#7531 ORCHARD YIELD ASSESSMENT IN NORTH-EAST OF MOROCCO USING SATELLITE IMAGERY

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ABSTRACT

Agricultural sector represents one of the pillars of the Moroccan economy. The Green Morocco Plan (GMP) established in 2008 present the main engine of development of this sector and for local economy. One of the objectives of Pillar I and Pillar II of GMP was to maximize production with less use of water resources. Currently, Morocco is experiencing a strong variability in spatial and temporal variability of precipitation with a detrimental effect on yield and quality of crop production. The aim of this work is to assess the potential of Sentinel-2 imagery in precision agriculture to assess interannual production variability in two of the most valuable orchard products in Morocco (Table grapes and Oranges). In this current study, commercial farms of 34 ha located in Oriental region of Morocco with citrus and table grapes were chosen: Oranges (Citrus sinensis L. cv. Navel Washington) planted in 1999 (8ha) and 2013 (8ha); 2ha of clementine (Citrus reticulata cv. Marisol) and 8ha of table grapes (Vitis vinifera cv. Mousca Italy) planted in 2008. The harvest date starts in October, January, and September for navel, clementine and table grapes, respectively. Yield data were collected during three years 2017, 2018 and 2019. The comparison of the interannual NDVI at monthly time scale with the yield monitoring values reveals (i) different patterns for young age orchard; (ii) different monthly trend as effect of climate pattern and consequently in terms of vegetation growth and vigor; (iii) different rate of change in terms of magnitude and sign of NDVI monthly series from blossoming to maturity are strictly correlated with final production, for both orchards. Marisol and Navel orchards showed the highest interannual variability in terms of production both for young and old plantation while table grapes exhibit a reduced range. For Navel orchard the rate of increase in the time series curve of NDVI, from July to December, is positively correlated with the final production and it is able to reconstruct most of the yearly variability (R^2=0.9). Instead, for tables grapes strongly NDVI rate variation (June-August) is negatively correlated with the final production (R^2= 0.98).

INTRODUCTION

Agricultural sector represents one of the pillars of the Moroccan economy. It generates around 14% of gross domestic product (GDP) (MAFRDWF, 2014), and this depending on the year and climatic conditions. Agriculture also remains the country's leading source of jobs, with 40% of the working population living in this sector. The useful agricultural area (UAA) is estimated at 8 700 000 ha. However, this figure should be qualified by emphasizing the importance of rangelands (over 20 million ha), which are not very productive, but which play a significant role in pastoral zones for feeding livestock. Moroccan agriculture has been developed, recently, thanks to the foundation of “Green Morocco Plan” (MAFRDWF, 2017). This project, launched in 2008, aims to make agriculture one of the leading sectors of the country, promote agricultural investments, ensure food security, stimulate exports and enhance local products. This program aims to support agriculture under two pillars. The first concerns modern agriculture with added value and high productivity. The second pillar, aim to improve the living conditions of small farmers and fight against poverty in rural areas by increasing agricultural income in the most vulnerable areas. The issue of water is essential for the development of agriculture. Morocco very early on turned towards the creation of large dams supplying irrigated areas which represent 1.1 million ha. Currently, small hydraulic structures and localized irrigation are favored and developed, which is more beneficial and therefore more suited especially during the situation of global warming. In recent years, nearly 400 000 ha irrigated by gravity have been converted to localized irrigation. Rained agriculture zones, present 83% of the UAA (MAFRDWF, 2014), but much less productive because they are severely affected during dry years. According to the Economic Social and Environmental Council, the water scarcity situation in Morocco is alarming since its water resources are estimated at less than 650 m^3 /inhabitant/year, against 2,500 m^3 in 1960, and should drop below 500 m^3 by 2030 (Puchot, 2020). As an effect of climate change, Morocco is experiencing a strong variability in spatial and temporal variability of precipitation with a detrimental effect on yield and quality of crop production. An increase in water demand by field irrigation and competition over conventional water resources were recorded during the last decade. Moreover, Moroccan agricultural policy is geared towards export rather than local consumption, which generates strong pressure on water resources for field irrigation. Thus, the Green Morocco Plan and the National Water Sector have adopted a national irrigation water saving program to face this issue. However, despite these efforts, the water constraint stills a problem that the country faces.

Many technologies and strategies of irrigation were investigated and developed to optimize water management for agriculture and face to the global warming. Using precision agriculture tools and especially satellite imagery and smart sensors is considered as one of the current topics of research in field of water optimization for irrigation. Aerial and satellite imagery have been recognized as excellent tools to obtain a large amount of spatial information (Herrero-Huerta et al. 2016). This is due to their ability to cover large areas and control crop water uses (Calera Belmonte et al. 2005). Hence, an open access to geo-referenced Landsat and Sentinel images in near real time (Skakun et al. 2016) are allowed. Several decision support systems based on web-GIS tools have been developed with different purposes (Gkatzoflias et al. 2013). Different geospatial applications have been used. For example, SPIDER software that used Landsat-5 imagery could estimate water requirements based on normalized difference vegetation index (NDVI) (Calera et al. 2017). The aim of this work is to assess the potential of Sentinel-2 imagery in precision agriculture to assess inter-annual production variability in two of the most valuable orchard products in Morocco.

