Real Time Canopy Mapping of an Apple Orchard with New Applied Sensors

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Abstract – One of the most difficult challenges in everyday practice is to describe the canopy growing of fruit trees. The accuracy of data determines the available yield quantity and quality. The photosynthetic activity is one of the most important properties concerning the primer production of plants, since there is a very close relationship between water use and the dynamic of tree development and the photosynthetic activity. Our experiment worked out in an intensive apple orchard at the Study and Regional Research Farm of the University of Debrecen near Pallag. This study shows the filtering and interpretation methods of created data. The produced high accuracy data can be directly used in the precision horticulture. It could serve as a guide data for the implementation a future "virtual horticulture". Higher spatial and temporal resolution can help for a better recognition of water balance of orchards. Therefore, the results can provide water and energy saving technologies to reduce the ecological footprint of fruit production.

Keywords: precision horticulture / spectral canopy mapping / laser scanning / apple orchard

1. INTRODUCTION

Currently in Hungary less than 100,000 hectares of orchards can be found, from which apple is cultivated one of the largest areas. Apple orchards cover about 60% of the total pomiculture in Hungary, although in the last period the production was reduced (GONDA – APATI 2011). The production of marketable horticulture products is difficult without quality horticulture practice, which in many cases is the primary condition of appropriate management and irrigation systems. The precision agriculture and precision horticulture contribute to the high quality yield production. Besides the environmental and field protection, the costs reduction, increases of efficiency are justified the widespread of precision techniques. Presently, the development of fast information technology gives our hand such methods like global positioning system (GPS), Geographic Information System (GIS), remote sensing (RS). Covered and uncovered ground can be quickly, accurately and cost effectively examined on large area (BURAI 2007). This ternary technology apace develop an integrated complementary in geospatial sciences and researches.

Remote sensing (RS) is rapidly developing discipline. Remote sensing, also called earth observation, refers to obtaining information about objects or areas at the Earth's surface without being in direct physical contact with the object or area (BELÉNYESI et al. 2008). According to LÓKI (1996) the remote sensing means not only a special data collection, but processing and evaluation of these data also. Remote sensing provides to get information from large areas beside/instead of traditional sampling data (BURAI 2007, TAMÁS et al. 2009).

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The principle of remote sensing based on interactions and investigations of electromagnetic radiation with material (e.g. earth's surface). These thoughts were formulated in the early 1930s by Krinov Soviet scientist. The basis of remote sensing is incoming radiation to the object (E_I). When the radiation incident upon the object's surface, is either reflected (E_R) by the surface, transmitted (E_T) into the surface or absorbed (E_A) and emitted by the surface. These variables are depending by the wavelength (λ). So, it could be created the following equation:

$$E_R(\lambda) + E_A(\lambda) + E_T(\lambda) = E_I(\lambda) \quad \text{(Eq. 1)}$$

It could be determined from the equation that on given wavelength the reflection, absorption and transmission are equal to the total incoming radiation (AGGARWAL 2004). The values are always depended on the physical characteristics of the object and the geometric structure (MOLENAAR 1993). When a remote sensing instrument has a line-of-sight with an object that is reflecting solar energy, then the instrument collects that reflected energy and records the observation. Most remote sensing systems are designed to collect reflected (E_R) radiation (SHORT 2011). Based on the measured values it could be concluded to physical and possibly chemical characteristic of the observed object (MOLENAAR 1993).

There are two types of remote sensing: passive remote sensing and active remote sensing. Passive remote sensing is detected natural radiation that is reflected by the object or surrounding area being observed. Reflected sunlight is the most common source of radiation measured by passive sensors (BELÉNYESI et al. 2008). The active sensors emit a certain radiation. It could be measured the reflected part of this emitted energy from the object. Active remote sensing systems are available in all weather conditions, day or night. The absorption and reflection of the solar radiation – or emitted light by an active sensor – are the result of relationship of the plants tissues, which are different by wavelengths (BERKE et al. 2004). Chlorophyll absorbs markedly spectral range between 450-670 nm. Reaching infrared spectral range, the reflectance of healthy vegetation increases rapidly. Healthy vegetation reflects the 40-50% of the incoming energy between 700-1300 nm spectral ranges due to the internal structure of the leaves, it is influenced mainly by the lignin content of cell wall and the parenchyma structure (GATES et al. 1965). In this way, the measured reflectance plays an important role in distinguishing different plant species, even if these species are seems to be similar based on visible spectral range (BERKE et al. 2004).

The remote sensing is an efficiency tool in shadowing of biomass production. It could be ability to create vegetation indices, which are correlated with the biomass. The plants reflect the visible (VIS) band in a small compass, but in near infrared (NIR) band the reflectance increases depend on the chlorophyll content of leaves, and changes proportionally to produced biomass. Used the reflection of RED (630-690 nm) and NIR bands (760-900 nm) it could establish the plant green mass. One of the most frequent indices is Normalized Difference Vegetation Index (NDVI) to investigate the surface coverage and biomass (NEMÉNYI et al. 2010). Used another bands of NIR and RED, it could be detect else important information about the vegetation, such as leaf area (QUAN et al. 2005), nitrogen supply (YODER – PETTIGREW- CROSBY 1995, CABRERA-BOSQUET et al. 2011), or the water content of plant tissue could be determined as well by the Water Band Index (WBI) (GAMON – QIU 1999, CHAMPAGNE et al. 2001, NAGY et al. 2010).

Another type of active remote sensing technique is laser scanning (LIDAR – LIght Detection And Ranging). The LIDAR are similar to RADAR systems, but in this case a laser light sweeps the object or the earth's surface (BELÉNYESI et al. 2008). The laser scanner analyzes a real-world or object environment to collect data on its shape and possibly its appearance (e.g. color). The collected data can then be used to construct digital, two-dimensional drawings or three-dimensional models useful for a wide variety of applications. The advantage of laser scanning is the fact that it can record huge numbers of points with high accuracy in a relatively short period of time (LERMA GARCÍA et al. 2008). The 3D model building is occurred, if it is known the distances (so positions) of the measured points to the laser scanner. Determination of one point's distance could be occurred based on 3 methods, which are, triangulation based measurement techniques, time-of-flight (TOF) and phase-based methods (LERMA GARCÍA et al. 2008, VOSSELMAN – HANS-GERD 2010).

To be able to measure multiple points from the same scanner point of view, the laser beam needs to be deflected. Instead of moving the laser itself, a deflection unit is used. Most deflection units make use of a mirror because they are much lighter and can thus be rotated much faster and with greater accuracy. A number of methods exist to deflect the laser beam towards a specific direction without having to move the scanner itself (LERMA GARCÍA et al. 2008). To the 3D modeling of a certain surface is necessary the object swept from more scan stations, so it could be get a point cloud, which is contain more million points. The instrument is put the scan stations in a common coordinate system, so it is create the spatial location of the target.

Airborne laser scanning has already been adopted and accepted as a very valuable tool in forestry applications shortly after its advent as a commercially available measurement technique in the 1990s. The using of terrestrial laser scanner (and mainly airborne laser scanning technology) has been even less spread in horticulture applications (VOSSELMAN – HANS-GERD 2010). Both in two areas (forestry and horticultural applications) with laser scanner technology it could be recognized the structure of trees, the canopy extension and else structural aspects, so it could be long term shadowing many biophysical processes and monitored the changes (ROSELL et al. 2009). So it could be recognized photosynthesis, growth, CO_2-sequestration and evapotranspiration (LI et al. 2002, ROSELL et al. 2009).

2. MATERIAL AND METHODS

On 3rd September (fully developed canopy condition) we carried out a terrestrial 3D laser scanning measurement in Study and Regional Research Farm of the University of Debrecen near Pallag. The study area was an intensive apple orchard with drip irrigation system, protected by hail net. The ScanStation C10 by Leica Geosystems uses the time-of-flight (TOF) principle for ranging. The light waves travel with a finite and constant velocity in a certain medium. Therefore, on the base of the time delay created by light travelling from a source to a reflective target surface and back to the source (round trip) their distance can be calculated. The scanner sweeps along the examined object with a green laser light. The laser beam deflection is occurred by a Smart X-Mirror™. This is an automatic fast spins polygon mirror system, which provides creating a point cloud composed of millions of points. The Field-of-View (horizontal 360° and vertical 270°) is arisen from the construction of instrument, since the laser scanner doesn't survey under itself in 90°. Near the laser emitter it could be found an auto-adjusting, high-resolution digital camera with zoom video. The integrated 4 megapixel (1920x1920 pixel) camera takes photos to color the point cloud. The Field-of-View of the camera is 17°, so the automatically spatially rectified (panoramic) dome was made form 260 images on each scan position. We have surveyed one row of study area with 7 scan stations. The overlapping of scanning areas provided the unifying of point cloud, and increased the accuracy of measurement. The scan resolution was 8 mm on 10 m; it means that the accuracy was below 1 cm on the right side. The processing of raw point cloud was carried out by Leica Cyclone 7.1 and 3DReshaper software. The two softwares are appropriate for cleaning the point cloud form noises, and ideal for several engineering calculations.

For further investigation of the fruit trees we used another active remote sensing instrument in data acquisition. On the 8th of November 2011 we carried out the measurement with GreenSeeker 505 vegetation indexmeter. The weed coverage of the soil surface and the spectral characteristic of the canopy were investigated by the instrument. The most information was provided by the NDVI value. Because of the GreenSeeker 505 is an active remote sensing tool, it has got an internal light to calculating NDVI. The sensor operates by emitting light (red band and infared band) from the rectangular window onto a crop's canopy.

Reflected light from the canopy is focused on a detector behind the circular window. The system is calculated the NDVI from the given values, based the following equation:

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad \text{(Eq. 2)}$$

Both the rectangular and circular windows need to be free of any viewing obstructions when mounted. The data collecting was carried out 0.8-1 m from the soil surface and 50-100 cm from the foliage. As an interface of GreenSeeker 505 is working AgGPS FmX integrated display by Trimble, which has two built-in GNSS (GPS and GLONASS) to achieve more accuracy. The satellites signals are taken by an external AgGPS 25 antenna. Based on the longitude and latitude the NDVI values were summarized by the job computer. The data are simply downloaded via USB connection. Processing of data we have used the Surfer 10 software. The NDVI, the altitude and the speed values were saved the hardware of job computer in each second. Both the AgGPS FmX and the Greenseeker 505 were mounted on a tractor. The speed of tractor was 2.38 km/h, it could be determined the data of job computer. The speed of tractor was even, this verified the low standard deviation of speed data.

3. RESULTS AND DISCUSSION

The vegetation index measuring and laser scanning were carried out in Study and Regional Research Farm of the University of Debrecen near Pallag. The collected data by the Greenseeker 505 were processed and evaluated in Surfer 10 software environment. In case of the first measurement we have investigated weed coverage of the soil surface (*Figure 1/A*). The left side of surveyed area had a relatively high NDVI value due to the high weed coverage. On the other hand, the reflectance characteristic of right side ("long row") is shown relatively low NDVI value, since the soil was bare. Exception of left side of the hail protected orchard of the soil surface was weedless. Due to the felt leaves from the senescent canopy, there were such parts of the investigated area, where it could be detected average (0.5-0.6) values. The NDVI map was created an interpolation technique by Surfer 10 software. The interpolation is a mathematical approximately method to determine the unknown values based on the known values. The interpolation of spatial data were carried out with Krieging method.

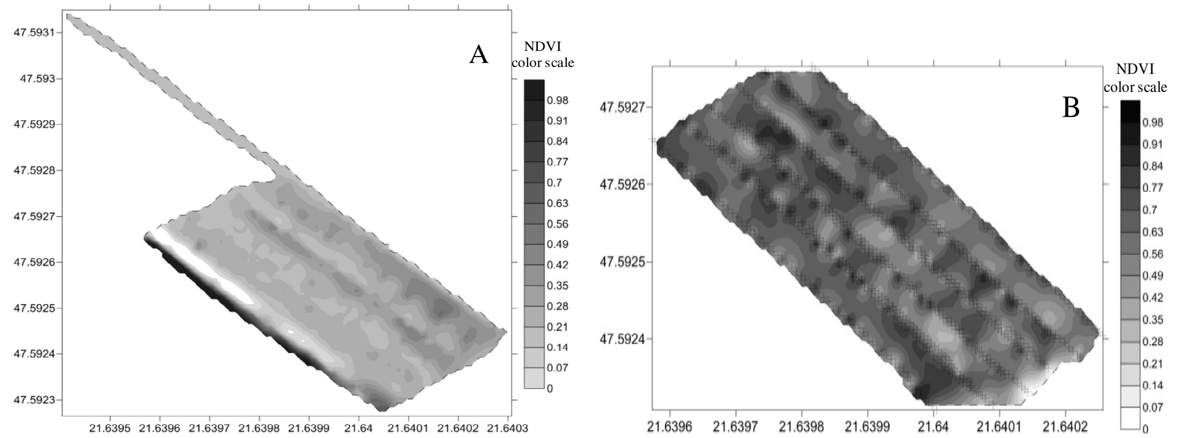

Figure 1. NDVI soil map (A) and NDVI vegetation map (B) of the investigated apple orchard

In the case of the second measurement, the canopy NDVI values were investigated. From the distance of 0.5-1 m were collected the data by the sensor. Based on the given NDVI map it could be established, where was higher the chlorophyll content. The higher NDVI values shown, which trees have not felt they leaves yet, and/or which leaves have not decayed they chlorophyll content (*Figure 1/B*).

The laser scanning survey has given opportunities to determine the 3D structure of trees of the trees from the study area. It could be fitted an object depending on the topology of the scanned point clouds by own software (Leica Cyclone 7.1) of Leica. We have modeled the stem of investigated tree, and Cyclone fitted the best shape which was a cylinder. Then we were able to determine some characteristics of this cylinder, such as (stem) diameter, height, surface and volume calculation too. Some trees on the study area had not been harvested yet, so the instrument scanned the fruits too. We have built the apples in 3DReshaper software by the Hexagon Group. The point cloud from the apples were not full, but the 3DReshaper fitted a sphere, based on the curvature of point cloud.

4. CONCLUSION

The results shown the used instruments were appropriate in horticulture applications. The vegetation activity of fruit trees and weeds could be detected, since there is a close correlation between NDVI and chlorophyll content, so it could be concluded health of the vegetation. Beside this, the NDVI could help in nutrient management and could support a precision pest management system. In the course of laser scanning we modeled in three dimensional of the fruit orchard. Further experiments are needed to recognize the canopy structure based on the combination of both high-tech instruments. The low NDVI values could mean a gap of the canopy, and a contactor could provide to get out more pesticide, where the NDVI is higher. To detect the weed flora of soil surface, it could work out an energy and pesticide saving precision pest management system to reduce the ecological footprint of fruit production.

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