The Use of Image Processing Techniques for Detection of Weed in Lawns

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***Abstract*—The presence of weed plants in lawns disrupts their behavior and correct growth. Moreover, it implies a lack of uniformity, which is one of the most important factors of the lawns. The early detection of weeds is crucial to minimize the need for phytosanitary products. Image processing techniques and machine vision are widely used in many different areas such as agriculture, industry, or object identification. In this paper, we propose the use of image processing techniques to detect undesired grass species in the lawn. We utilize a drone with an Arduino module to take pictures. The obtained images are used to determine the best option to detect the presence of weeds. Pictures from different grass species with and without undesired weed species are used. The Red, Green and Blue (RGB) layers of each picture are mathematically combined in order to obtain a new raster layer to automatically detect the weed. Two different methods are used. Different equations offer different results depending on the weed species. We can detect two big groups of weeds with the first or with the second method, according to their color. Finally, the proposed formulas are verified with pictures taken with different solar conditions. An aggrupation method to minimize the false positives is shown.**

Keywords-grass lawns; weed plants; image processing; RGB bands; drone.

I. INTRODUCTION

In order to maintain a great appearance for grass surfaces, certain requirements need to be addressed. Due to the activities that are carried out on the grass or around it, the grass suffers from compaction and the leaves are broken. Some of the activities performed on the lawns are: certain sports, entertainment, and enjoyment in residential areas or in public gardens. The users of the lawns demand a series of requisites, being the most important one the visual aspect of the lawns. The visual aspect can be expressed as the uniformity of the lawn, the greenness of the grass and the absence of grassless patches.

The existence of weeds in lawns is a problem. On the one hand, the weed presence implies a lack of uniformity on the surface. This lack of uniformity is the first cause of users' disappointment. On the other hand, the weeds will generate competition between them and the grass species. For this reason, it is necessary to carry out specific actions to solve the weed problem as soon as possible.

It is crucial to detect the appearance of weeds during the first days. Otherwise, the weed can infest huge areas of the lawn and it will be more difficult to eradicate. Nowadays, the best available techniques to detect weeds are the aerial images of the visual inspection of the lawns. The first option, the use of satellite images, offers multispectral images. Nonetheless, they have small spatial resolution and small temporal resolution. Thus, when we detect the weeds with the satellite image it may be too late and would be necessary to apply the phytosanitary treatment to a large area. The second option, the visual inspection, is useful for small areas as a private garden. Nevertheless, for big areas such as golf camps or big public gardens, this solution is not applicable. Therefore, the use of pictures obtained with drones and their analysis can be a solution for large surfaces. The use of image processing is widely used in many different areas and for countless purposes. In agriculture, it has been used for illness detection [1] and for fruit maturity evaluation [2]. In aquaculture, it has been used for feed falling detection [3]. Moreover, it is used for face detection [4] and car license plate identification [5].

The aim of this paper is to present the use of image processing techniques for detecting the presence of weeds in lawns. Thus, a series of pictures were obtained from different lawns with the presence and absence of weed. All the pictures were taken under the same solar conditions. Different grass species and different weed species appear in the pictures. Part of the pictures will be used to train our system and the rest of them to verify our findings. The goal is to use this methodology to automatize the monitoring of lawns in terms of weed detection. Therefore, it will be possible to detect the weed and apply the phytosanitary products only in the affected area.

The rest of this paper is organized as follows. Section II presents the related work. Section III describes the proposal. Section IV addresses the obtained results. Section V summarizes the conclusion and future work.

II. RELATED WORK

In this section, we are going to compare other techniques utilized to detect weed in different crops.

The detection of weeds is an important issue for agriculture. Therefore, many scientists have work on their identification using pictures. The use of drones has increased the possibilities, and, in recent years, several papers have been published.

