Received: April 19, 2023
Accepted: 21 July 2023

EVOLUTION AND RECOVERY OF PASTURES TO OPTIMIZE LIVESTOCK NUTRITIONAL YIELDS BY INTERPRETING NORMALIZED VEGETATION INDICES USING MULTISPECTRAL SURVEYS

EVOLUCIÓN Y RECUPERACIÓN DE PASTURAS PARA OPTIMIZAR LOS RENDIMIENTOS NUTRICIONALES DE LOS SEMOVIENTES INTERPRETANDO LOS ÍNDICES DE VEGETACIÓN NORMALIZADA USANDO LEVANTAMIENTOS MULTIESPECTRALES

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Cómo citar: Gualdrón Guerrero, L. D., Gualdrón Guerrero, O. E., & Maestre Delgado, M. (2023). EVOLUCIÓN Y RECUPERACIÓN DE PASTURAS PARA OPTIMIZAR LOS RENDIMIENTOS NUTRICIONALES DE LOS SEMOVIENTES INTERPRETANDO LOS ÍNDICES DE VEGETACIÓN NORMALIZADA USANDO LEVANTAMIENTOS MULTIESPECTRALES. REVISTA COLOMBIANA DE TECNOLOGIAS DE AVANZADA (RCTA), 2(42), 105–114. Recuperado a partir de https://ojs.unipamplona.edu.co/index.php/rcta/article/view/2701

Resumen: La agricultura de precisión ha experimentado avances significativos mediante el aprovechamiento de tecnologías como el uso de drones y la captura de imágenes espectrales. La aplicación del índice NDVI (Normalized Difference Vegetation Index) se ha convertido en una herramienta clave para la identificación de coberturas vegetales, permitiendo analizar la salud de los cultivos con gran precisión y la estimación del área ocupada según la densidad de biomasa. La combinación de estas tecnologías facilita la generación de tasas de crecimiento diario de la vegetación, lo que resulta fundamental para proyectar la recuperación de pasturas. En este trabajo, el NDVI se empleó para evaluar la salud y prever la necesidad de ajustes en la gestión y manejo de la pradera y los requerimientos del pasto kikuyo, Las proyecciones basadas en estos datos ofrecen una herramienta valiosa para la toma de decisiones, asegurando que las estrategias de recuperación de pasturas sean adecuadas y efectivas a medida que se optimizan los rendimientos para la nutrición de semovientes. El presente artículo se enfoca en el seguimiento de la evolución de la pastura de kikuyo, específicamente en un predio del municipio de Pamplona, Norte de Santander, la ventana de tiempo para el desarrollo del seguimiento se determinó en cuatro meses, en los cuales se efectuó un levantamiento multiespectral por mes, con la información obtenida se determinaron tasas de crecimiento diario y la proyección de los días para el restablecimiento del pasto, concluyendo que los tiempos de reposo de las praderas para un adecuado manejo es inversamente proporcional a la cantidad de área cubierta con material vegetal en óptima condiciones al inicio del restablecimiento de la pradera.

Palabras clave: NDVI, imágenes multiespectrales, drones, caracterización de suelos.

Abstract: Precision agriculture has experienced significant advances by taking advantage of technologies such as the use of drones and the capture of spectral images. The application of NDVI (Normalized Difference Vegetation Index) has become a key tool for the identification of vegetation cover, allowing for the accurate analysis of crop health and the estimation of the area occupied according to biomass density. The combination of these technologies facilitates the generation of daily vegetation growth rates, which is essential for projecting pasture recovery. In this work, NDVI was used to assess the health and anticipate the need for adjustments in pasture management and kikuyo grass requirements. Projections based on these data provide a valuable tool for decision making, ensuring that pasture recovery strategies are appropriate and effective as yields are optimized for livestock nutrition. This article focuses on monitoring the evolution of kikuyo pasture, specifically in a farm in the municipality of Pamplona, Norte de Santander, the time window for the development of the monitoring was determined in four months, in which a multispectral survey was carried out per month, and with the information obtained, daily growth rates and the projection of the days for the reestablishment of the grass were determined.

Keywords: NDVI, multispectral images, UAV, soil characterization.

