Variable Rate Application of Nitrogen Fertilizer in a commercial pear orchard

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Abstract
The application of high nitrogen (N) fertilization potentially leads to adverse environmental impacts due to nitrate leaching, ammonia volatilization, nitrous oxide (N_2O) emissions and soil acidification. Determining the optimum amount of N fertilizer and minimizing the environmental impact is a difficult task, but it can be accomplished using Precision Agriculture techniques. Based on this concept of precision agriculture, site-specific management (SSM), rather than the traditional whole field approach, is considered as a practice that enables the farmer to manage field variability. The yield monitor and variable rate chemical application together with the adaptation of existing technologies (GIS, GPS) have made possible the application of SSM. In this study results of using variable rate application (VRA) in a pear orchard are presented. The application of Nitrogen fertilization was conducted using the method of VRA based on the Nitrogen loses of the yield of the previous year according to the literature. The experiment took place in a commercial pear orchard in the area of Tyrnavos (Larissa). Crop yield was monitored in both years before and after the VRA of fertilizer. The yield in the second year was not only increased in quantity (4 tons more) but also the production capacity of the trees with minimum production were improved (from 10,5 kg/tree into 20,5 kg/tree).

Keywords: Nitrogen fertilization, Precision agriculture, Site-specific management, Pear orchard

Introduction

Farming operations entail complex decision making problems, characterized by considerable levels of uncertainty and alternative courses of action. A farmer needs to consider a variety of parameters such as crop yield, availability of water and nutrients, and a range of site- and soil-specific factors to optimize the plant treatment (e.g. application of fertilizer, pesticides, or irrigation). A high variability of these parameters within a single field further complicates the optimization of the plant treatment. The common practice of regarding the field as a homogenous entity creates a sub-optimal treatment, often leading to an oversupply of nutrients and pesticides, thus creating considerable costs for farmers and major environmental source of pollution (Aubert et al. 2012). Site specific management (SSM) meaning the application of inputs according to site rather than the traditional whole field approach is introduced through the general concept of Precision Agriculture (PA). There are several diagnostic tools which support the applicative processes of PA, where ultimate purpose has the management of field variability. According to Khosla et al (2010) the delineation of zones for crop management enables site-specific crop management avoiding the high costs associated with sampling and analysis for geostatistical analyses. Management zones can be useful for variable rate application of crop inputs using the spatial analysis tools of precision agriculture for improved crop management (Ferguson et al. 2003). There are numerous proposed methods for delineating management zones (Bhatti et al. 1991; Shanahan and Schepers 2003), often varying with the management inputs under consideration, but generally relying on spatial information that is stable or predictable over time and related to crop productivity (Doerge 1999). Recent technology involving GPS guided prescription map-based fertilizer spreading or real time sensing has been developed to manage orchardssite-specifically (Miller et al. 2003).

In Greece, site-specific management is lesspracticed than internationally due to the small farm size, slow adoption of new technology, crop subsidies from the European Union and lack of relevant technology for fruits and vegetables (Gemtos et al. 2002). Precision agriculture commenced in Greece in 2001 with cotton crops. Recently, Aggelopoulou et al. (2011) produced fertilizationmaps for apple trees, based on the amount of nutrients thatwere removed from the soil with the previous year yield. Also Fountas et al. (2010) delineated management zones for fertilization, using soilchemical properties.Internationally Lopez-Granados et al. (2004) created site-specific fertilizationmaps based on leaf nutrient spatial variability and Zaman and Schumann (2006) produced nutrient management zones in a citrus crop.