The use of image processing to determine the presence of weeds in maize fields was presented by X. P. Burgos-Artizzu in 2011 [6]. They detail a computer vision system that can be used with videos. They test their system under different light conditions. The system detects 95% of the weeds and 80% of the crops. A. Paikekari et al. presented in 2016 [7] an image processing methodology for weed detection. First, they use color to differentiate soil and grass. Then, the resultant image is converted into a greyscale picture to apply an edge detection technique. Finally, the resultant image of the edge detection is divided into 25 blocks. The analysis of each block determines if it contains weed with narrow leaves, weed with wide leaves, or crop. In 2018, J. Gao et al. [8] presented the use of aerial picture with an ultra-high resolution to detect intra and inter-row weed. They use a semi-automatic object-based image analysis with random forests. In addition, they use techniques to classify soil, weed, and crop. The authors applied this proposal to maize crop fields. The utilized pictures show the maize in the first days of growth. Their results have a coefficient of correlation of 0.895 and a squared mean error of 0.026. J. Marín et al. in 2017 applied simple image processing techniques in different publications to detect the grass coverage in lawns [9][10]. They work with the histograms of the grass pictures to determine the weight of the grass and the level of coverage (high, low, very low).

On the other hand, there are other types of studies focused on identifying different leaves affections. One example is the work developed by V. Khanaa and K. P. Thooyamani in 2017 [11]. They proposed an algorithm based on image processing. Their algorithm was able to detect different leave diseases, such as bacterial pith necrosis, early blight, white trail, and target spot among others.

III. Proposal

In this section, we detail the proposed system for lawns monitoring. The system is composed of a drone that flies over the lawn and takes photos. Then, the pictures are evaluated to determine where there are weeds in the lawn to program the application of phytosanitary products.

A. Drone

Our system uses a drone to take pictures of the lawn [12]. As long as we need that spatial resolution of 1mm, we should select a drone with a high spatial resolution flying at height altitude or drone with lower spatial resolution flying at a lower height. In order to calculate the flying height according to the camera resolution, we can use the equations proposed by Marin et al. in [10]. We are going to use an Arduino camera with 640X480 pixels and the flying height will be 2.3m.

It is important to note that for our proposal we are going to use a drone with no camera. We will add the above-mentioned camera connected to an Arduino node. The Arduino node will be in charge of taking pictures and analyzing them. On the other hand, the flying issues will be operated by the drone processor, not by the Arduino node. Thus, we can split the task into different processors and our system can be adaptive to different situations.

B. Image processing

Once the pictures were gathered by the drone, the node analyzes them. As we need a fast analysis because the processor should analyze the data during the flight, it is necessary to focus on simple image processing techniques. Therefore, we reduce our possibilities to the operations involving the RGB data of each pixel in the picture. These types of operations are common when we work with satellite images, which are multispectral images. Our challenge is to detect weed plants in the lawns with the combination of only 3 picture bands. The proposed system is shown in Figure 1, where one can see the different obtained bands and their names. Red, green and blue bands are named as Band 1, 2 and 3.

The first issue to be considered is that it is not possible to work with threshold values of only one of the layers because these values are greatly affected by sun exposure, the presence of clouds, and even the day of the year. Thus, we need to work with a mathematical combination of different bands to avoid this problem. The second issue is related to the values of the pixels. Each pixel has a value between 0 and 255 in each one of the bands. This value has no decimals and can only have a positive value. When we apply the mathematical combination, these rules are maintained, the resultant value of each pixel will be a positive value with no decimals. The last issue is the need of finding a way to assign values of 0 to the pixels that contain soil of dead grass. This should be done in order to avoid having false positives.

C. Studied lawns

The proposed system was tested in Finca El Encin, research facilities of the Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA) in Spain. There are small experimental plots where other scientists are testing multiple grass combinations. During their research, different weed plants appear in their lawns. We use their experimental plots to take pictures of different types of lawns with and without the presence of weed plants. By using this experimental plot, we ensure that we will have lawns with different types of grass and under different environmental conditions.