1. INTRODUCTION

In the Colombian agricultural context, the incorporation of new technologies faces several challenges (Garbero and Jäckering, 2021). One of the most outstanding challenges is the efficient management of economic resources, especially the reduction of agrochemical inputs. In this sense, the inclusion of spectral images emerges as a key strategy to optimize the use of inputs, allowing a more precise and targeted application (Cordero et al., 2020; Talaviya et al., 2020). This approach not only contributes to environmental sustainability by reducing pollution, but also represents a more effective management of natural resources (Bwambale et al., 2022). The combination of innovative technologies not only seeks to improve agricultural productivity (Griesche and Baeumner, 2020), but also addresses the need to harmonize technological progress with the preservation of the environment, thus promoting a sustainable balance.

The Normalized Difference Vegetation Index (NDVI) stands out as an essential tool in assessing vegetation status. This index uses spectral measurements to quantify plant health, providing valuable information on the quantity and quality of vegetation (Pelaez et al., 2020). NDVI's ability to detect changes in plant cover over time makes it a key tool for monitoring crop health and
prevent potential problems. Its wide use in precision agriculture allows farmers to make efficient and sustainable decisions (Cordero et al., 2020; Vecchio et al., 2020).

The deep exploration of the subject begins by understanding the behavior of electromagnetic waves, focusing particularly on their incidence on the leaves of plants and how they react to be reflected or absorbed. This fundamental knowledge lays the foundation for addressing multispectral image acquisition as an essential tool that captures in detail the aforementioned interaction (Deng et al., 2018). These images, by revealing the phenological characteristics of crops and soils, stand out as a valuable resource for understanding and analyzing the health of vegetation, establishing a bridge between the behavior of electromagnetic waves and their practical application in agriculture (Eddy et al., 2017).

The incorporation of standardized indices in the different sectors of Colombian agriculture in order to improve economic performance, makes it necessary to develop feasibility investigations and its proper implementation, the present research focuses on the recovery times of the pasture meadows, for a good management and performance of the areas assigned to grazing is essential to identify when they have been fully restored to provide good nutrition to livestock, which allows for increased milk production or weight gain in individuals, the percentages of areas occupied by the coverages identified by means of the NDVI index were monitored, the evolution of the Kikuyo pasture was monitored on a site in the municipality of Pamplona Norte de Santander, the time window for the development of the follow-up was determined in four months, in which a multispectral survey was carried out per month, with the information obtained we determined daily growth rates and projected days for the restoration of pasture.

2. METHODOLOGY

There are multiple methodologies that allow the best implementation of this type of monitoring technologies in which not only images in different light spectra can be acquired but also RGB images (Xie and Yang, 2020) with which level curves and high quality images can be obtained with metadata regarding the global positioning at the time they were acquired (Singh and De Silva, 2018). In the international market there are different types of sensors that stand out for the quality of images they acquire (RadhaKrishna et al., 2021) In addition, we can also count on monitoring by means of ground observation satellites that are very useful in the agricultural sector (Chuchico-Arcos and Rivas-Lalaleo, 2021; Whitcraft et al., 2022).

In this work a series of activities were developed that allowed a successful multispectral survey (Rivera, Bonilla and Obando-Vidal, 2021), since thanks to the information collected it was possible to generate orthophotomosaics where all the images acquired by the property are condensed, following the same methodology for all the properties.

Among the initial activities for the development of the project are the collection of geographical numerical data of the hectares of land that are the subject of study, using the Magna Bogotá reference system, in order to generate flight plans that will be followed by the unmanned aerial vehicle under autonomous flight mode (Modica et al., 2020).

The aerial vehicle has a built-in sensor capable of perceiving electromagnetic radiation with different wavelengths, highlighting specifically five spectral bands: red, green, blue, near infrared and red edge (Fern et al., 2018). The sensor was selected taking into account the number of available bands, in addition to the weight and the ability to store the information in a high-speed write SD memory, which rules out the possibility of loss of images. The resolution of the camera is 8 cm per pixel at 120 m with capture speeds of up to 1 capture per second.