MATERIALS AND METHODS

In this current study, commercial farms of 34 ha located in Oriental region of Morocco. The field experiments were carried out on an agricultural production farm located in Sector N°2, El Garet, Al Aaroui, Perimeter of Moulouya, Morocco (Latitude: 34 ° 56'10.8 “N and longitude: 3° 00 '19 “O). This region is characterized by a Mediterranean climate, with an annual precipitation rate that does not exceed 400-500mm. Citrus and table grapes were chosen for our trials: Oranges (*Citrus sinensis L.* cv. Navel Washington) planted in 1999 (8ha) and 2013 (8ha); 8ha of table grapes (*Vitis vinifera* cv. Mousca Italy) planted in 2008. Plant density for table grapes and oranges were 2000 and 500 plants/ha, respectively. The production was irrigated and fertilized with a drip irrigation system. Production management (from pruning to harvest) was done according to the production methods used by commercial growers of table grapes and citrus in Morocco. Yield data were measured for each treatment. Yield data were collected during three years 2017, 2018 and 2019.

The satellite solution chosen is the Sentinel-2 platforms (European Space Agency Copernicus program https://sentinel.esa.int/web/sentinel/missions/sentinel-2) to monitor the crop status at weekly frequency (Toscano et al. 2019). Those platforms provide free images with 13 spectral bands covering the visible, NIR and SWIR at 10, 20 and 60m spatial resolution (images available on ESA Sentinel Scientific Data Hub https://copernicus.eu/). Sentinel 2 platforms represent a valuable solution for crop monitoring, due to their high revisit time of about 2-3 days in mid-latitudes under cloud-free conditions. Polygons corresponding to the study areas will be extracted from each of the Sentinel-2 images. Reflectance values from bands 4 (red) and 8 (near infrared) will be used to calculate NDVI.

RESULTS AND DISCUSSION

For how concern the first Navel orchard, planted in 2013 (Figure 1), during the first two years of observation (2017 and 2018) NDVI shows substantially low values typical of a plant system that has not yet reached the optimum in both vegetative and reproductive stages.

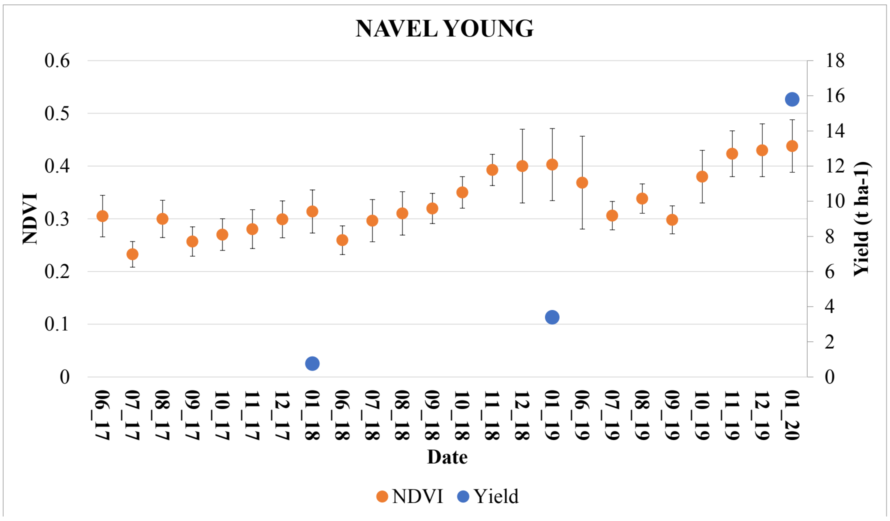

Figure 1. NDVI and yield comparison for Navel planted in 2013

Indeed, the NDVI average for the period June 2017 - January 2018 was of 0.28±0.03 and without showing a clear peak. In 2018 the orchard showed a slightly more pronounced peak with an average NDVI (June 2018 - January 2019) of 0.33±0.05. When a yield performance close to optimal conditions was finally expected in the third year of observation, the orchard was affected by unfavorable weather and water shortages (USDA 2020 annual report (https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Citrus%20Annual_Rabat_Morocco_12-15-2019), especially in the first part of the growing season. The NDVI (June 2019-January 2020) indeed presents a very low initial pattern and then reaches a peak in January (0.36±0.06).

