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Use of the active sensor OptRxTM to measure canopy changes to evaluate foliar treatments and to identify soil quality in Table Grape

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Abstract.

Table Grape (Vitis vinifera L.) is the main exporting horticultural crop in Chile, with the country being one of the top exporters at the world level.

Commonly, grape producers perform trials of different commercial products which are not evaluated in an objective way. On the other hand they do not have the tools to easily identify areas within the field that may have some limiting factor. The use of active ground sensors that pass under the canopy several times during the season may be a suitable tool to solve these problems. In this regard, in an average field, producers go under the canopy > 20 times during the season to perform different managements, occasions that could be used to monitor it.

In order to assess the use of active ground sensors to evaluate commercial treatments and to define areas with potential limiting factors, two field studies were carried out in the Central Region of Chile during the 2014/2015 season.

In the first study three table grape fields var. Red Globe with a commercial treatment and two with a control treatment (producer) were evaluated. Fields had an average area of 3 ha. After application of the treatments, the canopy of each field was evaluated through the use of the OptRx sensor

(AgLeader Technologies, Inc.) which was operated about one meter from the canopy, from an ATV, below the grapevine. The OptRx is an active three-band sensor, Red, Red Edge and near infrared (NIR), from which the NDVI was calculated. Evaluations were carried out on October 9, October 30, November 10, and December 5 2014; and January 12 and 28 2015. Within each field a systematic grid of 20 points was established; at each sampling point the number of clusters / plant and weight of bunches in four evaluation dates were determined: 12/5/2014, 1/12/2015, 1/29/2015 and 3/3/2015, the latter date to harvest. At harvest, the grapes collected at each point were assessed for: number of berries / bunch, berry weight, pH and Brix. Regression models using NDVI as an independent variable were developed to evaluate treatment effects.

In the second study, several fields of two table grape varieties (Thompson Seedless and Red Globe) were evaluated using the OptRx sensor in January 2015. With sensor data NDVI was estimated for each field. Fields were classified in three vigor zones (low, medium, and high NDVI). Each zone was sampled using composited soil samples and several chemical, microbiological and biochemical (enzymatic activity) were determined at 0-30 cm depth. Zones of low vigor of the Thompson Seedless variety were amended using compost and fields evaluated again one year later. Analysis of variance was used to evaluate the effect of zones on selected soil properties.

Results indicated that OptRx sensor is a simple and useful tool to study canopy changes in table grapes. The NDVI from the sensor is a good variable to incorporate in regression models to evaluate modest treatment effects. Stratified sampling using NDVI allowed identifying few soil properties that may explain plant vigor.

Keywords.

Table grape, NDVI, ground sensor, OptRx, canopy evaluation;

INTRODUCTION

Remote sensing has been used in horticultural crops, particularly wine grapes, in Chile for the last 15 years, for different purposes, such us differential harvest, yield prediction, and sampling stratification, among others (Ortega et al., 2008; Ortega y Gallardo, 2014). Most of the imagery utilized for these purposes has been airborne or satellite, and several vegetation indices (VI) have been used (Ortega and Molina, 2016).

Even though table Grape (Vitis vinifera L.) is the main exporting horticultural crop in Chile, with the country being one of the top exporters at the world level, little work has been done on the use of remote sensing for productive purposes.

Being table grape a high-value crop, commonly, producers perform trials of different commercial products, looking for increases in yield and berry quality, which usually are not evaluated in an objective way. On the other hand, they do not have the tools to easily identify areas within the field that may have some limiting factor. The use of active ground sensors that pass under the canopy several times during the season may be a suitable tool to solve these problems. In this regard, in an average field, producers go under the canopy > 20 times during the season, to perform different managements, occasions that could be used to monitor vegetation changes.