The image acquisition process began by establishing the points of the polygons corresponding to the boundaries of the land to be sampled, performing a visual inspection defining the physical properties of the terrain and identifying possible obstacles that the unmanned aerial vehicle may face in order to avoid accidents. The global positioning system points are obtained by means of kinetic real-time satellite navigation equipment, obtaining a high accuracy of the positioning acquired.

Once the polygons have been defined, flight plans are created in which the altitude at which the image acquisition will be performed is configured, setting the parameter between 100 and 120 m and the flight speed. The flight plan is executed by the vehicle under the supervision of the pilot in charge of the aircraft if intervention in any maneuver is necessary. Figures 1 and 2.

Fig. 1. Flight plan
Source: own of the author.

Image processing requires the use of photometry software that allows the

manipulation of RGB and multispectral images. Pix4D software was used on this occasion, which allows: capture images with any camera, transform images into digital models, manage quality reports and calibration details, measure distances areas and volumes and extract elevation profile data. On the other hand, it allows to calculate different vegetation indices among them the NDVI, which was the index selected for the current work.

Once multispectral orthomosaics are obtained for each of the locations, the images are presented with their proper georeferencing, in addition the results of the percentages of areas covered are grouped, in seven intervals in which the vegetation indices of normalized difference condensed into a table are categorized

Fig. 2. Drone with a multispectral camera
Source: own of the author.

3. RESULTS

In order to calculate the prairie rest time, the annual rate of change of the area covered by different coverages (TCDC) was applied to the area identified as highly optimal according to the data obtained in the interpretation of the multispectral image, allowing the identification of rates of growth of the pasture under study, by means of the exponential population growth equation with which the projection of time is made where the meadow should remain without grazing activity.

3.1 Interpretation of the first overflight.

The first multispectral survey was carried out on a pre-selected plot in the municipality of Pamplona, located in the department of Norte de Santander. The purpose of this

survey was to identify the different types of coverage present in the study area and determine the percentage of area covered. The information gathered in this process is established as the starting point for a multi-temporal analysis of the evolution of kykuyo grass. This approach enables clearer viewing and improved understanding of the data over the selected time interval. In addition, the number of samples defined in this multispectral survey is crucial for the interpretation of the evolution of coverage, which ensures a more accurate analysis and a more complete interpretation of the collected data. Figure 3 shows an Orthomosaic image of the area corresponding to the property.

Fig. 3. Orthomosaic of the premises.
Source: own of the autor

With the information of the infrared and red bands a multispectral orthomosaic is generated based on the normalized vegetation index (NDVI), which is generated by the normalization of the spectral bands mentioned above.

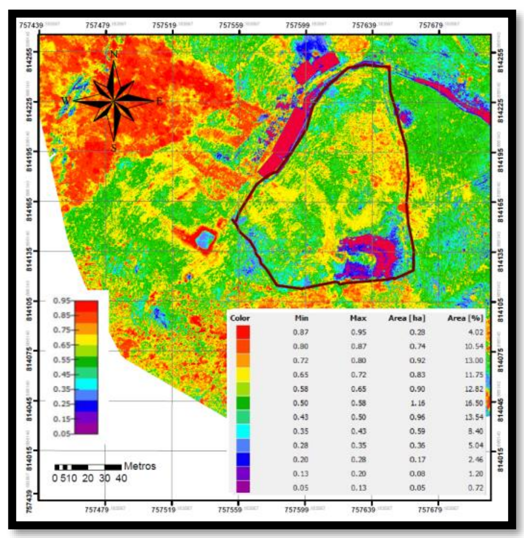

Fig. 4. Multispectral orthomosaic of the site.
Source: author's own

The values of the index are between -1 and 1, in the interpretation of the index the values close to 1 are considered areas with greater amount of biomass and the values close to zero are interpreted as zones without coverage present, finally the values below zero are categories of possible water footprint, rock or areas without information.

