COMPARISON OF VEGETATION INDICES FROM RPAS AND SENTINEL-2 IMAGERY FOR DETECTING PERMANENT PASTURES

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Commission III, WG III/10

KEY WORDS: remotely piloted aircraft systems, RPAS, UAV, Sentinel-2, Copernicus, NDVI, vegetation indices, agricultural monitoring

ABSTRACT:

Permanent pastures (PP) are defined as grasslands, which are not subjected to any tillage, but only to natural growth. They are important for local economies in the production of fodder and pastures (Ali et al. 2016). Under these definitions, a pasture is permanent when it is not under any crop-rotation, and its production is related to only irrigation, fertilization and mowing. Subsidy payments to landowners require monitoring activities to determine which sites can be considered PP. These activities are mainly done with visual field surveys by experienced personnel or lately also using remote sensing techniques. The regional agency for SPS subsidies, the Agenzia Veneta per i Pagamenti in Agricoltura (AVEPA) takes care of monitoring and control on behalf of the Veneto Region using remote sensing techniques. The investigation integrate temporal series of Sentinel-2 imagery with RPAS. Indeed, the testing area is specific region were the agricultural land is intensively cultivated for production of hay harvesting four times every year between May and October. The study goal of this study is to monitor vegetation presence and amount using the Normalized Difference Vegetation Index (NDVI), the Soil-adjusted Vegetation Index (SAVI), the Normalized Difference Water Index (NDWI), and the Normalized Difference Built Index (NDBI). The overall objective is to define for each index a set of thresholds to define if a pasture can be classified as PP or not and recognize the mowing.

1. INTRODUCTION

Permanent pastures (PP) are defined as grasslands, which are not subjected to any tillage, but only to natural growth, (self-seeded). There is more precisely defined by European Union's fundamental reform of the Common Agricultural Policy (CAP), which introduced the new Single Payment Scheme (or Single Farm Payment, SPS) for direct subsidy payments to landowners. The SPS definition of permanent pastures is as follows: "land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that is not included in the crop rotation of the holding for five years or longer". PP are a major source of nutrients for livestock and are of major importance from an ecological point of view and as carbon sinks in the carbon cycle. They are also important for local economies in the production of fodder and pastures (Ali et al. 2016). Under these definitions, a pasture is permanent when it is not under any crop-rotation, and its production is related to only irrigation, fertilization and mowing. The production capacity is therefore mostly associated to environmental factors and a certain type of human activity (Xu et al. 2008). Managing PP requires some activities of monitoring and control. In literature, investigations over PP have been carried out to determine the amount of vegetation cover under a certain type of actions (Schmidt et al., 2010), to evaluate the effects of grazing from livestock (Bastin et al. 2012, Blanco et al. 2009, Li et al. 2016), the impact of climate change over PP and ecological aspects thereof (Saornil et al., 2008, Förster et al., 2012).

Subsidy payments to landowners require monitoring activities to determine which sites can be considered PP. These activities are mainly done with visual field surveys by experienced personnel or lately also using remote sensing techniques. To monitor large areas with remote sensing, high-density temporal series are necessary, at least one image every ten days (Morel et al. 2014, O'Connor et al. 2012). In Italy, the Parmigiano-Reggiano area was subjected to investigation, using a persistency index of the Normalized Difference Vegetation Index (NDVI) from Landsat scenes over 10 years; PP has a persistency index value of >0.04, whereas pastures that are not permanent cycle through a range between -0.02 e -0.04 (Bocci et al., 2011). High-density temporal images are often not always available: for example because of cloud-cover, which is common in some areas. In addition, a delay between the tillage of a site and a cloudless image from a satellite might cause an incorrect false negative due to young vegetation growth happening between the tillage and the satellite visit.