There are several ground active sensors available in the market, commonly used for variable rate N application in field crops (Maharlooei et al., 2014). One of them is the OptRx (Ag leader Technology, Inc., Iowa, USA) which emits light at three wavelengths: 670 and 730 nm in the visible band, and 780 nm in the NIR band. Since this sensor has its own source of light, it is not affected by ambient light conditions and can work both during day and night. This sensor also has the unique ability to provide NDRE (Normalized Difference Vegetation Index Red Edge) values (Maharlooei et al., 2014). In 2013, we had determining the feasibility of using the OptRx in a looking up position, to evaluate table grape's canopy, which is usually conducted in a Spanish parron trellis system.

The objective of this work was to assess the use of active ground sensors to evaluate commercial treatments and to define areas with potential limiting factors in table grape.

MATERIALS AND METHODS

Two field studies were carried out in the Central Region of Chile during the 2014/2015 season.

In the first study five table grape fields var. Red Globe were evaluated: three of the fields were subjected to a new commercial foliar treatment and the remaining two had the producer's treatment and therefore considered a control. Each field had an average area of 3 ha.

After application of the treatments, at the beginning of the season, the canopy of each field was evaluated through the use of two OptRx sensors, which were independently operated, in a looking up position, about one meter from the canopy, from an ATV, below the grapevine. Each sensor was connected to a rugged field computer, with DGPS, and was operated using the SMS Mobile software (Ag leader Technology, Inc., Iowa, USA). Since the OptRx is an active three-band sensor, Red, Red Edge and near infrared (NIR), two VIs were obtained from the raw data: NDVI and NDRE. After filtering the data to eliminate some outliers, maps were produced using the Inverse Distance Weighting (IDW) algorithm within the SMS Advanced (Ag leader Technology, Inc., Iowa, USA) Software (Figure 1).

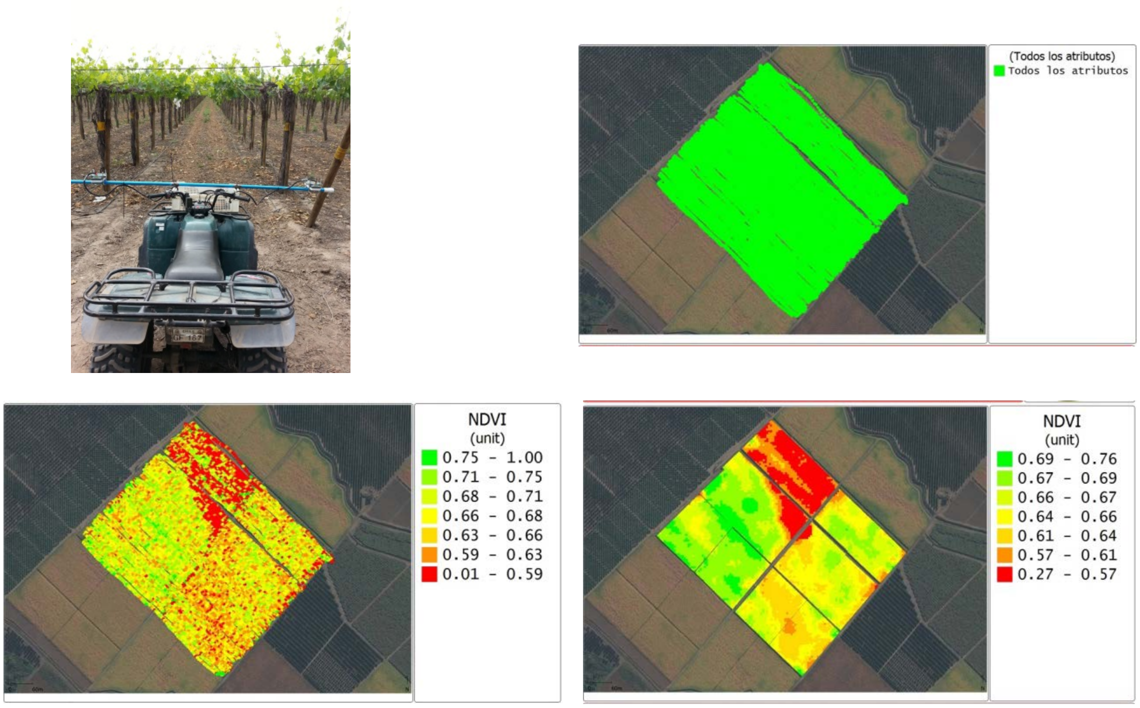

Figure 1. OptRx sensor setup, ground passes under the canopy and NDVI (raw and processed).