For the second NAVEL orchard planted in 1999 (Figure 2), an under optimal yield performance was experienced for the whole study period (expected 40 t/ha, harvested max 24.1 t/ha), due to non-optimal conditions (biotic and abiotic stresses) in part highlighted by NDVI during the reference periods June-January for each year. During the first year, although a monotonous growth in NDVI trend can be observed up to the peak of January, the absolute values are low and are the lowest for the entire period in conjunction with the lowest yield. The second year presents the higher yield and a monotonous trend of vigor with peak values that are not excessively high when compared to citrus NDVI values reported in other regions (Vanella et al. 2020). The third year on the other hand, although it shows the highest peak values at the end of the agricultural year, clearly shows a not monotonous trend with fluctuations in terms of NDVI values as an effect of water shortages.

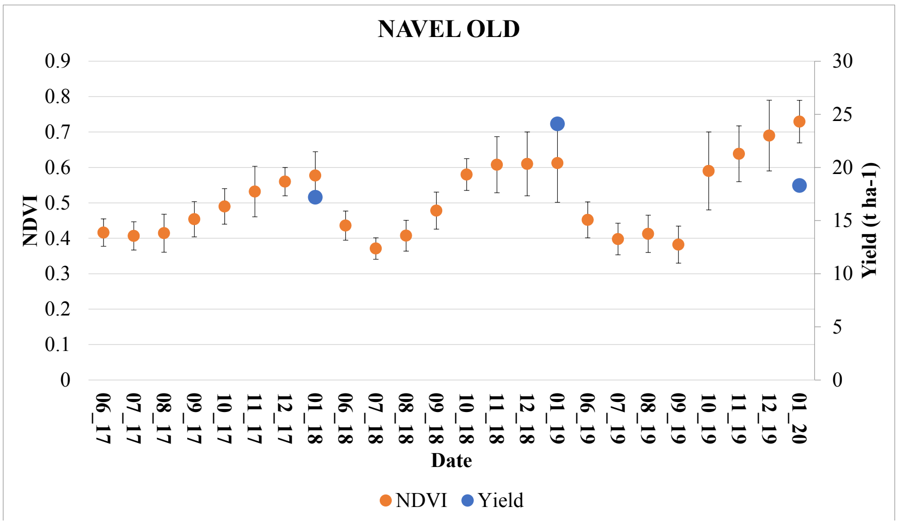

Figure 2. NDVI and yield comparison for Navel planted in 1999

For table grape (Figure 3) the NDVI values for 3 months (June-August) preceding the beginning of the harvest (September) were taken into consideration for the whole study period. Although the yield performance over the 3 years is substantially equal (30.5, 29.1 and 31.1 t / ha for 2017, 2018 and 2019, respectively), a strong correlation was identified between NDVI and yield. All 3 years show a similar trend with higher NDVI values in June and August and the lowest values in July (pruning effect), while the yield is strongly anticorrelated to ΔNDVI (delta NDVI) between June-July and August-July (R2 = 0.99). i.e. agricultural years characterized by greater regularity in the phases of vegetative development have higher yields. Therefore, the optimal yield is obtained when the vegetative development does not suffer from accentuated fluctuations, but follows regular patterns of growth and trend for NDVI. These results confirmed the hypothesized correlation between VIs acquired during orchard vegetative stage and production. This information, when coupled with weather observations and seasonal forecast, is valuable for forecasting yield, planning field activities and generating prescription for specific management practices to contrast the significant yield losses due to drought stress.

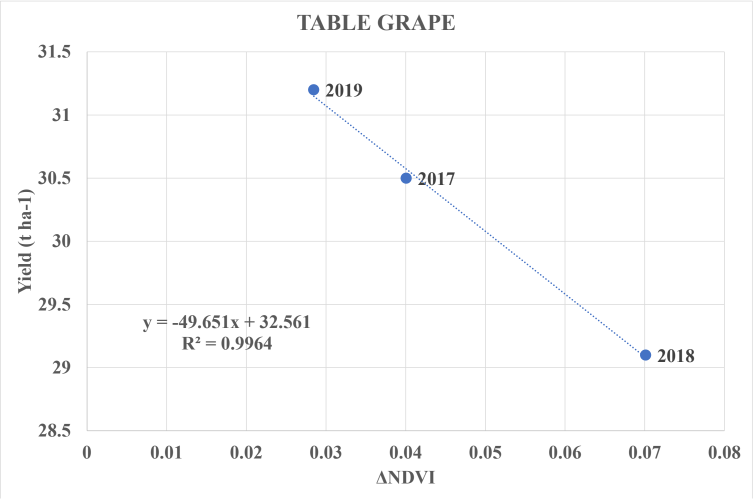

Figure 3. NDVI and yield comparison for Table Grape

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