Pear (Ryrus communis) is an important tree crop in Greece. The annual production of pears in Greece is about 44,000 tons (AgroNews 2012).The Greek pear orchards are managed traditionally, applying fertilizers and other inputs at uniform rates without considering the field spatial variability. This average recommendation will result in high yielding or large trees in the grove receiving relatively less fertilizer than they require and low yielding or small size tree areas receiving relatively more fertilizer than necessary (Zaman et al. 2005). Local over-fertilization may decrease ground water quality enhancing nitrate leaching, inducing ammonia volatilization and nitrous oxide (N_2O) emissions as well as soil acidification (Basso et al. 2012). Itmay also reduce profit margins, induce deficiency of other elements and interfere with metabolic processes.Under-fertilization may restrict yields and quality. Variable rate application avoids these problems but requires knowledge of the scale of variability of soil and tree characteristics within each field and whether such variability is random or patterned and the precise nutritional requirements (Mulla and Bhatti 1997).

In the present paper experimental results from a commercial pear orchard in which variable rate nitrogen fertilization was applied (VRF) is presented and discussed. No other experiment was found in the literature related to PA and SSM on pear trees in Greece.

Materials and Methods

A 0.55 ha of 9 years old coscia variety pears orchard was studied in Tirnavos area (Fig.1). The first task in order to apply PAon a field is the definition of variability.This definesa number of measurements and calculations that should be carried out. Apparent soil electrical conductivity (ECa) was measured, using EM 38 (Fig.2), as well as tree's vegetation index (NDVI), using Crop Circle (Fig.3). The instruments were connected to a GPS (Garmin) and data were collected by moving them between the tree rows. Soil texture, pH, $CaCO_3$, K, P, Mg, organic matter and soil moisture were also measured.

Figure 1. The orchard under study.

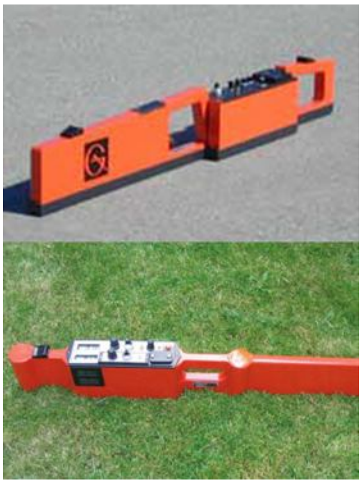
Figure 2. EM 38 of Geonics.

Figure 3. Crop circle.

Yield mapping was performed for 2011 and 2012. The harvest was carried out by hand, and the yield was recorded per five trees in the row. The workers were placing the pears in plastic beans as they were moving along the row on a platform. The bins were weighed as soon as they were filled and their position was georeferenced using a hand held GPS.

Maps of the measured parameters were produced by Surfer 9. Based on the nutrients removed by the crop yield of 2011and the yield variation a site specific basic fertilisation prescription map was produced. The applied N-fertiliser was replacing the removed nutrients. According to the literature (IFA 1992), 25.08 kg/ha N are removedfrom the soil of a pear orchard with 20.23 t/ha yield. This quantity of N represents thetotal uptake (fruits, branches, leaves, etc.). From the yield map of 2011, the amount ofnitrogen that was removed from the soil for every five trees was calculated and thenitrogen application map for year 2012 was created.

Results and discussion

Figure 4 shows the ECa map of the field. It is clearly shown the high variability in the field. Two or three management zones could be delineated based on the ECa measurements.