Table 1: Classification of identified coverages

Category	NDVI interval		Area (%) First Overflight
	Min	Max	
Highly Optimal	0,75	1,00	14,60
Óptimal	0,50	0,75	54,10
Low Vegetation Cover	0,25	0,50	27,00
Zero Vegetation Cover	0,00	0,25	4,40
Zero Coverage (Possible Water Footprint)	-0,30	0,00	0,00
Zero Coverage (Rocks)	-0,60	-0,30	0,00
Null	-1,00	-0,60	0,00

The analysis made it possible to classify 68.7% of the area, indicating a high cover of green grass that is suitable for livestock feeding. Similarly, 27% of the studied territory is associated with green grass of reduced cover, probably due to processes of forage regeneration after grazing of livestock or in early phenological phases. The interpretation of the NDVI index suggests that this percentage could also represent dry grass areas, indicative of water stress or an intermediate phytosanitary status due to the presence of pests or diseases. Finally, the analysis revealed that 4.4% of the area consists of bare soils.

3.2 Interpretation of the second overflight.

As previously indicated, a second multispectral survey was carried out on the same plot, with a lapse of one month with respect to the first overflight. The main purpose is to identify the percentages of area covered at the time of data acquisition of existing plant material. This makes it possible to evaluate the evolution of the plant material between the two overflights. Figures 5 and 6 show the orthomosaics resulting from the processing of multispectral images.

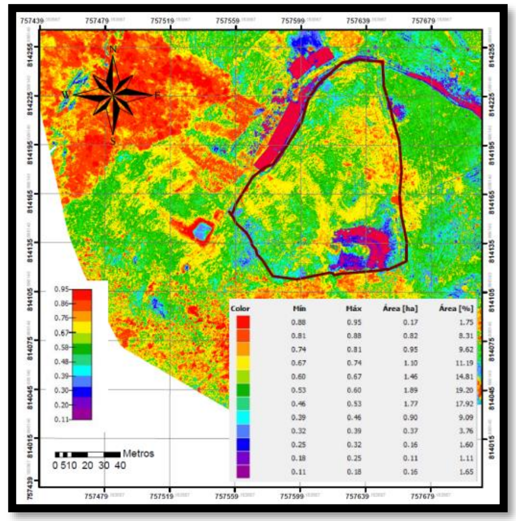

Fig. 5. Spectral orthomosaic second overflight
Source: own of the author

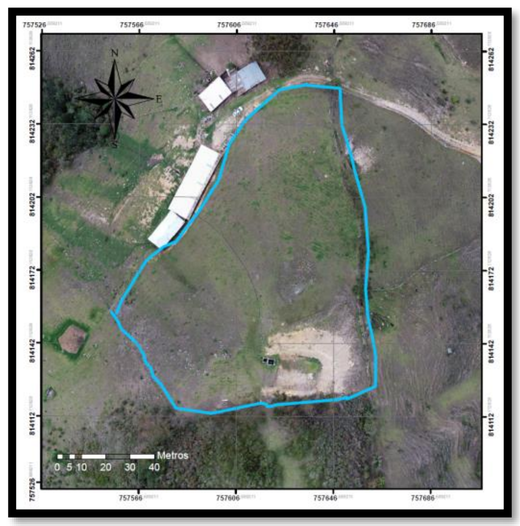

Fig. 6. Orthomosaic of the second overflight
Source: own of the author

Based on the reclassification of the NDVI index, the percentage area of coverage present in the study area was identified, which are presented in Table 2 below

Table 2: Classification of NDVI intervals of the site

Category	NDVI interval		Area (%) Second Overflight
	Min	Max	
Highly Optimal	0,75	1,00	19,68
Óptimal	0,50	0,75	45,20
Low Vegetation Cover	0,25	0,50	32,37

Category	NDVI interval		Area (%) Second Overflight
	Min	Max	
Zero Vegetation Cover	0,00	0,25	2,76
Zero Coverage (Possible Water Footprint)	-0,30	0,00	0,00
Cero Cobertura (Rocas)	-0,60	-0,30	0,00
Nulo	-1,00	-0,60	0,00

The analysis made possible the classification of 64.68% of the area, indicating a high cover of green grass that is suitable for livestock feeding. Similarly, 32.37% of the studied territory is related to green grass with reduced cover, probably due to processes of forage regeneration after grazing of livestock or in early phenological phases. The interpretation of the NDVI index suggests that this percentage could also represent dry grass areas, indicative of water stress or an intermediate phytosanitary status due to the presence of pests or diseases. Finally, the analysis revealed that 2.76% of the area consists of bare soils.