Sensor evaluations were carried out on October 9, October 30, November 10, and December 5 2014; and January 12 and 28 2015. Within each field a systematic grid of 20 points was established; at each sampling point the number of clusters/plant and weight of bunches, in four evaluation dates, were determined: 12/5/2014, 1/12/2015, 1/29/2015 and 3/3/2015, the latter date corresponded to harvest. At harvest, grape bunches collected at each point were assessed for: number of berries / bunch, berry weight, pH and Brix.

Using Geographic Information Systems (GIS) tools, NDVI values were extracted from VI maps for each sampling point, in order to build a complete data set.

Regression models including NDVI as an independent variable were developed to evaluate treatment effects on measured variables. The models used were the following:

$$y_t = \beta_0 + \delta treat + \beta_1 t + \beta_2 NDVI_t + \varepsilon \quad \text{[eq. 1]}$$

$$y = \beta_0 + \delta treat + \beta_1 NDVI + \varepsilon \quad \text{[eq. 2]}$$

Where:

treat= binary variables, taking values 1 for new treatment an 0 for control

t=days after treatment application

In equation 2, NDVI corresponded to the one collected on December 5, 2014.

Regression models used were evaluated for heteroscedasticity, multicollinearity, and autocorrelation of the residuals. Analysis were performed in software Stata (StataCorp, 2013).

In the second study, 12 fields of table grape variety Thompson Seedless, and 7 fields of variety Red Globe were evaluated using the OptRx sensor, in January 2015. With sensor data, NDVI was estimated for each field. Fields were classified in three vigor zones (low, medium, and high NDVI). Zones were determined by the natural breaks classification algorithm. This method of data clustering was designed to optimize the assignment of pixels into different classes. Method minimizes the variance within classes and maximizes the variance among classes (Jenks, 1967).

Each zone was sampled using composited soil samples (20 subsamples/sample) and several chemical, microbiological and biochemical (enzymatic activity) properties were determined at 0-30 cm depth. Variables included: pH, EC, available N, Olsen-P, extractable bases (K, Mg, Ca, Na) and micronutrients, texture, aggregate stability, enzymatic activity (dehydrogenase, β-glucosidase, alkaline and acid phosphatase), yeast count, pruning weight and root density

In the case of Thompson Seedless variety, low vigor zones were amended using compost and fields evaluated the following season.

Regression analysis was used to evaluate the effect of zones on selected soil properties. Model used was the following:

$$y = \beta_0 + \delta_1 \mathrm{RG} + \delta_2 \mathrm{MV} + \delta_3 \mathrm{LV} + \delta_4 \mathrm{RGxMV} + \delta_5 \mathrm{RGxLV} + \varepsilon \quad \text{[eq. 3]}$$

Where:

y=dependent variable

RG=Red Globe variety (1 for RG and 0 otherwise)

MV=medium vigor by NDVI (1 for MV and 0 otherwise)

LV=low vigor by NDVI (1 for LV and 0 otherwise)

Base variety=Thompson Seedless

Base vigor=High vigor by NDVI

RESULTS AND DISCUSION

Study 1:

An important spatial and temporal variability of the NDVI was observed in all the studied fields. At the initial growth stages of the crop, spatial variability showed natural forms, probably derived from soil variations. However, as the crop developed and canopy management started, the variability of the NDVI took artificial forms (Figure 2).

