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- pour un ouvrage : HAUHOUOT Asseypo Antoine, 2002, *Développement, aménagement, régionalisation en Côte d'Ivoire*, EDUCI, Abidjan, 364 p.

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- Pour les documents électroniques : INS, 2010, *Enquête sur le travail des enfants en Côte d'Ivoire*. Disponible à : http://www.ins.ci/n/documents/travail_enfant/Rapport%202008-ENV%202008.pdf, consulté le 12 avril 2019, 80 p.

Éditorial

Comme intelligence de l'espace et savoir stratégique au service de tous, la géographie œuvre constamment à une meilleure compréhension du monde à partir de ses approches et ses méthodes, en recourant aux meilleurs outils de chaque époque. Pour les temps modernes, elle le fait à l'aide des technologies les plus avancées (ordinateurs, technologies géospatiales, à savoir les SIG, la télédétection, le GPS, les drones, etc.) fournissant des données de haute précision sur la localisation, les objets et les phénomènes. Dans cette quête, les dynamiques multiformes que subissent les espaces, du fait principalement des activités humaines, offrent en permanence aux géographes ainsi qu'à d'autres scientifiques des perspectives renouvelées dans l'appréciation approfondie des changements opérés ici et là. Ainsi, la ruralité, l'urbanisation, l'industrialisation, les mouvements migratoires de populations, le changement climatique, la déforestation, la dégradation de l'environnement, la mondialisation, etc. sont autant de processus et de dynamiques qui modifient nos perceptions et vécus de l'espace. Beaucoup plus récemment, la transformation numérique et ses enjeux sociaux et spatiaux ont engendré de nouvelles formes de territorialité et de mobilité jusque-là inconnues, ou renforcé celles qui existaient au préalable. Les logiques sociales, économiques et technologiques produisant ces processus démographiques et ces dynamiques spatiales ont toujours constitué un axe structurant de la pensée et de la vision géographique. Mais, de plus en plus, les sciences connexes (sciences sociales, sciences économiques, sciences de la nature, etc.) s'intéressent elles aussi à l'analyse de ces dynamiques, contribuant ainsi à l'enrichissement de la réflexion sur ces problématiques. Dans cette perspective, la revue Géovision qui appelle à observer attentivement le monde en vue de mieux en comprendre les évolutions, offre aux chercheurs intéressés par ces dynamiques, un cadre idéal de réflexions et d'analyses pour la production d'articles originaux. Résolument multidisciplinaire, elle publie donc, outre des travaux géographiques et démographiques, des travaux provenant d'autres disciplines des sciences humaines et naturelles. Géovision est éditée sous les auspices de la Commission des Études Africaines de l'Union Géographique Internationale (UGI), une instance spécialement créée par l'UGI pour promouvoir le débat académique et scientifique sur les enjeux, les défis et les problèmes spécifiques de développement à l'Afrique. La revue est semestrielle, et parait donc deux fois par an (en anglais et en français).

Bouaké, le 16 Septembre 2019

La rédaction

AVERTISSEMENT

Le contenu des publications n'engage que leurs auteurs. La Revue Géovision ne peut, par conséquent, être tenue responsable de l'usage qui pourrait en être fait.

SOMMAIRE

DRONE AS AN AUXILIARY TOOL FOR DEGRADED MANGROVES CHARACTERIZATION IN THE NORTH OF LIBREVILLE – NW/GABON

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ABSTRACT

Unmanned Aerial Vehicles (UAVs), or commonly known as drones, are increasingly popular in everyday tasks because of their advantageous characteristics. In environmental studies, aerial imagery allows to analyze (by photointerpretation, for example) or to process acquired information through Geographic Information Systems (GIS) to map areas of interest. This paper aims to prove the feasibility of using drones to validate land use mapping, and to present an automatic recognition system of degraded land cover areas from captured images. The mapping was carried out in the mangrove region of the north of Libreville (Corisco Bay) at the mouth of the Rio Mouni River. The classification validation presented here used a small Multirotor quadcopter for aerial image capture, whose process to identify mangrove vegetation was developed through PIX4D software. The results show the efficiency of drone use for validation, especially in difficult sites, and that the developed system has a considerable accuracy to recognize degraded areas.

Keywords: Mangrove, Drone, Environmental Monitoring, Libreville, Gabon.

LE DRONE COMME OUTIL AUXILIARE DE CARACTERISATION DES MANGRONES DEGRADEES AU NORD DE LIBREVILLE – NO/GABON

RÉSUMÉ

Les véhicules aériens sans pilote (UAV), communément appelés drones, sont de plus en plus populaires dans les tâches quotidiennes en raison de leurs caractéristiques avantageuses. Dans les études environnementales, l'imagerie aérienne permet d'analyser (par photo-interprétation, par exemple) ou de traiter les informations acquises grâce aux Systèmes d'Information Géographique (SIG) pour cartographier les zones d'intérêt. Cet article vise à prouver la faisabilité de l'utilisation de drones pour valider la cartographie de l'utilisation des terres et à présenter un système de reconnaissance automatique des zones d'occupation des terres dégradées à partir d'images capturées. La cartographie a été réalisée dans la région de mangrove au nord de Libreville (baie de Corisco) à l'embouchure de la rivière Rio Mouni. La validation de la classification présentée ici a utilisé un petit quadricoptère *Multirotor* pour la capture d'images aériennes, dont le processus d'identification de la végétation de la mangrove a été développé via le logiciel PIX4D. Les résultats montrent l'efficacité de l'utilisation du drone pour la validation, en particulier dans les sites difficiles, et que le système développé a une précision considérable pour reconnaître les zones dégradées.

Mots clés : Mangrove, Drone, Surveillance Environnementale, Libreville, Gabon.

1. INTRODUCTION

Environmental monitoring is a complex task and usually involves the use of satellite images to verify land cover. These images can be georeferenced and analyzed through digital image processing techniques in a Geographic Information System (GIS).

Drones (UAVs) were initially developed for military applications. Nowadays, they are increasingly used around the world in various applications, extending to environmental mapping and monitoring of certain areas. They have various advantageous characteristics, such as the ability to travel safely at a considerable distance, a reduced time and a lower cost, and to obtain images on cloudy days. From an aerial image, it is possible to check vegetation faults and to identify several types of land cover and use in a region. Small Drones do not exceed 10 kilograms. They have the ability to perform autonomous flights, based on a pre-programmed, GPS-aided or remotely controlled flight plan data link.

The environmental applications of drones are the most widely used in agriculture. For example, a drone can be used to verify possible vegetation or maintenance abnormalities as shown in HERWITZ et *al*. (2004). Here the Pathfinder Plus model NASA, flying over US airspace, monitored a coffee plantation located in Hawaii. It collected images for several hours through coupled high-resolution cameras to identify pockets of invasive weeds, abnormalities in irrigation or fertilization. The model presented by AHMAD et *al*. (2013) deals with obtaining aerial images to use in several applications such as thematic and topographic mapping using the CropCam model, produced in Canada. This drone, self-guided by GPS, produces digital images from a high resolution camera and then used in GIS. It proves suitable for covering small areas, allowing environmental processes mapping such as landslides, coastal erosion or deforestation. There is also an increasing use of drones for urban cadastral applications, as shown by the study of MANYOKY & *al*. (2012) where Huanglongbing (HLB) infestation, a very destructive disease found in citrus agriculture, is demonstrated in Brazil.

In many other situations, the use of drones may be essential for monitoring, because, as described by MANYOKY & *al*. (2012), the task of conventional landscape mapping presents some difficulties: site inaccessibility to validate data, precise mapping impossible by satellite images. Finally, these limitations are making it impossible to visualize the complex diversity of coverage and use of the region, thus the importance of drone use.

In Gabon, drone use is beginning to spread. It is used for conservation tasks (PATTON, 2013), oil production installation mapping (NYF, 2014), and even to collect images and biomass from the blow of whales (WOLINSKY, 2017). Recently, the Gabonese Agency for Spatial Observation and Study (AGEOS) has invested in the acquisition of some platforms capable of operating in various land cover and use areas, developing spatio-maps capture for different applications, as well as in aircraft projects for forest applications.

The aim of this work is to prove the feasibility of using a small-scale multirotor drone to validate land use mapping and land use typologies through aerial images, as well as to present an image processing system capable of automatically identifying areas of degraded mangroves inside of a vegetation cover. This work is relevant because it presents a low cost solution capable of assisting environmental analysis, especially in regions with difficult human access. It also helps identifying and estimating the percentage of exposed soil in a fast and precise way. Section 2 presents characteristics of the system's functionalities for the detection of exposed soil areas, as well as the methodology used for validation. In section 3, the results are presented with some images obtained by the UAV and an example of estimation of areas of interest in the image. Finally, section 4 presents the final considerations.

2. MATERIALS AND METHODS

The first part describes the methods used in the implementation of the algorithm for image processing, involving preprocessing and segmentation steps. The second part presents the methods used for the validation of dominant landscape groups.

Aerial images were obtained by a DJI quadcopter Phantom 3 Advanced model (Figure 1) remotely controlled to fly over the mouth of the Rio Mouni River, located in the North of Libreville. This drone uses a coupled RGB camera and captures images with a resolution of 1280 x 720 pixels. Such images are used to validate mapping. The image processing system allows to identify and generate percentage data of degraded mangroves areas in relation to areas of natural mangroves vegetation.

Figure 1: DJI quadcopter Phantom 3 Advanced Model used for obtaining images.

Source: D. Moukétou-T., 2017.

2.1. Image processing

The image processing steps used in this work consists of transforming optical images in binarized images, so that the exposed soil area is highlighted in relation to the vegetation area. For this, the system must first perform all the necessary pre-processing of the images. The Pix4D software used, automatically processes terrestrial and aerial imagery acquired by light-weight drones or aircraft using its innovative technology based purely on image content. This desktop software converts the images into highly precise, timely and customizable results for a wide range of GIS and CAD applications.

The representation of a digital image $f\ (x, y)$ can be organized into a numerical data matrix, where the point of intersection of a line and a column is called a pixel. It stores the value of light intensity, or gray level, in the coordinate of the pixel. Digital image processing consists of changing values of this numerical matrix in order to modify some parameters of the image for the execution of certain tasks. The method implemented is based on the GONZALEZ study (WOODS, 2010). It divides an image processing system into three processes, from acquisition to recognition: low, medium and high level, according to Figure 2. As the intention of this work is to evaluate the feasibility of using drone and the potential failures in the identification method, some stages of the processing will not be detailed. The result presented in this paper is obtained from regular preprocessing and segmentation of images.

Figure 2: All the workflow of the data acquired by a drone (Remotely Piloted Aircraft System, RPAS)

Source: https://pix4d.com/

Preprocessing, for example, noise reduction using a spatial Gaussian filter, aims to improve the image and facilitate following steps. Preprocessing performed on images transforms the original images into grayscale allowing the thresholding step to be performed. It is then implemented through the parameter *cvtColor* available in the Pix4D library. The threshold stage was used (ROSIN; IOANNIDIS, 2003) to form an image composed of light objects on a dark background so that the pixels of the object and background had intensity values grouped into two dominant groups.

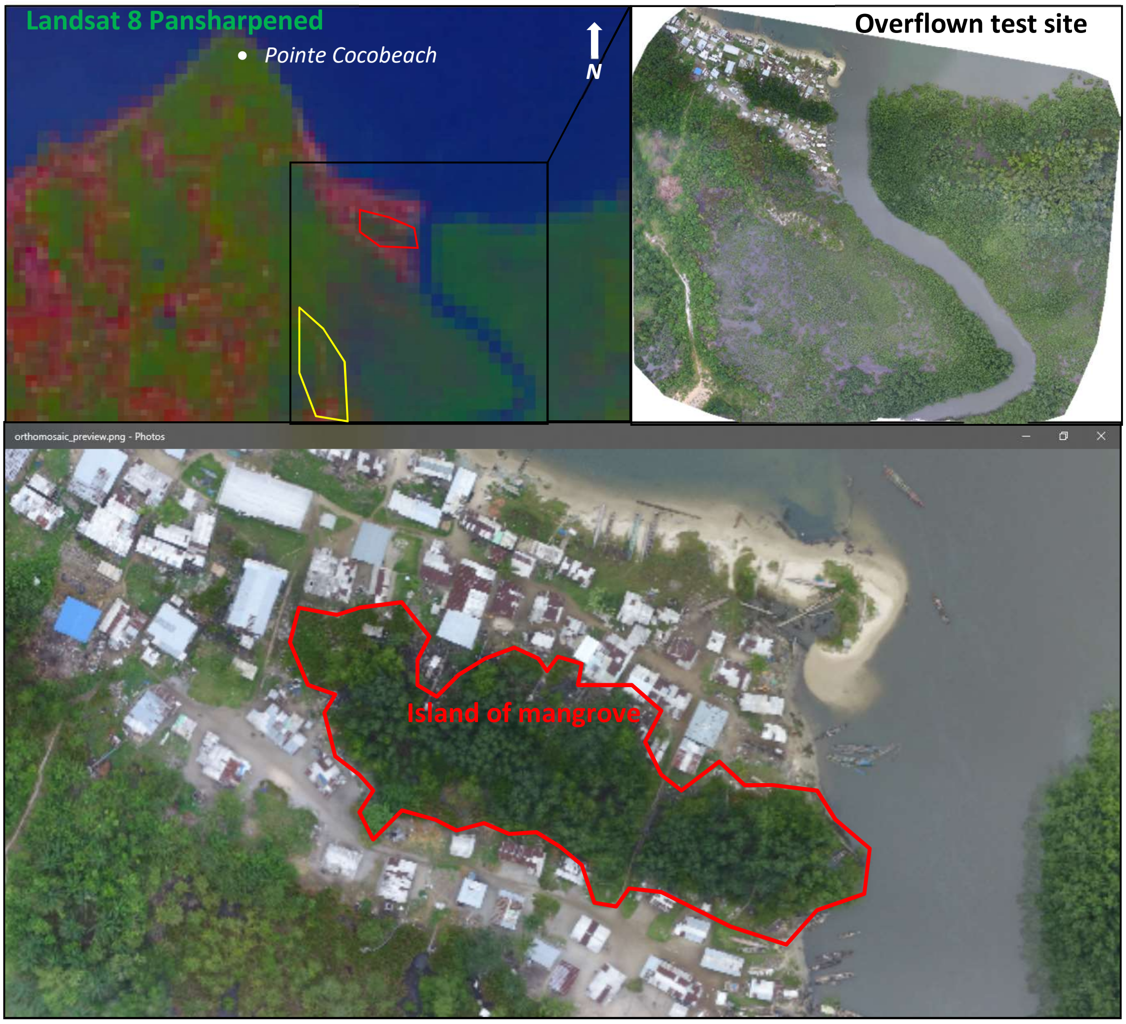
The thresholding function used a TT = 200, which means that pixel values less than 200 will be set to zero. Pixels at 200 or over are set to a one value. A binarized image is obtained. The value TT was initially tested, so as to expose soil areas were best represented. The value varies according to the type of vegetation, due to the intrinsic characteristics belonging to the group of images.

Image segmentation was based on the watershed technique which deals with a popular image segmentation algorithm and consists of the visualization of a three dimensional image similar to a topographic surface. Spatial coordinates xx and yy are present and the height is equal to the gray level of the corresponding pixel. This step consists in highlighting the two dominant groups of pixels in the preprocessed image, so that the final result can unite disconnected pixels with the same intensity, removing small white noises and generating an output image highlighting the areas of interest. A part of the code is responsible for counting the pixels, whose value can be 0 (zero) or 255, respectively, representing the black and white colors of the binarized image. An error percentage can then be calculated.

2.2. Validation step

Mapping is based on the Landsat 8 satellite images (Figure 3a), with spatial resolution of 15 meters (Panchromatic) and 30 meters (Multispectral) with a low cloud cover. However, due to the extension of the mapped area and the presence of some cloud cover, the acquisition of terrestrial ground truth points (GTP) for orbital remote sensing data validation was essential. Thus, fieldwork was carried out with the objective of acquiring geographic coordinates of mangroves types, areas and uses. In some places, natural conditions (closed mangrove and flood areas, for example) prevented access to the exact location selected for geographic coordinates collection. With drone use (Figure 3b), this limitation was overcome and it was possible to acquire GTP data to validate mapping results. Thus, the aerial imaging performed with drones establishes new quality standards in relation to the spatial resolution of the images acquired in aerial **surveys.**

Figure 3: Landsat 8 OLI/TIRS satellite image of the study area (Up left) and the Test-site overfly (Up right) located in black on Landsat 8 OLI. The red and yellow circles show respectively remnants of mangrove forests and an access track to a mangrove wood exploitation area for coal.



Source: D. Moukétou-T., 2018.

Due to the high resolution images obtained, data extraction for identification, description and analysis of mangrove health become more reliable and faithful to the field reality (spatial and vegetation cover description and identification).

3. RESULTS AND DISCUSSION

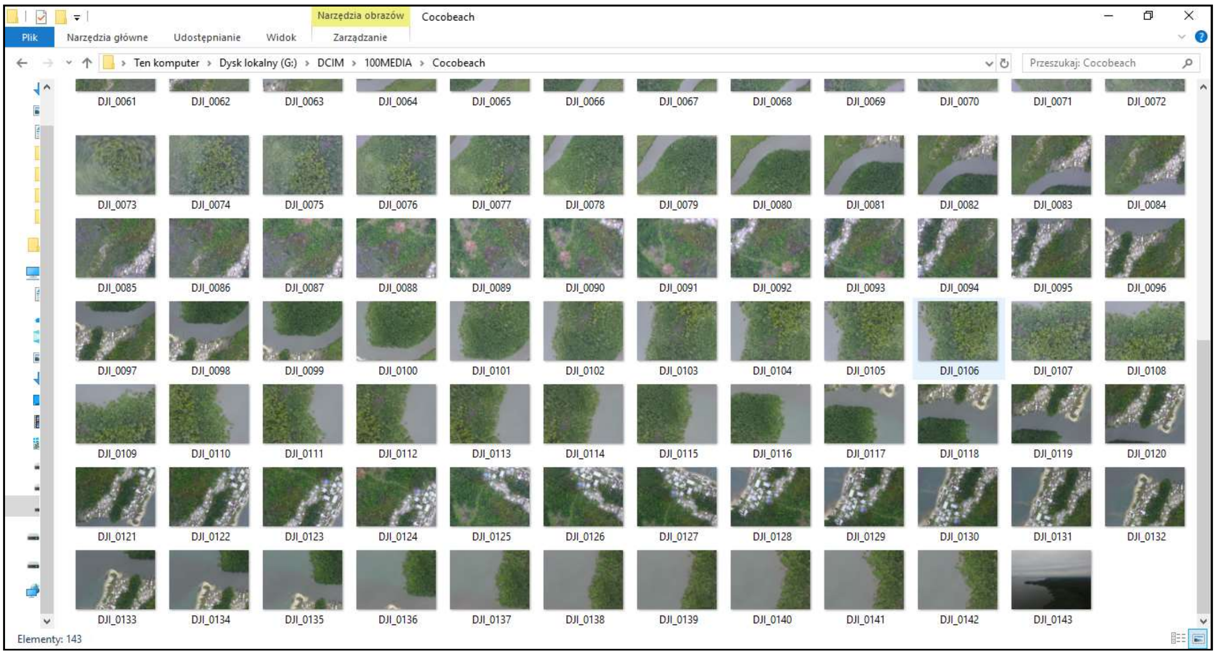
With drone use, it is possible to identify areas with greater accuracy in comparison to satellite images, particularly to visualize deforested mangrove areas by charcoal production and to classify the species of the study area.

Two field campaigns in a difficult-to-access mangrove area covered by clouds in the satellite image, confirmed the feasibility of using the drone. The first field trip was carried out by a team of researchers and students of the Lagrac laboratory (UOB) and necessitated a great walking/climbing effort (Figure 4) in order to verify the typology where the clouds were overlapping data in the satellite image. A second field campaign was carried out at the same site and it took only fifteen minutes to obtain aerial images (high resolution) and complete the ground measurements with sufficient quality for a reliable coverage analysis (Figure 5).

Figure 4: Examples of the necessary team deployment for drone and ground data collection on mangrove forests in the North-West Gabon: Akanda National Park (a & b), Donguila (c), Pongara National Park (d)

Source: D. Moukétou-T., 2017.

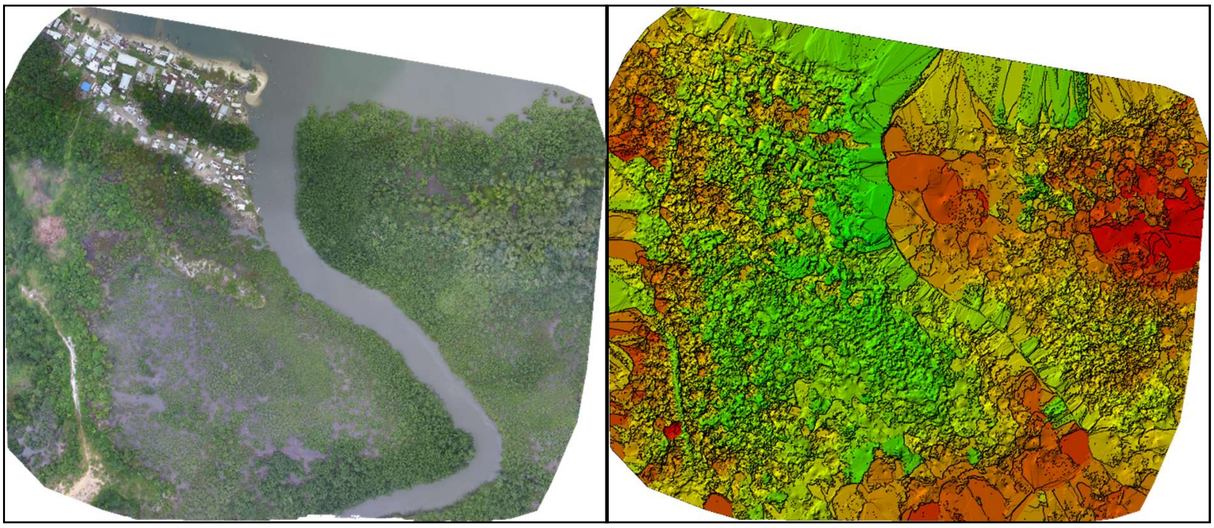
Figure 5: Examples of aerial images obtained by the Phantom 3 Advanced quadcopter.



Source: D. Moukétou-T, 2017.

As for multirotor quadcopter Phantom 3 Advanced image processing, there is a considerable accuracy in degraded mangrove area identification (comparison between Figures 6a and 6b). Although the obtained images present a slight distortion of geometry due to the characteristics of the camera used, it is possible, in addition to visual analysis, to approximate a percentage of degraded mangrove areas. For the study area, the software calculated an approximate percentage of 3.65% of degraded mangrove area in the image presented in Figure 6b. This physiognomy analysis applied to forestry helps comparing plant density areas (high or lower density, absence of the trees).

Figure 6: Preprocessing generated orthomosaic (a) and the output preprocessing generated (b).



Source: D. Moukétou-T., 2017

The results obtained in this article involved several stages of preprocessing to improve input images, avoiding any kind of manual preprocessing. Thus, the original image is inserted into the program that will perform the processing and will result in a binarized output with the approximate calculation of the area of failure, reducing the human effort to process the images and obtain results, optimizing the analyzes of the generated data.

The remote sensing data obtained by drone is classified in the very high spatial resolution, which then makes it possible to identify elements such as gaps due to naturally dead trees or to identify establishments of illegal immigrants, illegal housing estates and even to validate the results obtained from data of satellite platforms. All these elements indicate the degree of anthropization of the mangroves in the sector studied, corroborating the ideas already presented in previous studies.

It should be noted that the level of data detail collected by drone is not limited to spatial resolution but extends up to temporal resolution. The same test sites for the study of mangroves can be revisited in a short time interval, in the order of a week, a day or even an hour on the same day. All of the features of this remote sensing platform open up a range of possibilities in mangrove studies, including enabling studies that were previously unfeasible from field data, aerial photographs and/or satellite platforms. In short, the drone comes as a complementary and supportive tool to the old methods and techniques of studying mangroves, reputed to be very hostile and difficult to access ecosystems.

4. CONCLUSION

Drone use contributes to the optimization of agricultural studies, as well as natural and cultural environmental studies. It reduces expenses significantly and generates very high precision data. The recognition system of degraded mangroves areas contributes to a quick image analysis, to an accurate diagnosis and a swift decision making.

The obtained results demonstrate that drone use gives us the means to observe our environment from a new angle, at a much higher resolution than the usual satellite imagery. It is an important complementary tool to fieldwork as we strive to better understand these complex and very difficult ecosystems.

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This study reaches the expected objective, contributing through a low cost solution for the correct identification of regions of interest, which, in this case, is degraded mangrove vegetation cover, through an efficient light system.

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