

CGS is an application that seeks to solve a specific problem of soil cover analysis without neglecting the user experience. Since the development followed a user-centered design, the idea of an intuitive and easy-to-use application was kept in mind at all times. Another major challenge was to perform image processing on a mobile device. The application is available as an open-source project, so not only is it a software product created to solve a need, but it also is the foundational basis for future developments to expand its functionality and areas of application. The source code is available by contacting the authors of this work.

Fig. 8: Session details exported as PDF.

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