Since the OptRx produces comparable readings among dates, it was possible to build growth curves for the canopy of each field. Figure 3 shows the average growth curve for the control and treated fields. It can be observed that the minimum and maximum values for NDVI obtained were approximately 0.45 and 0.75, respectively, with a 67% increase. Small but significant initial differences were observed between treated and control fields which further justify the use of NDVI in regression models as a co-variable. Table 1 shows the results of regression analysis for bunch weight using two models: model 1, from equation 1 and model 2, which adds the number of bunches as a control variable, since it may affect bunch weight, even though usually it is controlled at the field level by bunch thinning. It can be seen that in both models the coefficient for NDVI was significant ($P<0.06$), and that, accounting for all the control variables (t, NDVI, number of bunches), the average difference in bunch weight (3.22 to 4.54 g) between treated and control fields was not significant. Clearly the inclusion of NDVI improved the accuracy of the treatment effect.

Table 1. Regression models for bunch weight as a function of treatment and other control variables including NDVI.

	Model 1		Model 2	
	Coefficient	*P-value*	*Coefficient*	*P-value*
Intercept	98.36	0.02	95.56	0.03
T	1.25	0.00	1.27	0.00
Treat	4.54	0.28	3.22	0.48
NDVI	-111.62	0.06	-113.24	0.06
Number of bunches			0.25	0.41
N	119		119	

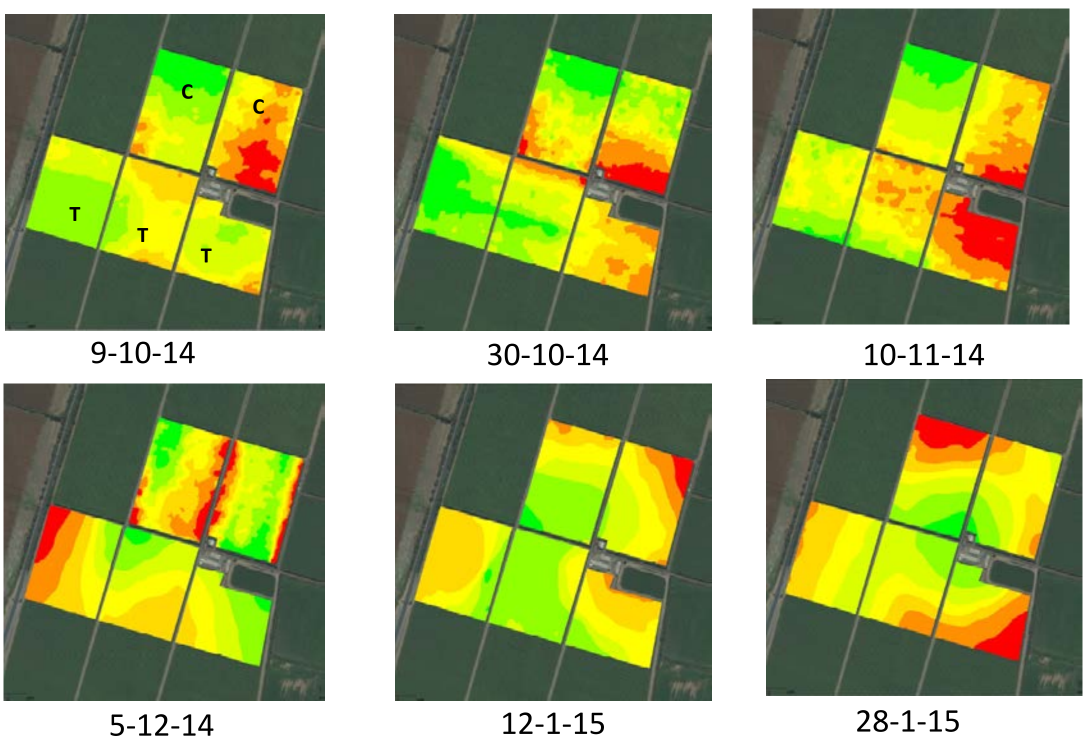

Figure 2. Spatial and temporal variability of NDVI in Table Grapes. Fields with letter C are the control while fields with letter T corresponded to the treated ones. Canopy management started at the end on December 2014.

Table 2 shows the results of the regression analysis using model in equation [2] to evaluate the treatment effect on several fruit variables. It can be observed that correcting for NDVI at veraison, there were significant differences (P<0.1) between the control and treated fields for number of berries/bunch and brix. On the other hand, a tendency (P<0.16), in terms of berry weight in favor of the treated fields was observed.