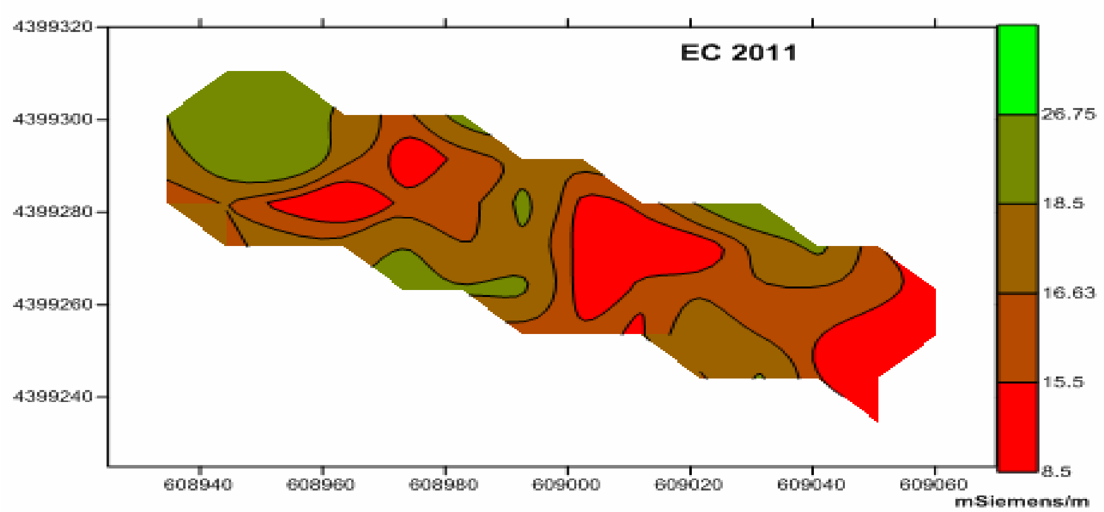

Figure 4. ECa map of the field, year 2011.

The maps that were created depicting pear yield for years 2011and 2012 are presented in Figures 5 and 6.

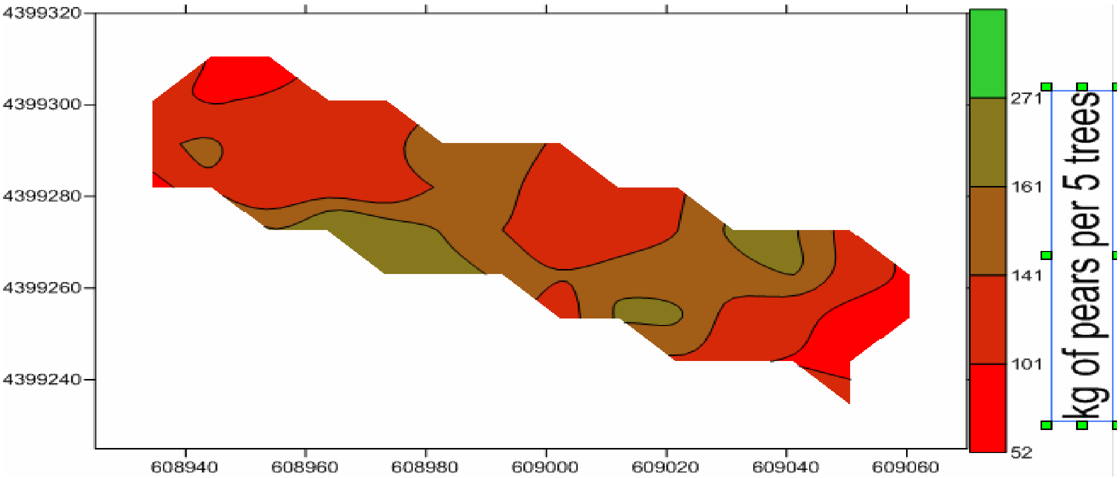

Figure 5. Yield map 2011.

