Chapter 4
Towards Fully Automated Decision-Making Systems for Precision Agriculture:
Soil Sensing Technologies – "The Missing Link"

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ABSTRACT

As the world population increases, food demands continue with it. This puts the challenge to feed the world in a continuously rising priority position, which requires to be timely and properly addressed. Precision agriculture (PA), a concept that has been around for decades with the potential to address this challenge by maximizing agricultural efficiency and effectiveness, hasn't yet seen worldwide adoption due to missing enabling technologies. Soil sensing technologies able to monitor soil fertility/quality can close the loop in maintaining optimum soil conditions for maximizing crop yield and quality through the implementation of agricultural automated decision-making systems (ADMS). This chapter provides an overview of the existing soil sensing technologies towards the implementation of ADMS and highlights the major challenges in the development of such systems. The chapter continues to give an insight on how different technologies could be combined to form sophisticated systems for agricultural applications.

INTRODUCTION

Current and future generations face an ever-increasing challenge concerning food supply. "As the population increases, there is an escalating demand for food, especially fruits and vegetables" (M. Sophocleous & Georgiou, 2017). The world population is projected by the Food and Agriculture Organization (FAO) of the United Nations to reach more than 9 billion people by 2050(FAO, 2009). At the same time, it is

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agreed by analysts that inter-country and inter-regional inequalities within the developing world would become more pronounced (Zarco-Tejada, Hubbard, & Loudjani, 2014). Furthermore, the projected global economic growth (2.9% annually) would lead to a major reduction of absolute economic poverty in developing countries; however, this will be far from solving the problem of economic deprivation and malnutrition of large parts of the global population (FAO, 2009). These trends suggest that the market demand for food will continue to grow(Alexandratos & Bruinsma, 2012). The rise of biofuels has the potential to alter some of these trends and cause an eruptive upsurgeon food demand that will mainly depend on energy prices and governmental policies(Stafford, 2000). Nowadays, that rural labor force is decreasing and the rise of a huge upcoming bioenergy market is on the horizon, farmers are given the burden to produce more food and fiber to feed the continuously increasing population. Furthermore, agriculture is now required to adapt to new, more efficient, sustainable and environment friendly production methods. The projections show that with a world population exceeding 9 billion people in 2050, overall food production must rise by approximately 70% comparing to 2005/07 production (FAO, 2009). Especially in developing countries, the production would need to double implying major increases in key commodities production. FAO expects that 90% of the global growth in crop production would come from higher yields and increased cropping intensity. Only 10% increase will be achieved by land expansion. Additionally, irrigable land would expand by 11% and harvested irrigated land by 17% with the increase happening entirely in developing countries.Fresh water resources follow a similar trend to the land availability(FAO, 2009; Zarco-Tejada et al., 2014). Overall, the total amount of water resources is sufficient but it is distributed in certain regions. There is an increasing number of countries reaching alarming levels of water scarcity whilst other countries have enough water to provide for more people than the country's population. However, there are still plenty of opportunities to increase water use efficiency. The potential to improve crop yields, even with the existing technologies is still significant but socio-economic reasons do not encourage the farmers to invest significant amount of money to bridge the gaps.Unfortunately, the same projections show that production increases alone would not be enough to ensure food for everyone(Bongiovanni & Lowenberg-Deboer, 2004). Governments need to ensure food access even to their most vulnerable groups. These projections emphasize the importance of establishing effectivepoverty reduction strategies, safety netsand rural development programs. The problem is further accentuated by healthier diet trends and an increase in veganism. A significant increase in demand of agricultural products puts an even heavier burden on farmers to improve their crop yields (Zhang, Wang, & Wang, 2002).

In the past centuries, in many surviving writings, it is obvious that especially for larger fields the spatial and temporal differences within the same field were highly appreciated. The first seeds of a concept to adopt to these variations were planted back in the 1930s by Linsley & Bauer (Linsley & Bauer, 1929) and possibly also by Eden & Maskell(Eden & E.J., 1928). The technology that actually initiated the progress of this concept was the development of the Global Positioning System (GPS) back in the 1970s. In 1983, the concept of custom prescribed tillage was developed, paving the way to use technology and automation for increased crop production (Stafford, 2000).

Although in previous centuries, due to the smaller agricultural areas, these spatial and temporal variations were manually controlled, nowadays due to much larger production demand and agricultural land, these variations are impossible to be controlled manually. The concept of using sensing technologies and automation to respond to spatial and temporal variations within a field is now called Precision Agriculture (PA). PA is also called Satellite Farming or Site Specific Crop Management (SSCM) and is described as a key component of the third wave of modern agricultural revolutions (Marios Sophocle-

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