Table 2. Treatment effect on selected fruit variables corrected by NDVI.

Treatment	Variable	n	Average	Std. deviation	P-value*
Control	N° berries/bunch	40	70	20.0	
Treatment	N° berries/bunch	39	63	17.5	0.10
Control	Berry weight (g)	40	12.7	1.62	
Treatment	Berry weight (g)	39	13.5	1.45	0.16
Control	pH	40	3.8	0.1	
Treatment	pH	39	3.7	0.1	0.41
Control	°Brix	40	17.2	1.1	
Treatment	°Brix	39	16.5	1.4	0.05

*significance obtained using regression model in equation 2.

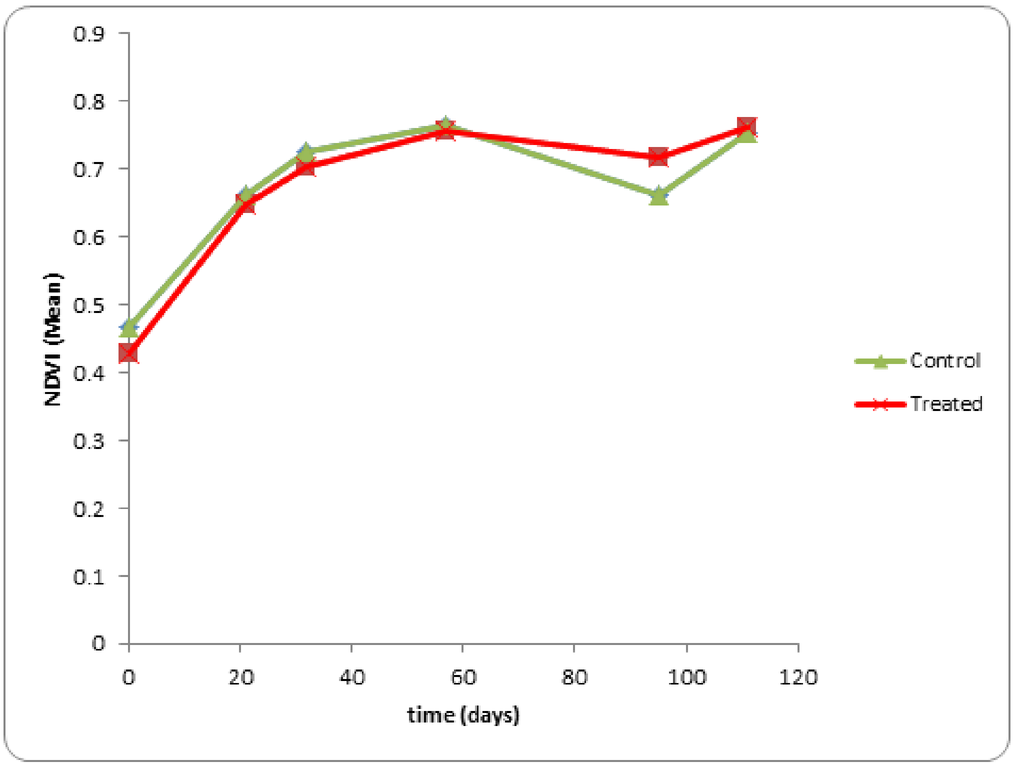

Figure 3. Evolution of the average NDVI readings for control and treated fields.

Study 2.

Figure 1 shows the spatial variability of NDVI readings for both table grape varieties and their corresponding three-zone delineation using the natural breaks algorithm. On the average, Red Globe had larger ($P<0.12$) NDVI values than Thompson Seedless, which corresponds with the characteristics of each variety.