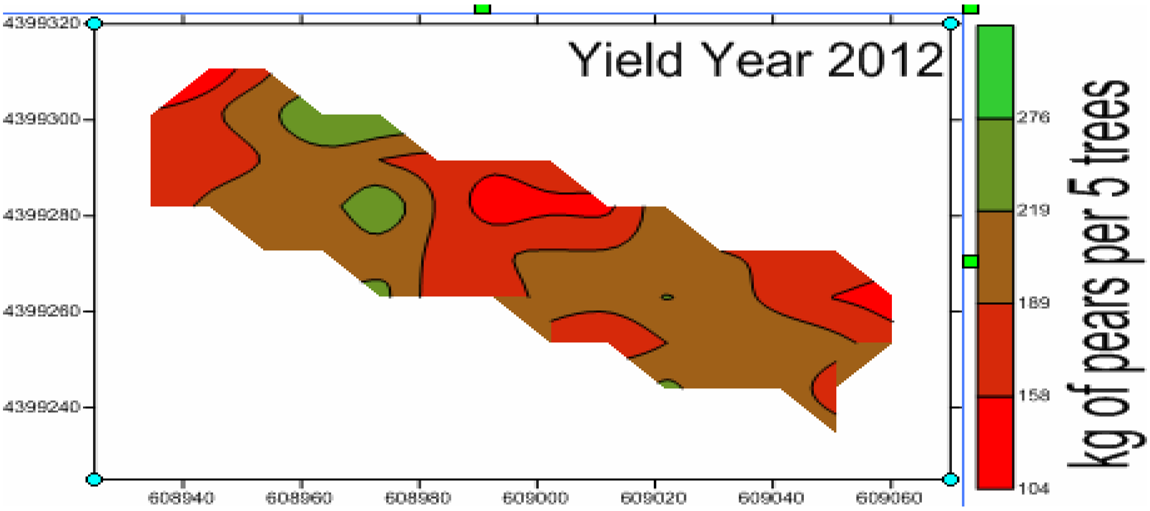

Figure 6. Yield map 2012.

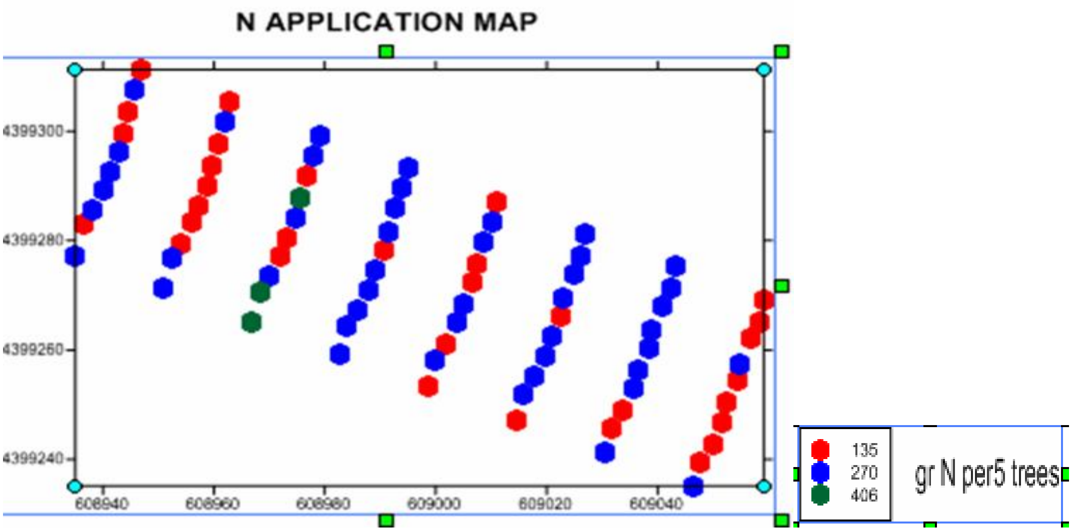

Figure 7. Application map of N fertilizer.

As already mentioned the creation of N-fertilizer map was based on the yield of 2011 and applied at the beginning of the following growing season of 2012 (end of February). According to the farmers statement the amount of N fertilizer he intended to apply in the particular field was 41 kg (about 82 kg/ha). Due to the variable rate application of the fertilizer the total amount of nitrogen that finally applied was 17.7 kg, meaning a reduction of 43% in the use of N-fertilizer. More over the application of the site-specific N-fertilizer improved the production capacity of the trees which had a minimum production the previous year as it is showed in figures 5 and 6, where the minimum kg per five trees in the year 2011, 52 kg, were doubled the following year, 104 kg, whereas the maximum production capacity almost didn't change.

Conclusions

From the presented results the following conclusions can be drawn:

1. High yield variability was present in this very small orchard justifying the application of site specific management.
2. Prescriptionmaps based on nutrients removal by the previous year yield could be produced and used for VR fertiliser application
3. VRF can reduce overall N application by 43% without adversely affecting next year's yield.

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