IV. Results

In this section, we show the obtained pictures and their processing to determine the presence or absence of weeds. First, we show the process to obtain the equations to detect the weed. Finally, we present its verification.

D. Image processing: soil removal

The image processing method is shown in this subsection. First, Table 1 presents the RGB pictures in four different cases. The first one is a lawn with low grass coverage and with the presence of weeds at the top-center part. The weed has darker coloration than the grass. Furthermore, it presents higher relative values in the blue band, compared with the rest of the grass. Picture 2 is taken in a lawn with high grass coverage. There is a weed plant at the bottom-left of the picture. As in the previous case, the weed plant has more bluish coloration.

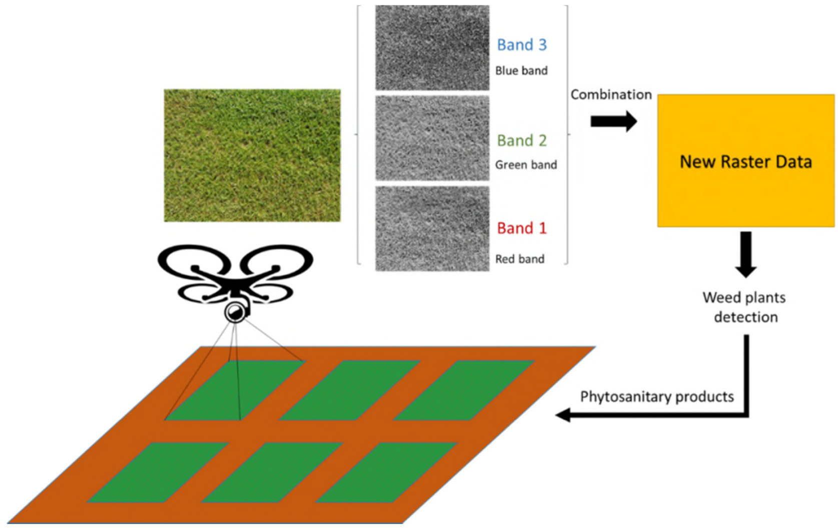


Figure 1. System description.

In picture 3, we can see a lawn with low grass coverage and with the presence of the weed plant in the bottom right of the picture. In this case, the weed plant has more yellowish coloration, compared with the grass. Finally, picture 4 represents typical lawns with no weed plants; but, under light water stress. Thus, there are some parts of the grass that have yellowish coloration due to the lack of water.

The first issue that we can pay attention to is the fact that the soil has higher values of brightness in the red band than in the green band. Therefore, considering that the values of the pixels only can be positive and without decimals, we divide the green band into the red band obtaining a new raster, which gives us information about the soil/plant coverage, see (1). The result of this mathematical relation between bands can be seen in Table I. Grass pixels have values higher than zero and are colored in green. The soil pixels have values of zero and are colored in yellow.

Unfortunately, the grass that is stressed or has been strongly compacted has a similar color as the soil and it is classified as soil. For our application, it is not a problem, because the important part for us is the green grass and the green weeds.

$$Soil\ removal = {}^{Band\ 2}\!/_{Band\ 1} \quad (1)$$

A. Image processing: weed detection

The next step is to find a mathematical relation, which gives, as a result, a new raster with different values for pixels of grass and pixels of weed.

As we have two different types of weed, the ones with more bluish color, and the ones with more yellowish color than the grass. Consequently, we will need two different equations to detect the presence of weeds. One equation for the bluish weed, the ones that appear in pictures 1 and 2 of Table 1, and another equation for yellowish weed as the one that appears in picture 3 of Table I. The first equation, (2), will be used to detect the bluish weed. This resultant raster after applying (2) will have high pixel values where there is a bluish weed. Thus, the equation has to maximize the data of pixels with higher relative blue values. Then, the data from blue band should be divided under the data from red and green band. As in the dividend of the equation (Blue brightness value of the pixel) has lower values that the divisor (Green x Red brightness values of pixels), and the pixels can only be a natural number almost all the pixels have the value of zero. Thus, no differences were found. In order to increase the value of the dividend, we square the dividend. Nevertheless, the value of the dividend is still lower than the value of the divisor in the majority of the cases and most of the pixels have a value of zero in the resultant raster. Finally, we cube the divisor. Then, we obtain a new raster with different values for different coverage surfaces. The last step is to apply (1) to the used formula. The obtained raster combination that is used to detect bluish weeds can be seen in (2).