Lately remotely piloted aircraft systems (RPAS) have gained a strong momentum in terms of usage. This is due mainly to lower costs, lighter apparatus and longer lasting batteries, which allow longer flights and lower costs. Also improvements in software development have contributed to a growth in popularity of close-range remote sensing with RPAS (Rutzinger et al., 2016). Multi-spectral cameras mounted on RPAS allow custom deployment for multi-band imagery over areas of interest. RPAS is therefore a suitable candidate to fill the gaps in the timeline where satellite imagery is not available (Pirotti et al., 2015), be it for long revisit times, for cloud cover or for a combination of both (Pirotti et al., 2017).

In the following note a specific region is considered were the agricultural land is intensively cultivated for production of hay harvesting four times every year between May and October. The regional agency for SPS subsidies, the Agenzia Veneta per i Pagamenti in Agricoltura (AVEPA) takes care of monitoring and control on behalf of the Veneto Region. Usually the controls are made manually with trained personnel moving physically to the area that must be assessed. Latest developments in remote sensing technologies have pushed AVEPA to investigate over using such technologies for decision support. The objectives of the presented investigation are to integrate temporal series of Sentinel-2 imagery with RPAS imagery for monitoring candidates to PP. The analysis uses existing vegetation indices to relate reflectivity of different amounts of grass cover, which indicates how the pasture is managed and if it can be considered PP. The indices that will be used are the following: NDVI, to monitor vegetation presence and amount, the Soil-adjusted Vegetation Index (SAVI) to take into consideration the effect of soil, the Normalized Difference Water Index (NDWI) to test if information on wetness improves results, and the Normalized Difference Built Index (NDBI) to see if such information also provides significant information to define a pasture.

The overall objective is to define for each index a set of thresholds to define if a pasture can be classified as PP or not, and to detect mowed PP.

2. MATERIALS AND METHOD

2.1 Study area and dataset

The study area is located in the north of Italy, in the Veneto Region; five sites in the area were investigated (Figure 1)

Figure 1. Study area with five sites: 1 Piciacio, 2 Albereria, 3 Palmirona, 4 Rossano, 5 Dussin

The five sites are distributed in different municipalities, where land use and cultural calendar is known; cultural calendar means that the type of crop present at a time of the year is known. The areas are defined as Piciacio, Albereria, Palmirona, Rossano and Dussin (see Figure 2).

The five test areas were surveyed with a remotely piloted aircraft system, the "eBee Sensfly" equipped with a multispectral multiSPEC 4C camera. Flights were carried out between April and October 2016 for five flights over each site. The sensor records incoming radiation in four bands, respectively Green (G) - 550 nm, Red (R) - 660 nm, Red Edge (RE) - 735 nm and Near Infrared NIR - 790 nm). A number of targets were used as Ground Control Points (GCPs) whose coordinates were measured with a GNSS receiver in RTK mode. The images were processed with Pix4D© creating an orthomosaic with ground sampling distance of 0.2 m.

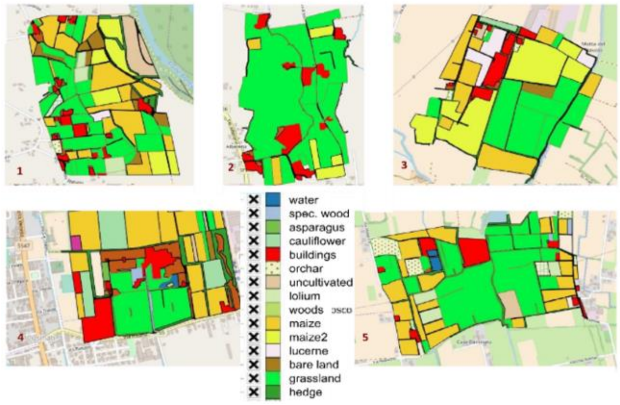

Figure 2. Land-use maps of the five sites: 1 Piciacio, 2 Albereria, 3 Palmirona, 4 Rossano, 5 Dussin

Satellite imagery of the area was downloaded for dates as close as possible to the dates of the RPAS flights (Figure 3. Sentinel-2 images, freely available from the European Space Agency (ESA), where used. The following vegetation indices were extracted: NDVI, SAVI, NDWI, and NDBI. For each of these indices, local statistics, i.e. average and standard deviation, have been extracted for three different groups: urban, PP and mowing on PP. The urban class is related to rooftops, which should have more stable values of these indices, and can therefore be used to monitor small differences which can be caused by factors other than the surface composition – e.g. atmospheric effects.