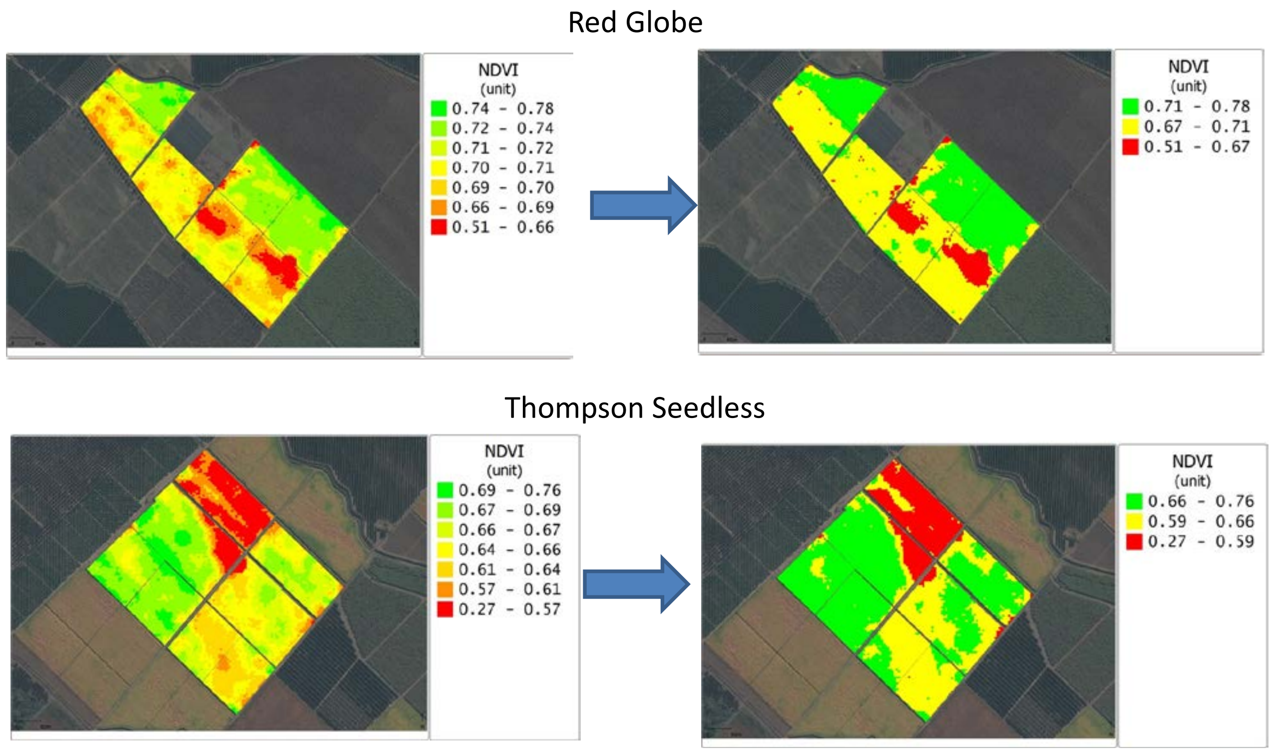

Figure 4. Spatial variability of NDVI and vigor zone delineation by natural breaks algorithm.

Significant differences (P<0.03) in pruning weight in recess, for the Thompson Seedless variety, were observed only between the high and medium NDVI strata (Figure 5). Probably, the canopy management that it is usually performed during the season masked the differences observed in NDVI.