3. 3 Behavior of coverages.

The evolution of the coverage of the study area within the time window between the first and second multispectral surveys, from the obtained data is interpreted that the highly optimal coverage presents a gain of 508 m2, in the optimal coverage a loss of 890 m2 is presented, in the area identified as low coverage presents a gain of 537 m2, finally the areas where no vegetation cover is identified presents a loss of 164 m2

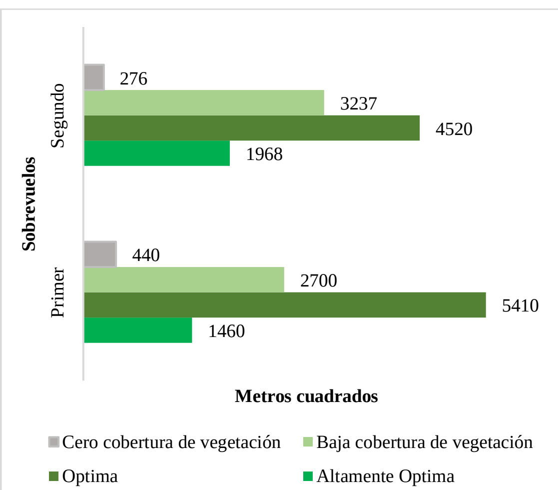

Fig. 7. Vegetation cover behaviour

3.4 Interpretation of the third overflight.

With the third multispectral shot the data for the identification of the evolution of the plant material is strengthened, which develops one month after the second shot, in figures 8 and 9, Orthomosaics resulting from multispectral image processing are displayed.

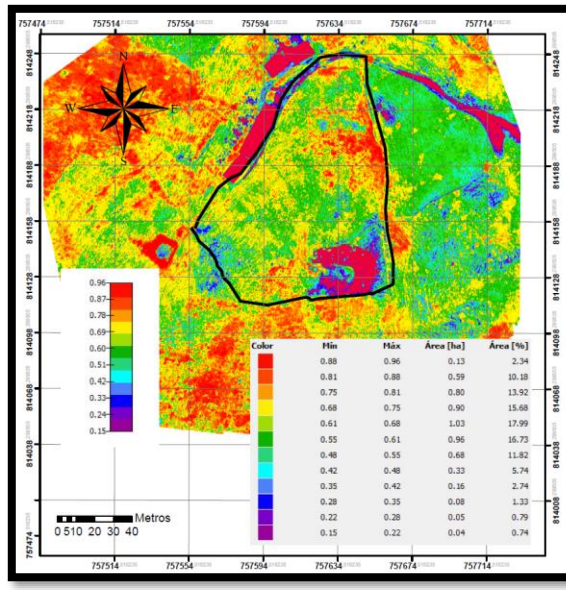

Fig. 8. Multispectral orthomosaic third overflight.
Source: author's own

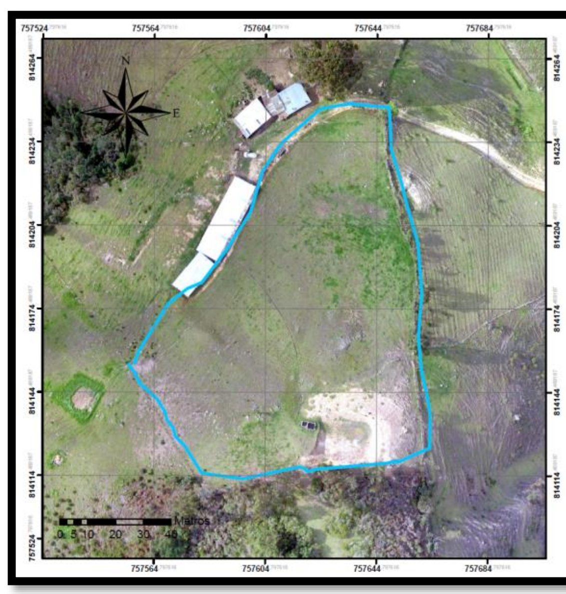

Fig. 9. Orthomosaic third overflight
Source: own of the author

Based on the reclassification of the NDVI index, the percentage area of coverage present in the study area was identified, which are presented in Table 3 below