On the other hand, we have the picture with yellowish weed. To detect them we should use the opposite steps that in the preceding paragraph, we have to use the data from green and red bands for the dividend and the data from the blue band for the divisor. As in this case, the values of the dividend are always higher than the values of the divisor, it is not necessary to neither square nor cube any of them. As in the previous case, it is necessary to add the soil/plant coverage correction factor. Therefore, the proposed formula that can be used to detect the yellowish weed is given by (3).

$$Weed = \left({Band\ 3^3}/{Band\ 2\ \times Band\ 1} \right) \times \left({Band\ 2}/{Band\ 1} \right) \quad (2)$$

$$Weed = \left({Band\ 2\ \times Band\ 1}/{Band\ 3} \right) \times \left({Band\ 2}/{Band\ 1} \right) \quad (3)$$

The result of applying (2) and (3) to the pictures of Table I can be seen in Table II. We apply both formulas to all of the pictures to show the effectiveness of each formula for generating a new raster that contains information about weed presence. The different colors represent different values in the raster. The pixels with yellow tones have lower pixel values. On the contrary, the pixels with purple and blue colors have the highest values. In the RGB picture, the weeds position is indicated with red circles. As it is expected, the pixels that contain bluish weeds (Picture 1 and Picture 2 in Table I and Table II), present higher values in the resultant raster after apply (2) than the pixels that contain grass or soil. The pixels of the resultant raster that have higher brightness values are represented in purple and blue colors. Meanwhile, the pixels with low brightness values are colored in yellow and light yellow. We can see that in Pictures 1 and the resultant raster of (2) present higher pixel values, colored in blue, in the area where there are weed plants. The resultant raster of (3) presents highest values in the pixels, which represents one of the grass species in Picture 1. In Picture 2, there is no specific area that contains pixels with high values.

For Picture 3, we can see that the pixels of the raster obtained with (2), which have the highest values, are not related with the presence of weeds. However, in the raster obtained with (3) we can clearly identify the presence of the weed plant. We can see that one of the grass species present in the lawn of Picture 3, are giving high values (red color). But the purple and blue colors are only related with the weed presence.

Finally, the resultant raster of the picture from the lawns without weed do not present any areas with high values. In the case of resultant raster of (2) there are some pixels with high values but they appear along the raster, not joined in one area as in the other cases. Meanwhile, in the raster of (3) almost all the pixels present low values and few pixels have high values.

TABLE I. FIGURES UTILIZED TO OBTAIN EQUATIONS FOR WEED DETECTION

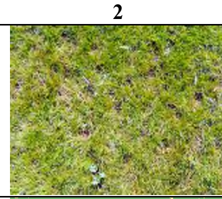
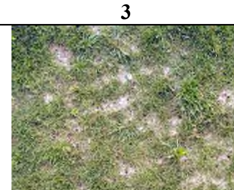
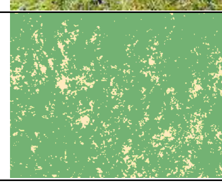
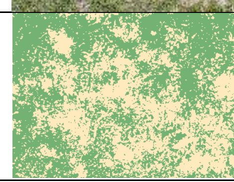
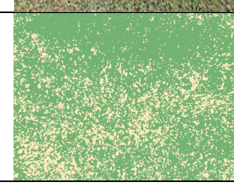
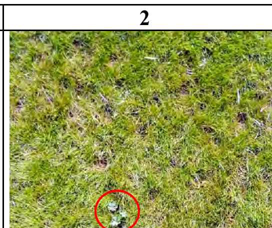
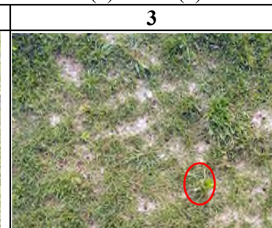
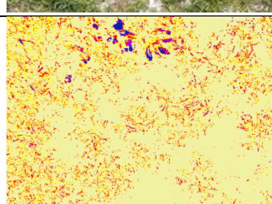
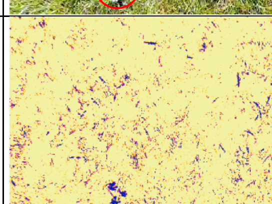
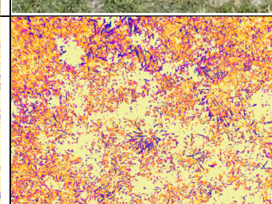
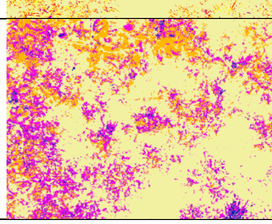
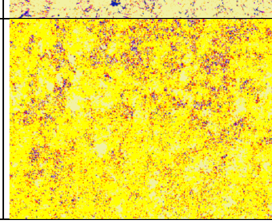
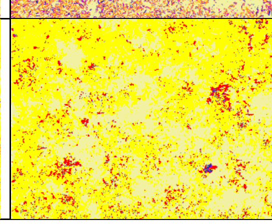
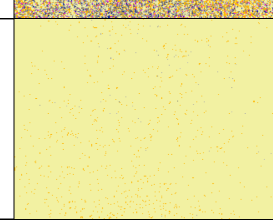
Picture nº	**1**	**2**	**3**	**4**
RGB picture				
Soil/Grass Coverage				

TABLE II. RASTER OBTAINED AFTER APPLY THE FORMULAS OF (2) AND (3) FOR WEED DETECTION

Picture nº	**1**	**2**	**3**	**4**
RGB picture				
Result of apply (2)				
Result of apply (3)				

In all the cases, there are some pixels that do not belong to weed that have high values and may be considered as a false positive. However, as long as these pixels are isolated and their neighbors have low values it can be easily solved by using smoothing techniques.

As the higher values indicate the presence of weeds, in the verification test we are only going to consider the pixels with the highest values. We will use the natural breaks, jenks, to divide the pixels into 5 groups and only the last group will indicate the presence of weeds.

E. Verification process

One of the major advantages of the proposed system is that its results should not be affected by changes in the solar exposition. Thus, we are going to verify the obtained formula with pictures gathered in another time period with different environmental conditions. Moreover, in the verification test, we are going to evaluate the use of the smooth technique to reduce the false positives.

To smooth the resultant raster we are going to aggregate the data. There are different available options in terms of the cell factor and in terms of the aggregation technique. In our case, we are going to test cell values of 5 and 10, and aggregation techniques of minimum, mean, and media.

The used pictures and the results of the verification can be seen in Table III. Again, the position of weed is indicated with a red circle in the RGB picture. Picture 5 was gathered on a sunny day and represents a lawn with low grass coverage, with two types of soil (light and dark brown) and the presence of a lot of weed plants. Some of the weeds of Picture 5 are a bluish weed, then, the results are after apply (2). Picture 6 was done a day with less solar radiation. The picture represents a lawn with some grass patches and the presence of yellowish weed at the bottom of the picture. Therefore, the verification is done with (3). Finally, Picture 7 represents a lawn with regular grass coverage on a cloudy day. In Picture 7, no weed plants are present, the results are obtained with (2). We select (2) because it is the one that gives more false positives in the previous test.

The results with the cell value of 10 have not been presented because they were not representative. We are going to present in Table III the results of the aggregation with a cell value of 5. First, we present the results of the aggregation technique that uses the mean as a result. This technique is quite accurate in terms of identifying the leaves of the weed plants. However, there are still some false positives, which identifies as a weed plant normal grass leaves. The false positives are more visible in the case of Picture 7, where there was no weed. The aggregation technique that uses the median, as a result, has less false positives. But, it is less precise in terms of weed plant leaves identification. Finally, if we use the minimum as a result, there are no false positives. Nevertheless, this results with this technique have some false negatives.

Thus, depending on the application and the produces effects on the case of false positives and false negatives, we can use one aggregation technique or other. For our application, as the point is to maximize the grass quality by minimizing the phytosanitary products usage, we prefer to have false positives than false negatives. Therefore, we propose to use the aggregation technique that uses the median as a result.

V. Conclusion

In this paper, we have presented our proposal for weed detection in lawns using image processing. The objective is to detect the weed plants to apply the phytosanitary products just to the affected area and not to the entire lawn.

We use a mathematical combination of the RGB layers to obtain new raster data that can be used to detect the weed. First, we found a formula that can be used to remove the soil from the pictures. Then, after analyzing the RGB values of the weed plants and the grass, we realize that there are two big groups of weed plants. The ones with a bluish coloration and the ones with a yellowish coloration, compared with the grass. Thus, we need to use two different formulas to detect the weed. Finally, we verify the proposed method of two equations and apply aggregation techniques to minimize the number of false positives.

The future works will be related to the identification of different weed species. Moreover, we will work with other image processing techniques including the boundary detection and its combination with our current findings.

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References

[1] J. Lloret, I. Bosch, S. Sendra, and A. Serrano, "A wireless sensor network for vineyard monitoring that uses image processing", Sensors, 2011, vol. 11, no 6, pp. 6165-6196.

[2] P. D. Surya and K. J. Satheesh, "Assessment of banana fruit maturity by image processing technique", Journal of food science and technology, 2015, vol. 52, no 3, p. 1316-1327.

[3] L. Parra, L. García, S. Sendra, and J. Lloret, "The Use of Sensors for Monitoring the Feeding Process and Adjusting the Feed Supply Velocity in Fish Farms", Journal of Sensors, 2018, vol. 2018.

[4] H. Li, Z. Lin, X. Shen, J. Brandt, and G. Hua, "A convolutional neural network cascade for face detection", Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition. 2015. pp. 5325-5334.

[5] G. Maria, E. Baccaglini, D. Brevi, M. Gavelli, and R. Scopigno, "A drone-based image processing system for car detection in a smart transport infrastructure", Electrotechnical

Conference (MELECON), 2016 18th Mediterranean. IEEE, 2016. pp. 1-5.

[6] X. P. Burgos-Artizzu, A. Ribeiro, M. Guijarro, and G. Pajares, "Real-time image processing for crop/weed discrimination in maize fields", Computers and Electronics in Agriculture, 2011, vol. 75, no 2, pp. 337-346.

[7] A. Paikekari, V. Ghule, R. Meshram and V. B. Raskar, "Weed detection using image processing", International Research Journal of Engineering and Technology (IRJET), 2016, vol. 3, no 3, pp. 1220-1222

[8] J. Gao et *al*. "Fusion of pixel and object-based features for weed mapping using unmanned aerial vehicle imagery", International journal of applied earth observation and geoinformation, 2018, vol. 67, pp. 43-53.

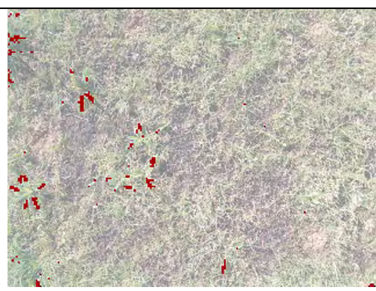
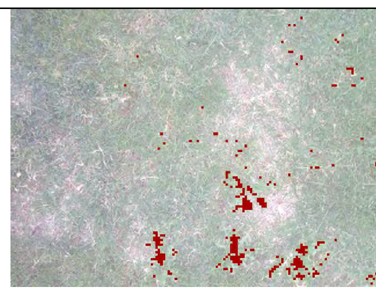
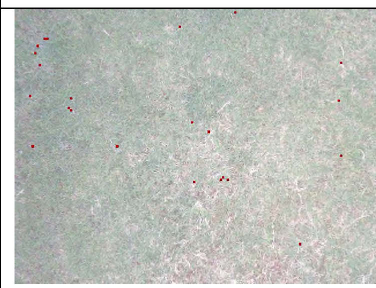
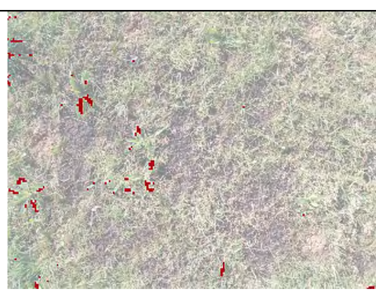
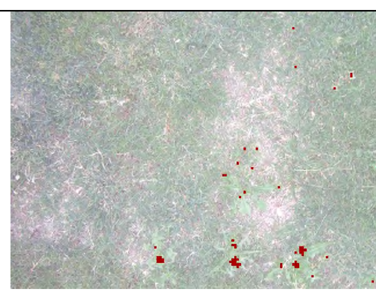
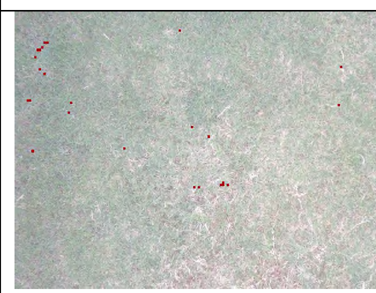
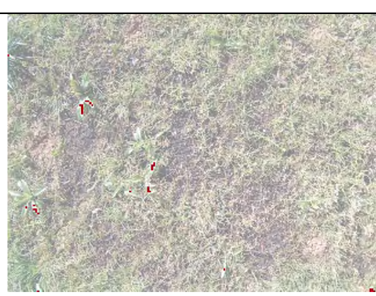
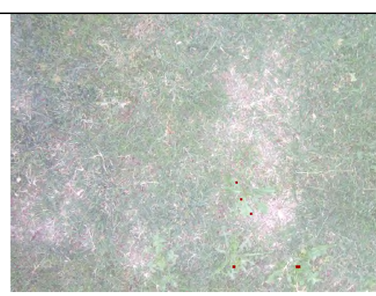
[9] J. F. Marín Peira, *et al*. "Automation in the characterization of the cultivation of lawns in urban grasslands", Proccedings of the IX Congresso Ibérico de Agroengenharia, Braganza, Portugal, 4 – 9 Sept. 2017.

[10] J. F. Marín Peira et al. "Urban Lawn Monitoring in Smart City Environments". Journal of Sensors, 2018, vol. 2018.

[11] V. Khanaa and K. P. Thooyamani, "An Efficient Weed and Pest Detection System", Indian Journal of Science and Technology, 2015, vol. 8, no 32.

[12] C. C Baseca, J. R. Díaz, J. Lloret, Communication Ad Hoc protocol for intelligent video sensing using AR drones, 9th International Conference on Mobile Ad-hoc and Sensor Networks (MSN 2013), Dec 11 - 13, 2013. Dalian, China

TABLE III. PICTURES AND OBTAINED RASTERS IN THE VERIFICATION PROCESS

Picture nº	**5**	**6**	**7**
RGB picture			
Aggregate data: Cell size 5 Aggregation type: Mean			
Aggregate data: Cell size 5 Aggregation type: Media			
Aggregate data: Cell size 5 Aggregation type: Minimum			

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