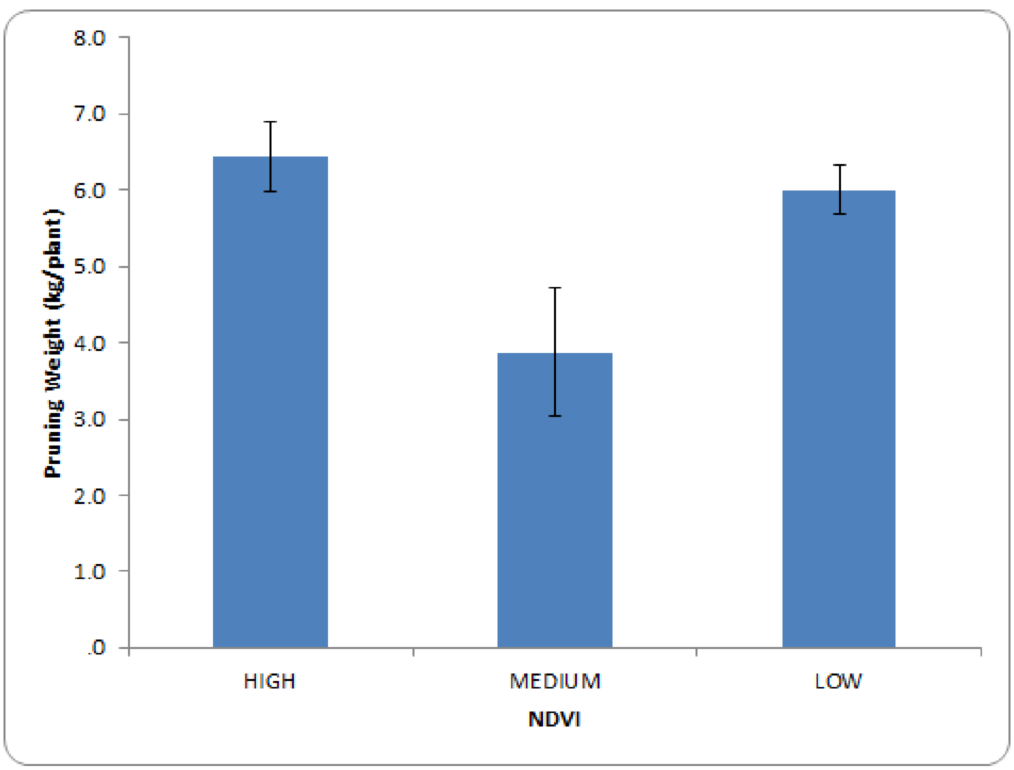

Figure 5. Pruning weight at recess as affected by NDVI zones.

There were not significant differences among NDVI zones, in either variety, for most physical, chemical and biological soil properties. Few significant interactions variety x NDVI zone were observed for biological properties, for example for acid phosphatase activity, which increased with vigor only at the Red Globe fields (Figure 6).