Table 3: Classification of NDVI intervals of the site in third overflight

Category	NDVI interval		Area (%) Third Overflight
	Min	Max	
Highly Optimal	0,75	1,00	26,44
Óptimal	0,50	0,75	62,22
Low Vegetation Cover	0,25	0,50	9,81
Zero Vegetation Cover	0,00	0,25	1,53
Zero Coverage (Possible Water Footprint)	-0,30	0,00	0,00
Zero Coverage (Rocks)	-0,60	-0,30	0,00
Null	-1,00	-0,60	0,00

The analysis made it possible to classify 88.66% of the area, indicating a high cover of green grass that is suitable for livestock feeding. Likewise, 9.81% of the studied territory is related to green grass of reduced cover, probably due to processes of forage regeneration after grazing of the cattle or in early phenological phases. The interpretation of the NDVI index suggests that this percentage could also represent dry grass areas, indicative of water stress or an intermediate phytosanitary status due to the presence of pests or diseases. Finally, the analysis revealed that 1.53% of the area consists of bare soils.

3.5 Behavior of the coverages.

The evolution of the coverage of the study area within the time window between the second and third multispectral surveys, from the obtained data is interpreted that the highly optimal coverage presents a gain of 676 m2, in the optimal coverage a gain of 1702 m2 is presented, in the area identified as low coverage presents a loss of 2256 m2, finally the areas where no vegetation cover is identified presents a loss of 123 m2

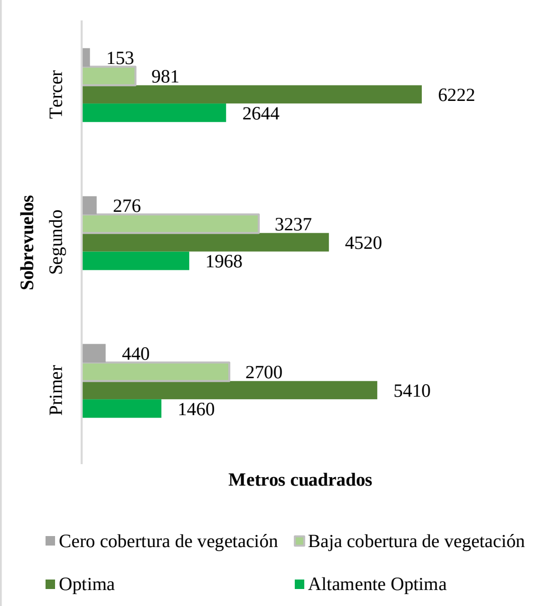

Fig. 10. Vegetation cover behaviour from first to third overflight
Source: own of the autor

From the above it can be interpreted that the meadow is in a process of regeneration, which is evidenced by the loss of the categories with lower presence of biomass and the gain of the cover with greater forage, A daily growth rate of 1.14% can be calculated, determined that in the meadow to restore the highly optimal coverage in its entirety since the taking of the third multispectral survey will be approximately 116 days.

3. 6 Interpretation of the fourth overflight.

Finally, the fourth overflight as planned takes place with a one-month time window between the previous overflight, where it was possible to consolidate the required information aimed at identifying the percentages of area of each coverage present in the study area, allowing to visualize more precisely the evolution of the coverings and the projection of the time of restoration of the meadow.

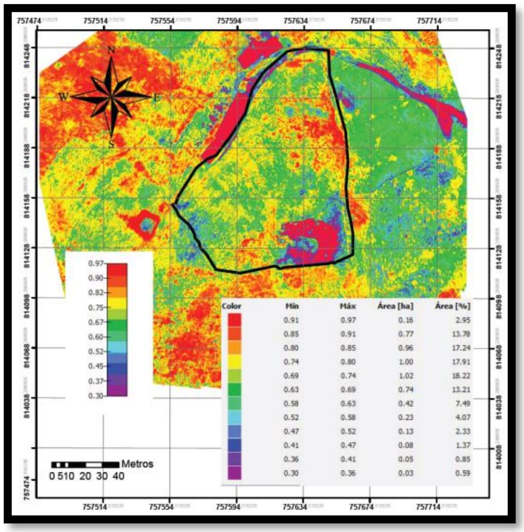

Fig. 11. Multispectral orthomosaic fourth overflight. Source: author's own

Fig. 12. Orthomosaic of the fourth overflight Source: own of the autor

Based on the reclassification of the NDVI index, the percentage area of coverage present in the study area was identified, which are presented in Table 4 below

Table 4: Classification of NDVI intervals of the site in fourth overflight

Category	NDVI interval		Area (%) Fourth Overflight
	Min	Max	
Highly Optimal	0,75	1,00	51,88
Óptimal	0,50	0,75	42,99
Low Vegetation Cover	0,25	0,50	5,14
Zero Vegetation Cover	0,00	0,25	0
Zero Coverage (Possible Water Footprint)	-0,30	0,00	0
Zero Coverage (Rocks)	-0,60	-0,30	0
Null	-1,00	-0,60	0

The analysis made possible the classification of 94.87% of the area, indicating a high cover of green grass that is suitable for livestock feeding. Similarly, 5.14% of the studied territory is related to green grass with reduced cover, probably due to processes of forage regeneration after grazing of livestock or in early phenological phases.

3.7 Behaviour of the coverages

The evolution of the coverage of the study area within the time window between the third and fourth multispectral surveys, from the obtained data is interpreted that the highly optimal coverage presents a gain of 2544 m2, optimal coverage presents a loss of 1923 m2, in the area identified as low coverage presents a loss of 467 m2, finally the areas where no vegetation cover is identified presents a loss of 153 m2

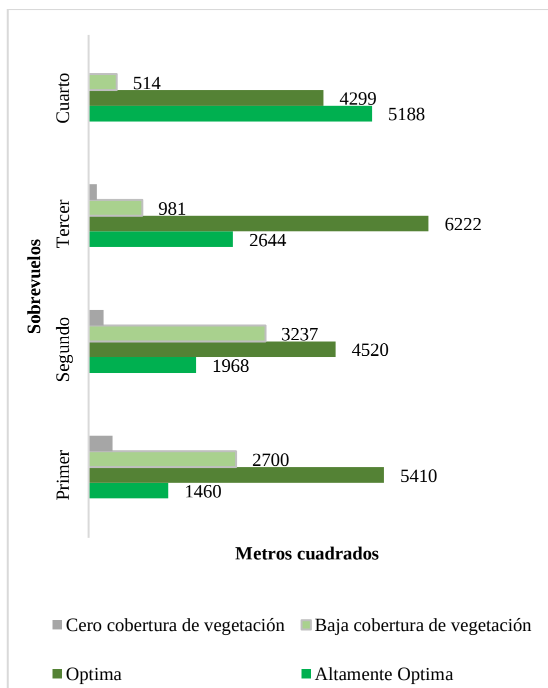

Fig. 13. Vegetation cover behavior from first to fourth overflight

From the above it can be interpreted that the meadow is in a process of regeneration, by the increase in the percentage of area of the highly optimal coverage and the loss of area of the other coverages, a daily growth rate of 3,21%, determined that in the meadow to restore the highly optimal coverage in its entirety since the taking of the third multispectral survey will be about 20 days.

4. CONCLUSIONS

Taking the data collected between the four multispectral surveys, it can be affirmed that the use of multispectral images with the normalization of the red and infrared bands for the generation of the NDVI index, it is an appropriate input in determining the percentage of area occupied in the reclassification intervals, as well as in the determination of coverages, thus enabling the state of pasture regeneration to be identified, as well as the determination of the growth rate for the projection of the remaining days that allow to restore in full its use, optimizing the decision making for proper management.

In the time window between the first and fourth spectral survey, a daily grass growth rate of 2.84% is identified, so the time required to restore one hectare of Kikuyo grass for its use is 67,82 days, starting from 1460 m2 of highly optimal coverage when the meadow enters in rest, concluding that the rest time is inversely proportional to the amount of area established in highly optimal coverage.

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