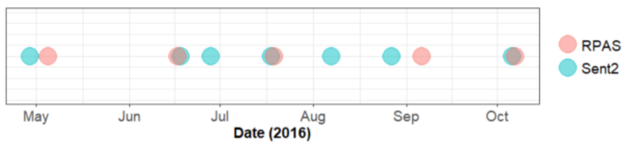

Figure 3. Timeline of data acquisition.

2.2 Tested vegetation indices

2.2.1 NDVI: is the well-known normalized ratio between red (R) and near infrared (NIR) (Rouse et al. 1973) and it is one of the most used vegetation indices (Baluja et al. 2012, Bendig et al. 2015, Diaz-Varela et al. 2014, Herwitz et al, 2004, Pérez-Ortiz et al. 2015, Sugiura et al. 2005, Tokekar et al. 2013, Torres-Sánchez et al. 2015, Tucker 1979, Turner et al. 2010). The formula is the following:

$$NDVI = \frac{NIR-R}{NIR+R} \tag{1}$$

The anatomy and physiology of the leaf absorbs radiation from wavelengths around the red area of the spectrum and reflects the near infrared. The index varies between -1 and 1. Higher values are related to healthy photosynthetic vegetation, lower values are related to stressed vegetation or no vegetation (bare soil). In literature, NDVI is used to study monitor vegetation health, hydrologic stress and the amount of biomass. In this study, NDVI has been extracted from RPAS and satellite imagery. In RPAS imagery, the NIR band that is available from the MultiSPEC 4C sensor is related to a wavelength of 790 nm. Therefore, NDVI was calculated using this wavelength as NIR band.
Sentinel-2 has different bands in the NIR area of the spectrum. Usually band number 8 is used for NDVI extracting, having

information from radiation in the 842 nm and 10 m ground sampling distance (GSD). In our case, we used also band 7, which has a GSD of 20 m, but represents reflectance from radiation at 783 nm, very close to the recorded wavelength of the MultiSPEC 4C NIR band.

2.2.2 SAVI originates from the NDVI index (Huete *et al*. 1988) and uses a constant factor, L, for correcting for luminance. L varies depending on terrain conditions and vegetation cover. An L value of 0 indicates areas with dense vegetation cover, whereas 1 indicates areas without or with very little vegetation. The formula is the following:

$$SAVI = \frac{NIR-R}{NIR+R+L} * (1 + \mathrm{L}) \qquad (2)$$

In this investigation, we empirically applied an L value equal to 0.5. The hypothesis is that upon mowing, the pasture there will be a significant radiometric contribution by bare soil. Therefore, SAVI can give an improved description of the situation of the pasture cover.

2.2.3 NDWI is a normalized ratio between a NIR band and a Short-Wave Infrared (SWIR) band, respectively around 860 nm and 1240 nm wavelengths. It is an index is correlated with the water content of vegetation. It is widely used in precision agriculture, forest health monitoring and other applications were the status of vegetation is sensible to its modification in terms of water content. It varies between -1 e 1, where green healthy vegetation has values between 0.02 and 0.6 (Sentinel-Hub, 2018, Quadratic 2018). In literature, NDWI is calculated using SWIR at 1240 nm because in this region there is high reflectance by water and low absorbance by cellulose. Other areas in the wavelength spectrum, which have a strong reflectivity by water, are in the interval between 1500-2500 nm. In case of dense vegetation, these are less efficient. Nevertheless, Sentinel 2 does not have a band a wavelength of 1240 nm. The bands 11 and 12 have wavelength of 1610 and 2190 nm can be used for this purpose. Using the band 11, the dry vegetation reflectivity is 0.3 and the green vegetation reflectivity is 0.6. Using the band 12 the dry vegetation reflectivity is 0.15 and the green vegetation reflectivity is 0.4 (Gao, 1996). Band 11 has been used to calculate the NDBI index. To avoid overlapping with band 11, and considering the sparse vegetation cover of mowing and the summer hydric stress, NDWI index has been calculated to using the band 12.

$$NWI = \frac{NIR\ 0.842-NIR\ 2.190}{NIR\ 0.842+NIR\ 2.190} \qquad (3)$$

2.2.4 NDBI is a normalized ratio between a SWIR and NIR bands, and it varies between -1 e 1. It is useful to recognize urban areas from vegetated areas, o water bodies. The vegetated areas and agricultural lands have negative or zero values, whereas barren lands or buildings have positive values (Zha et al. 2003). In this study, the NDBI ratio has been calculated using the band number 8 and 11 of Sentinel 2 around 842 nm and 1610 nm wavelengths. The aim is to recognize bare soil and the not vegetated areas due to harvesting in agricultural land.

$$NBI = \frac{NIR\ 1.610-NIR\ 0.842}{NIR\ 1.610+NIR\ 0.842} \qquad (4)$$

3. RESULTS AND DISCUSSION

Results report on average and standard deviation of values of indices mentioned in the previous section, for three classes, PP, mowed PP and urban elements (i.e. rooftops). Discussion on these values refer to Figure 5, which is available in the next page.

NDVI value was first calculated for urban areas as reported in Figure 4. These areas should have a stable trend during the year. The value is the mean of pixels falling completely inside the area of the urban element (i.e. rooftop) as depicted in Figure 4.

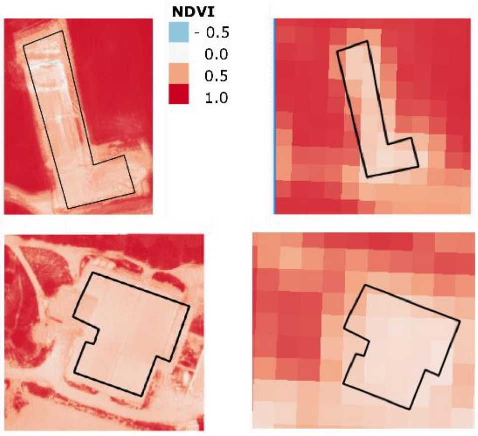

Figure 4. Comparison between NDVI calculated using RPAS images with resolution of 20 cm/pixel (left) and Sentinel 2 images with resolution of 10 m/pixel (right).

NDVI values calculated with band 7 of Sentinel 2 are higher than NDVI values obtained with using the band 8 (Figure 5). Furthermore, the NDVI from the Satellite imagery exceed the NDVI from RPAS. The spatial resolution of 10 meters is sufficient to recognize the buildings, but it is affected by noise of neighbour green areas, in particular using the band 7 with resolution of 20 meters. The images were acuired in diffet time, so it is not possible to calculate the diffrences. The graphic comparison between satellite and RPAS highligth a difference of 0.15.

Regarding PP, only two areas in Piciacio site (355 and 360) have NDVI values higher than 0.70 as shown in Figure 5. The NDVI, which has been calculated in the area 355 using the band 8 of Sentinel 2, ranges between 0.66 and 0.80 (Figure 5). The minimun value is reached during summer season in July and August. The NDVI trend, which has been calculated using RPAS, is similar to satellite ones. Nevertheless, since 19th July the RPAS NDVI exceeds the Satellite NDVI. The NDWI and SAVI trend are similar to the NDVI ones. NDWI maximum value, reached in July, is 0.65. The minimun NDWI value, reached in August, is 0.42. The NDBI has a different behaviour reaching the maximum of -0.13 during the summer. In the springs and autumn, the minimum values are stable around -0.38.

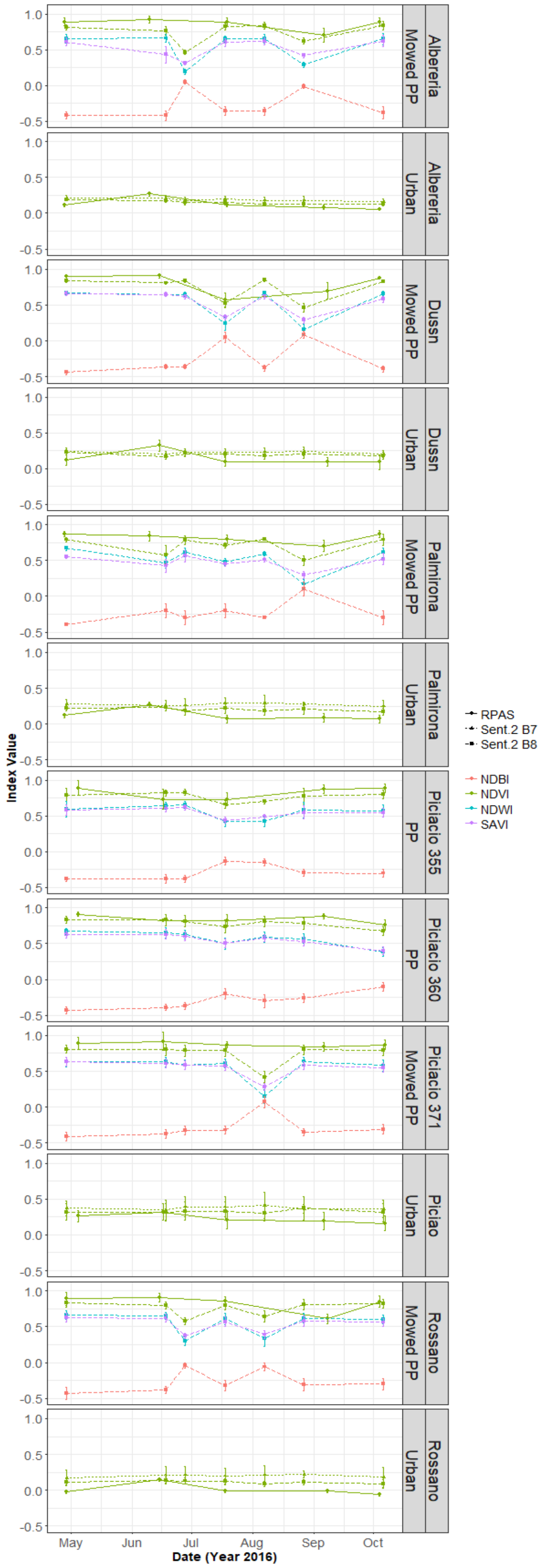

Figure 5. Mean values of indices inside areas with different classes – standard deviation is reported in error bars.

The NDVI, calculated in Piciacio site at area 360 with Sentinel 2 band 8, ranges between 0.74 and 0.83 in Figure 5, and the minimun value is reached in July. The NDVI, which has been calculated using RPAS, exceed the NDVI calculated using Satellite. RPAS shows a stable trend around 0.82, whereas the satellite has values around 0.74. The NDWI trend is similar to NDVI. The minimun value is 0.42, and it was registered in July and August. The SAVI is smiliar to NDWI trend, and the minimun value is 0.50. The NDBI ranges between -0.40 in spring and 0 in autumn. In summer the average values is -0.20.
The mowed PP class has been recognized in each testing areas as shown in Figure 5.

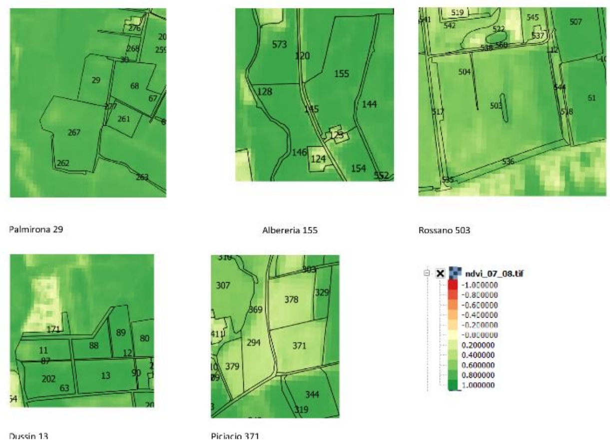

Figure 6. Mowed PP class in each testing area

The NDVI has been calculated using Sentinel-2 in the Piciacio study site in area 371. It reach a negative peak of 0.42 as shown in Figure 5. The SAVI and NDWI are 0.15 and 0.28, whereas NDBI is positive. In literature, positive values indicate hurban areas or barren land. Considering, the low values of NDVI and SAVI and positive values for NDBI the cover is thin, and probably the imagery were acquired in the same period of the mowing Instead, the peak can not be recognized using the RPAS. Indeed, there is not a temporal overlap between the peak and the RPAS imagery.

The NDVI calculated in Albereria site has two negative peaks. The first one is at the end of June, and NDVI is 0.46. The second one is at the end of August, and NDVI is 0.62 as shown in Figure 5. In June, the SAVI is around than 0.3, and NDWI is around 0.2. NDBI assumes positive values, which confirms the mowing. In August cutting of the pasture (i.e. mowed PP class) is related to a negative peak, where NDVI is 0.62, SAVI 0.41, NDWI 0.29, and NDBI -0.02. NDBI values near zero has been intepreted as vegetation growth.

RPAS imagery in two cases does not recognize the mowing of pasture grass because the two flights were done one month before and one month later, as Figure 5 – Albereira area and Piciacio 371 area.

In the area Palmirona, between June and September the NDVI trend is not stable as shown in Figure 5. In the middle of June NDVI value is 0.59. NDWI and SAVI range between 0.5 and 0.5, whereas NDBI is -0.23. Probably, mowing has occurred between 10th and 18th of June.

In July, NDVI is decreasing from 0.78 to 0.71. Then, it increases to 0.80. SAVI and NDWI ranges between 0.48 and 0.61, and NDBI reach the peak at -0.18. The High NDVI values, which are above 0.70, but instable, coupled wioth the other indices suggests it can be a stress of vegetation. Nevertheless, between 28th of June and 18th of July there are no data to exclude mowing activity.

In August, the absence of vegetation is clear as shown by low NDVI, NDWI and SAVI and NDWI values. NDVI is 0.50, NDWI is 0.17, and NDBI is positive. This highligths the presence of dry vegetaion or barren land. RPAS NDVI is stable, and in September it is decreasing.

In Rossano area, the average value for NDVI calculated using Satelltie is 0.8 as shown in Figure 5. In July and August the NDVI reaches the minimum of 0.58 and 0.64. The other indices have the same trend, and NDBI ranges between -0.04 and -0.06. Consequently, considering indices values, the PP has been probably mowed. Instead, in the same period, NDVI derived from RPAS imagery showed a decrease in September. The NDVI in september is 0.61 and it is similar to satellite values registered in July and August. On one hand it can suggest that pasture grass was cut, on the other hand there are no satellite data to confirm this hypothesis.

In the Dussin area, the indices fall in July and August. In both dates it is clear that the steep decrease of NDVI going to values of 0.52 and 0.57. A similar tend has been found for NDWI, SAVI and NDBI. In July and August, NDWI values are 0.24 and 0.16, SAVI values are 0.33 and 0.29, and NDBI values are 0.05 and 0.09 as shown in Figure 5. This trend has been detected by both Sentinel-2 and RPAS data.

The minimum values for the indices have been summarized in the following tables Table 1 and Table 2.

PP	Piciacio 355 min peak	Piciacio 360 min peak	Average
RPAS NDVI	0.73	0.76	0.75
SAT. NDVI	0.66	0.74	0.70
SAT. NDWI	0.42	0.50	0.46
SAT. SAVI	0.44	0.50	0.47
SAT. NDBI	-0.13	-0.20	-0.17

Table 1. Minimum and average values used to set the PP threshold.

	Average all areas
RPAS NDVI	0.57
SAT. NDVI	0.53
SAT. NDWI	0.26
SAT. SAVI	0.35
SAT. NDBI	0.02

Table 2. Minimum and average values used to set the threshold for the Mowed PP class.

Then, the PP class average has been compared with average of the Mowed PP class (Table 1 and Table 2) to set classification threshold as shown in table below.

	Mowed	Probably Mowed	PP
NDVI SAPR	< -0.57	0.57 - 0.75	> 0.75
NDVI	< 0.53	0.53 - 0.70	> 0.70
NDWI	< -0.26	0.26 - 0.46	> 0.46
SAVI	< -0.35	0.35 - 0.47	> 0.47
NDBI	> 0	-0.25 - 0	< -0.25

Table 3. Threshold defined according to tables above.

4. CONCLUSION

In this paper we report results on a comparison of NDVI, NDWI, SAVI and NDBI in urban areas, PP and mowed PP. NDVI has been calculated using RPAS imagery and Sentinel 2 imagery. NDWI, SAVI and NDBI have been calculated using Satellite imagery.

In the urban areas NDVI has been calculated using 20 centimiter GSD RPAS imagery and band 7 and 8 of Sentinel 2. Band 7 has 20 meters of GSD, and 8 has 10 of GSD. The NDVI calculated using RPAS imagery is slight higher than Sentinel 2. The two dataset do not overlaps perfectly in terms of timeline, so we can not calculate the difference analitically. Nevertheless, the difference derived from the graph is 0.15. Finally, the band 8 of Sentinel 2 is more suitable than the 7 because the spatial resolution is higher.

In this study two PP have been recognized. NDVI values exceed 0.65 also during the summer, when water stress can occur. The values in mowed PP range between 0.4 and 0.60. Therefore, using Sentinel 2 a conservative threshold has been set at 0.70. Using RPAS imagery, the threshold is 0.75.

The information derived from satellite's NDVI and from RPAS's NDVI can be temporally integrated, such as in the parcel Dussin 13 and Rossano 503. In Dussin 13 there is a steep decrease of NDVI recorded using both sensors. In Rossano 503 NDVI from RPAS's imagery detects a probabaly mowed PP.

The NDWI has been calculated with the band 12 of Sentinel 2 for assessing water stress. The PP have minimum value of 0.42, whereas the value in mowed PP ranges between 0.15 and 0.47. This values are comparable with 0.4 green vegetation and 0.15 for dry vegetation found by Gao, 1996. SAVI does not add information as it is highly correlated to NDWI.

The NDBI has negative values for green vegetation. According the growing rate, the values for mowed PP ranges between -0.23 and 0.0. In absence of vegetaion or sparse vegetation the index has positive values. The threshold that separte PP and mowed PP has been set at -0.25.

This information has several applications that are important in land monitoring. The immediate application is to detect mowing in PP, which is a delicate matter as variance of NDVI can be from low synthetic activity and thus be low, and pastures with mowed grass will have low values of NDVI for a short time, as renovation in vegetation will not take more than some weeks, depending on season of course. Other applications which are important are related to anthropic impact (Piragnolo et al., 2014) which is the focus of creating permanent pastures, to limit anthropic impact in ecological aspects.

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