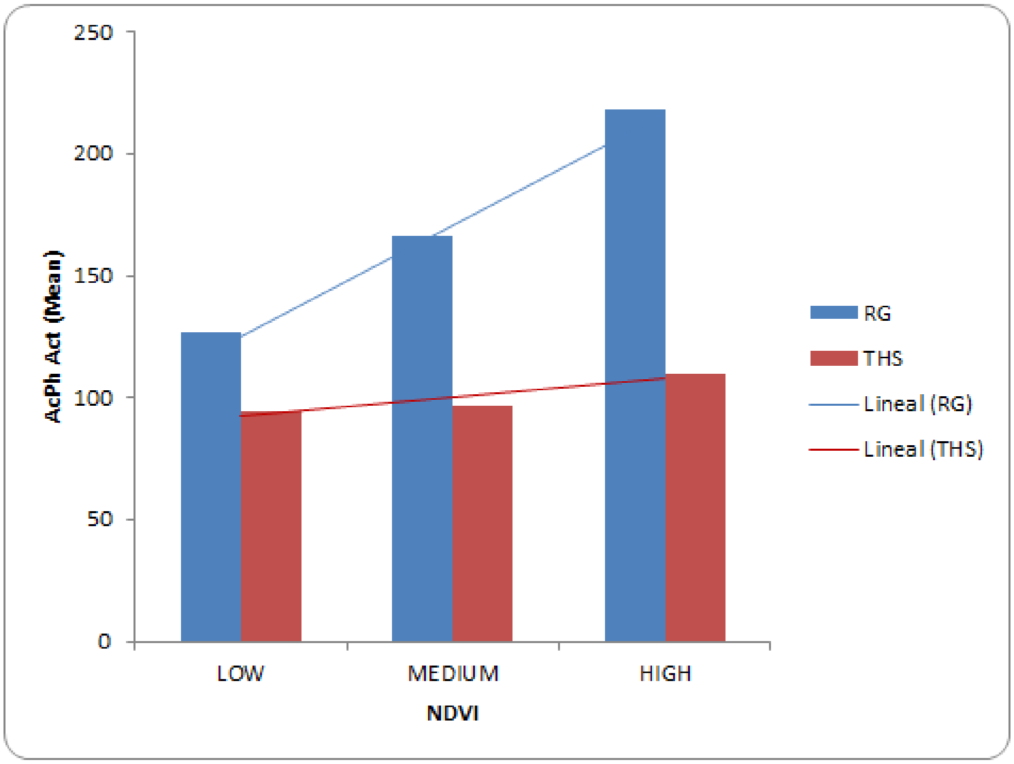

Figure 6. Acid phosphatase activity as affected by NDVI zone and Table Grape variety.

In the low vigor areas of the Thomson Seedless variety, a differential treatment consisting on compost addition was applied during recess time. After application, during the following season, the fields were evaluated again with the OptRx sensor. It could be observed that the low vigor area had disappeared and that the fields were more homogeneous (Figure 7).

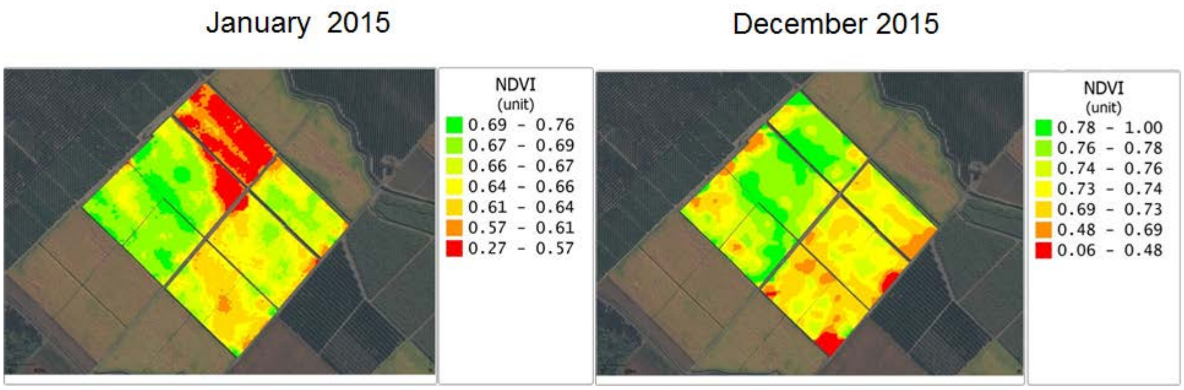

Figure 7. Changes in NDVI readings after a differential treatment applied in the low (red) NDVI area.

Conclusions

Results indicated that OptRx sensor is a simple and useful tool to study canopy changes in table grapes. The NDVI obtained from the sensor is a good variable to incorporate in regression models to evaluate modest treatment effects or to perform follow up on management effects. Stratified sampling using NDVI allowed identifying few soil properties that may explain plant vigor, particularly biological ones.

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References

Jenks, George F. 1967. The Data Model Concept in Statistical Mapping. International Yearbook of Cartography 7: 186–190.

Maharlooei, Mohammadmehdi, et al. 2014. Evaluation Of In-Field Sensors To Monitor Nitrogen Status In Soybean. Proceedings of the 12th International Conference on Precision Agriculture (ICPA).

Ortega, R. and Molina, M. 2016. Evaluation of vegetation indices and apparent soil electrical conductivity for site-specific vineyard management in Chile. *Precision Agriculture*. 17:434–450.

Ortega, R.A., L.A. Jara, A.A. Esser, and A.A. Inostroza. 2008. Using multispectral imagery and directed sampling to estimate wine grape yield. Proceedings of the 9th International Conference on Precision Agriculture (ICPA).

Ortega, R. y Gallardo A. 2014. El campo hecho datos. Uso y potencialidades de los sensores en agricultura. Revista MundoAgro 57: 44-49. Agosto 2014.

StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP.