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Coping with the Impact of Climate Change: A Dive into Precision Agriculture in the United States

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Abstract

With the continued increase in the number of people that are food insecure globally, which could be increasing because of the ongoing Ukraine-Russia war, leading to reduction in international agribusinesses, coupled with drastic climate change exacerbating the problem of food insecurity, there is a constant need to come up with innovative approaches to solve this global issue. In this article, we articulated how precision agriculture can be a tool for ensuring food security in the United States. This study aims to reiterate the significance of precision agriculture in solving global food insecurity.

Keywords

United States, Food Insecurity, Precision Agriculture, Positioning Systems, Climate Change

1. Introduction

There are discussions around the world about changes in weather and climate. These changes have affected human lives and activities in many ways. From cultural changes covering events, clothing, human behaviour, and others to economic changes as individuals, companies, communities, and nations are affected by mild and drastic effects of climate change such as flooding, drought, famine, and many more. In this article, we will look at the impact of climate change on food insecurity, focusing on the United States of America.

The United Nations (U.N.) organization defines Climate Change as the "long-term shifts in temperatures and weather patterns" [1]. These changes happen in several ways and can occur as increased seasonal variations in temperature and precipitation, or they may occur as increased frequency and extremity of weather events [2].

Climate changes either happen because of natural actions, such as the movement of tectonic plates, oceanic processes, and biotic processes [3], or human actions, such as carbon emission from vehicles and machines [4] [5]. However, the industrialisation of the 1800s led the way for human actions to be the main driver for climate change even until now. Man's efforts to improve lifestyle, finances and economy increased activities in mining and burning of coals, gas, oil, and other fossil fuels. These activities result in greenhouse gas emissions that result in an additional layer around the earth, trapping heat from the sun and increasing the temperatures in various regions on earth to varying degrees [5] [6]. "The immediate effect of increase in greenhouse gas emissions without offsetting increases in carbon storage on earth" is called global warming [5].

According to business dictionary, precision can be defined as a close, careful conformity to a convention, pattern, or objective standard in a minute detail. Agriculture refers to the practice of growing crops and rearing animals to provide food and other products for consumption. The practice of agriculture is usually limited by various factors such as low quality and fertility of soil, pest and disease infestations, poor planting decisions, etc. These factors can be remedied by practicing precision farming. Over the last few decades, many new technologies have been developed for, or adopted to, agricultural use. Examples of these include low-cost positioning systems, such as the Global Navigation Satellite System (GNSS), proximal biomass and leaf area index determination from sensors mounted on-board agricultural machinery, geophysical sensors to measure soil properties, low-cost remote sensing techniques and reliable devices to store, process and exchange/share the information [7]. In combination these new technologies produce a large amount of affordable, high-resolution information and have led to the development of fine-scale or site-specific agricultural management that is often termed Precision Agriculture (PA).

2. Food Insecurity

In 1996, the World Food Summit decided defined food security in this way: "food security exists when all people at all times have physical or economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [8]. In 1989, the Life Sciences Research Office (LSRO) convened an expert panel, which defined estimating food insecurity in the United States. Food Security was defined as "access to enough food for an active, healthy life" [9]. Meeting this definition requires nutritionally safe and adequate foods to be readily available. It also requires that an individual must be able to meet this definition through socially acceptable means. Hence, meeting food needs through stealing, scavenging, begging, or emergency services does not count as food security.

Food insecurity often (but not always) goes before hunger and malnutrition

[10] [11]. Food insecurity can be measured at the Household level, National Level, and Global Level [11]. It is important to measure food security on a Household basis instead of measuring at an individual level because it is possible for individuals within a household to be food secure while others are food-insecure, and any household with one or more food-insecure persons is regarded as food-insecure [12].

According to the Food and Agriculture Organisation (FAO), Socio-economic conditions are more important than agro-climatic conditions when measuring food insecurity [11]. This rationale is because the impact on domestic production is not the only factor to consider in measuring food security in a Nation, one also must consider the effects of climate change on foreign exchange earnings, the ability of other countries to produce excess food for exportation, and the minimum wage or incomes of the poorest people in that society [13]. Certain processes (production, processing, storage, distribution, consumption, and others) along a food chain need to occur to bring about food security, and the summation of these processes is called the "food system", and the performance of food systems determines food security [14].

Hence, factors that affect food security in a country include the effects of climate change on foreign exchange earnings, employment availability and the income of the poor, physical condition of individuals, effects of climate change in that country, effects of climate change in other countries, and ability of countries with surplus food to export for commercial purposes.

Food Insecurity Prevalence in the USA

According to the United States Department of Agriculture (USDA), 89.8% of households in the US were food insecure throughout 2021 [15]. As of 2021, that percentage represented 118.5 million people in the USA. This was a 0.3% increase from 2020, when 89.5% of U.S. households were food secure. For the 10.2% (13.5 million) of U.S. households that were food-insecure, the USDA categorized them into "households with low food insecurity" and "households with very low food insecurity".

Households with low food security can get enough food to avoid disrupting their eating patterns or reducing food intake significantly. These households were 6.4% (8.4 million) of the population. Households with very low food security are households with members who, at various times within the year, lacked access to food and had to reduce food intake, and disrupted eating patterns due to lack of funds or resources for food. These households were 3.8% (5.1 million).

Essentially, 33.8 million people lived in food-insecure households in 2021. 8.6 million adults lived in food-insecure households, and 5 million children lived in food-insecure households where adults and children were food-insecure. 521,000 (0.7%) children lived in households where one or more children experienced very low food insecurity.

Some other important data from the USDA reports include:

- 11.0% of Americans lived in food-insecure households between 2019 and 2021. Texas (16.8%), Mississippi (15.6%), Oklahoma (15.3%), Louisiana (14.8%), and Arkansas (14.3%) were the states with the highest percentage of food-insecure individuals from 2019 to 2021.
- 5% of children in the U.S. lived in food-insecure households in the 2019-2021 period. The states with the highest rates of food-insecure children were Delaware (20.2%), Mississippi (19.0%), Oklahoma (18.9%), Michigan (18.6%), and Louisiana (18.2%).
- Nationally, 8.2% of employed adults in the U.S. lived in food-insecure households from 2019 to 2021. The states with the highest rates of food insecurity among employed adults were Arkansas (11.9%), Delaware (11.4%), Texas (11.3%), Louisiana (11.2%), and Oklahoma (11.2%).
- In the U.S., 7.0% of older Americans, defined as people 60 years and older, lived in food-insecure households. Mississippi had the highest rate of food insecurity among older Americans at 12.6%, followed by Louisiana (12.3%), the District of Columbia (11.5%), Oklahoma (9.6%), and South Carolina (9.6%).

3. Climate Change Impact on Food Insecurity in the USA

Climate change has affected food insecurity in the USA by affecting the USA and other foreign countries. The world is interlinked; climate change in one place affects food insecurity elsewhere [13] [11]. Climate changes have either direct or indirect effects on food security. Direct effects result from climatic factors like increased temperature, precipitation, and the like. In the United States, a USDA report by [16] showed that there had been climate changes nationwide in the past hundred years. However, [16] shows that climate changes in Alaska have been most significant, with a one to two degrees Celsius rise in average temperature. The Northern Midwest and the Southwest have also seen temperature rises, although not as significant as Alaska. The United States has a complex topography; not all regions have seen temperature rises. [16] report that the Southeast has cooled in the last century even though there have been temperature rises in the last decade. [17] recorded that yearly temperature record highs in the USA and many parts of the globe were three times higher than record lows.

Some effects of such temperature rise include crops needing more water and livestock becoming more stressed [18]. Indirect effects on food security because of increasing temperatures include increased pests and diseases, survival and increase of weed and insect populations, increased cost of pest management, and increased cost of food items. [16] records that some regions of the country, like the Northwest, Southern, and Central USA, have seen more precipitation than regions like the Eastern Seaboard and the Rocky Mountains. The year 2022 saw a spike in heat waves across Europe and several parts of the United States, disrupting farming activities and reducing productivity.

As greenhouse effects from carbon emissions increase, the risk of climate change increase, damaging food security within the United States of America. Climate change affects agricultural production and other elements of national and global food systems that are important for achieving food security [11] [14] [19]. For instance, the increased temperatures could result in a higher cost of production, and increased temperatures could result in flooding, displacing employers, and employees. Hence, there is a reduction in food production, and the costs of food items go up while some households become socio-economically unable to meet food security requirements.

4. Precision Agriculture and Its Benefits in the US

Although more complex definitions exist, the simple description of the Precision Agriculture is a way to "*apply the right treatment in the right place at the right time*" [20]. It is a farming management concept based upon observing, measuring, and responding to inter and intra-field variability in crops or in aspects of animal rearing. The first actual definition of PA came from the US House of Representatives (1997), which defined PA as "*an integrated information- and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment*". Such a definition focused on "whole farm" management strategies using information technology, highlighting the potential improvements on production while reducing environmental impacts. Also, it already envisioned that PA was applicable not only to cropping systems, but to the entire agricultural production system (*i.e.* animal industries, fisheries, forestry).

The Site-Specific Crop Management (SSM) approach according to [21] "*a form of PA whereby decisions on resource application and agronomic practices are improved to better match soil and crop requirements as they vary in the field*". The variations indicated in such a definition are not limited to spatial (*i.e.* within-field variability) but also comprise observations throughout a season or between seasons. Actual PA implementation in the 1980's started when farmers integrated newly developed fertilizers capable of deploying variable rate application (VRA) technology with maps that showed the spatial variability of soil chemical properties. PA is also related to more recent approaches linked to climate change resilience, such as Climate Smart Agriculture (CSA), aiming at developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change [22].

It is widely accepted that better decision making in agriculture should provide a wide range of benefits. From the economic point of view, a review of 234 studies published from 1988 to 2005 showed that precision agriculture was found to be profitable in an average of 68% of the cases [23]. In an agriculture market where gross margin and profitability are getting tighter; farmers are looking for technologies that reduce costs without decreasing production. Although this is probably the primary reason for farmers to adopt such a farm management approach, it is not the only justification. In fact, in large parts of Eastern EU 28 countries, the aim is to increase production, and here direct economic benefits are likely to be larger.

The application of information technologies into PA methods has clear benefits to optimize production efficiency and to increase quality, but also to minimize environmental impact and risk, which includes undesirable variability caused by the human operator. PA nowadays is seen as an "*environment friendly system solution that optimizes product quality and quantity while minimizing cost, human intervention and the variation caused by unpredictable nature*" [21]. In fact, all new definitions of PA include terms related to risk, environmental effects, and degradation, as they are key concerns in the late 20th and early 21st centuries. PA becomes a management practice of increasing interest because it links to key drivers directly related to worldwide issues such as Sustainable Agriculture and Food Security [20].

There is some evidence from research which shows that environmental degradation is reduced when PA methods are applied, including increased fuel use efficiency resulting in lowering carbon footprints. Some other examples include nitrate leaching in cropping systems, demonstrating that variable rate application methods were successful in reducing groundwater contamination and that PA methods may reduce erosion when precise tillage is conducted. Therefore, PA is seen to help meet the measures defined in environmental legislation present in countries such as USA and Australia. In fact, this issue was proposed within the EU, as PA was identified as a way to meet future EU directives in Member States to reduce agro-chemicals [24].

Precision Agriculture also presents some benefits for social and working conditions. For instance, auto-steer systems are available for a variety of tractor models making the work less fatiguing. Also, the evolution of precision dairy farming technologies provides tremendous opportunities to improve delivery of automatic individual cow management applications and thus reduce labour requirements such as milking two times per day, and there are also arguments of increased animal welfare.

The implementation of PA has become possible thanks to the development of sensor technologies combined with procedures to link mapped variables to appropriate farming management actions such as cultivation, seeding, fertilization, herbicide application, and harvesting. For what concerns technologies, progress has been possible due to the rapid development, miniaturization, and improved accuracy of the Global Navigation Satellite System (GNSS) technology since 1999. In fact, GNSS technology (of which GPS is the most used at present) is now widely used in many farms for tasks related to geo positioning (*e.g.* auto-steer systems) and production of geo-reference information (*e.g.* yield mapping). GNSS has enabled the expansion of machinery guidance, auto steering and controlled traffic farming (CTF) systems. Such methods enable machinery to drive along repeatable tracks with accuracy, reducing errors made by the operator, reducing fatigue, and permitting more timeliness of operations. Another important element is the use of Variable Rate Technology (VRT) that allows precise seeding, optimization on planting density and improved application rate efficiency of herbicides, pesticides, and nutrients, resulting in cost reduction and reducing environmental impact. Many sensors are currently available and used for data gathering or information provision as part of the PA implementation. These devices are designed for both *in-situ* and on-the-go recording. Devices exist to assess the status of soils, such as apparent electrical conductivity (ECa) sensors, gamma-radiometric soil sensors, and soil moisture devices, among others. Others record weather information or micro-climate data (thermometer, hygrometer, etc.). Importance is given to sensors developed to quantify the physiological status of crops (*e.g.* Nitrogen sensors). These sensors are based on remote sensing principles, gathering point- or spatial-based data where the spatial resolution, that is the size of the pixels digitally imaged, can vary from less than 2 cm to over 10 metres. Sensing across various wavelengths (visible, near infrared, thermal) using multispectral and hyper spectral cameras on board airborne and satellite platforms, often has the goal to derive vegetation indices which explain the crop canopy condition (*e.g.* chlorophyll content, stress level) and its variability in space and time. Special interest is devoted lately to the use of low-cost lightweight unmanned aerial vehicles (UAV) often called drones, but now more correctly termed remotely piloted aerial systems (RPAS), initially developed for military purposes which are now being applied in civil applications. RPAS are already available and operational, enabling the generation of very-high resolution (2 to 10 cm) farm-level imagery. Availability from satellite platforms is generally, at lower resolution (0.5 to 10 m) and is generally more costly, whilst the new EU Copernicus programme should provide easier and cost-free access to satellite data but only at 10 m or lower resolution. There is a need of knowledge and skill on how to transform, through Geographic Information Systems (GIS), data collected by different sensors and geo-referenced into maps to provide information on crop physiological status and soil condition status. Additional skills and knowledge are required concerning how to use the large, heterogeneous data sets and information gathered to assess the effects of weather, soil properties on production, and to develop management plans to increase efficiency and adjust inputs in following years. Models are needed to understand the causalities and interrelations between plant, soil and climate before inputs can be spatially adjusted. These Farm Management Systems are made accessible to farmers through consulting, advisory and training services and/or directly through dedicated software products.

However, studies have revealed that Precision Agriculture technology and applications has not been well used by large number of farmers as they are the important actor in the adoption of Precision Agriculture technology. Coupled with this is the problem of certain level of discouragement due to the lack of support and the relatively low profitability obtained. The adoption of this approach relies currently almost entirely on the private sector offering devices, products, and services to the farmers. Public service advice is generally very limited.

4.1. Application of Precision Agriculture

4.1.1. Precision Farming on Arable Land

The use of PA techniques on arable land is the most widely used and most advanced amongst farmers. Perhaps the most successful example is the use of Controlled Traffic Farming (CTF). CTF is a whole farm approach that aims at avoiding unnecessary crop damage and soil compaction by heavy machinery, reducing costs imposed by standard methods. Controlled traffic methods involve confining all field vehicles to the minimal area of permanent traffic lanes with the aid of GNSS technology and decision support systems. The environmental benefits of using CTF are acknowledged in the literature with several examples. A study performed in Denmark showed that compared to standard methods, CTF reduced environmental impacts such as eutrophication (nutrient leaching in surface and ground water). Reductions are enabled by higher grain yields grown with less soil compaction, which decreases P-compound runoff and in-field soil N_2O and NH_3 emissions, and the use of auto-guidance, which reduces overlap during application of fertilizers and pesticides [25]. Another important application of Precision Agriculture in arable land is to optimize the use of fertilizers, starting with the three main nutrients Nitrogen, Phosphorus and Potassium. In conventional farming these fertilizers are applied uniformly over fields at certain times during the year. This leads to over-application in some places and under-application in others. The environmental cost is directly related to over-application which allows nitrogen and phosphorus leaching from the field into ground- and surface waters or to other areas of the field where they are not desired. With the use of PA methods, fertilizers can be applied in more precise amounts, with a spatial and temporal component to optimize the application. The technology that allows the farmer to control the amount of inputs in arable lands is the Variable Rate Application (VRA), which combines a variable-rate (VR) control system with application equipment to apply inputs at a precise time and/or location to achieve site-specific application rates of inputs. VRs are decided based on prior measurement, *e.g.* from remote sensing or machine mounted sensors. A complement of components, such as a DGPS receiver, computer, VR software, and controller are integrated to make VRA work.

4.1.2. Precision Farming within the Fruits and Vegetables and Viticulture Sectors

In fruit and vegetable farming the recent rapid adoption of machine vision methods allows growers to grade products and to monitor food quality and safety, with automation systems recording parameters related to product quality. These include colour, size, shape, external defects, sugar content, acidity, and other internal qualities [26]. Additionally, tracking of field operations such as chemicals sprayed, and use of fertilizers can be possible to provide complete fruit and vegetable processing methods. This information can be disclosed to consumers for risk management and for food traceability as well as to producers for precision agriculture to get higher quality and larger yields with optimized inputs. In the case of pesticide application in orchards, methods normally consist of spraying constant volumes of plant protection mixtures without considering the actual variability of size and density of the tree crowns. The lack of adjustment to account for the orchard variability often leads to a substantial loss of the mixture. In recent years several new approaches were developed that consider the actual size of the tree, the condition of the crop, but also the environmental conditions [27]. The development and adoption of PA technologies and methodologies in viticulture (termed Precision Viticulture, PV) is more recent than in arable land. However, driven by the high value of the crop and the importance of quality, several research projects already exist in wine production areas of the world including [28] [29] [30]. Grape quality and yield maps are of great importance during harvest to avoid mixing grapes of different potential wine qualities. The parcels with greatest opportunities for PV are those which reveal a high degree of yield variation. A high degree of variation will mean higher VRA of inputs and, therefore, greater economic and environmental benefit in comparison with uniform management.

Irrigation or in more general terms the use of water, is increasingly becoming an important issue. In high-value crops, precise irrigation methods are developing rapidly to save water while improving yields and fruit quality. In precision viticulture, three main stages of development over the last 20 years occurred:

1) Sensing systems were initially dedicated to improving existing features on the machinery;

2) Machinery were equipped with sensors to adjust operational aspects;

3) Advanced systems were deployed that collect high-resolution information (yield, sugar, harvest colours monitoring).

Although irrigation has been practiced for centuries, precision irrigation has only been used recently as the sector had to respond to societal demands for reductions in water allocation and improvements in efficiency. A major gap still exists between research and on-farm irrigation practice, which is reflected in large differences between actual and potential yield. In most cases, such ‘yield gaps’ can be attributed to suboptimal management, inappropriate technology and/or lack of training. Irrigation strategies have been proven to successfully increase Water Use Efficiency (WUE) reducing water use. Several strategies have been tested, such as regulated deficit irrigation (RDI), partial root drying (PRD) and sustained deficit irrigation (SDI). The successful use of RDI in fruit trees and vines demonstrated not only increases in water productivity, but also in farmers’ profits [31]. Since Europe (especially the south-western part) is very much affected by climate change which increases the variability of precipitation and the need for water in the face of increasingly frequent hot southern gusts, precision irrigation may develop in the coming years and play a predominant role in water management.

4.1.3. Precision Livestock Farming

Precision livestock farming (PLF) is defined as the management of livestock production using the principles and technology from process engineering. PLF though an integrated management system (IMS) attempts to recognize each individual animal and is typically applied to the more intensive husbandry of pigs and poultry, and dairying. Processes suitable for the PLF approach include animal growth, milk and egg production, detection and monitoring of diseases and aspects related to animal behaviour and the physical environment such as the thermal micro-environment and emissions of gaseous pollutants. The advance of monitoring and control systems has led to the development of automatic milking machines now being marketed by several European manufacturers. Essentially, automatic attachment of teat-cups connects each cow, at a time of its own choosing, to the vacuum milking line. The cups must be applied firmly but gently to the cows' teats, avoiding damage to the cow and the likely consequent damage to the machine. These voluntary milking systems handle 65 or more cows on an average of 2.7 times per day. New systems include milk monitoring systems to check fat and microbial levels, helping to indicate potential infections, as well as new robotic feeding systems, weighing systems, robotic cleaners, feed pushers and other aids for the stockman such as imaging systems to avoid direct contact with animals. The economic justification for these expensive units is that they offer each cow the opportunity to be milked more often than the usual procedure (twice a day). This is beneficial for the cows, and it increases milk yield. New systems for data monitoring for feed and water consumption can be used to the early detection of infections. Other developments include the monitoring on the growing herd where measurement of growth in real time is important to provide producers with feed conversion and growth rates. Acoustic sensors detect an increase in coughing of pigs as an indicator of respiratory infection. Recent studies discuss that improved management could raise cow yields to 20,000 litres per lifetime whilst increasing the life expectancy of cows. Higher yield and longer life could reduce agricultural methane emissions by 30%. Quality of feed is difficult to measure but by using a pH bolus in the rumen of sentinel cows the pH can be accurately tracked and feed adjusted as necessary. Other sensors are now used to provide alerts concerning birthing and fertility. A vaginal thermometer monitors the temperature, imminence of birthing and the breaking of waters, and communicates to the farmer via SMS. Also, a sensor placed on an animal's collar records parameters to detect signs of oestrus and the readiness for fertilization. An SMS message then allows the farmer to plan for insemination. The use of GNSS technology has enabled tagging of cows to provide tracking information related to animal behaviour. Monitoring behaviour is relevant for detection of cow fertility or illness. It is also important for providing information on pasture use density and to manage fields accordingly to the information recorded previously. The development of tag technology is in rapid development to increase the accuracy and reduce power consumption.

One example is the E-Track project (https://www.euro-access.eu/en/calls/465/Digital-and-data-technologies-for-livestock-tracking) which proved to provide adequate information for remote animal monitoring and management. Virtual fencing uses the GNSS based location of an animal in combination with a sound or electrical stimulus to confine animals inside a predefined geographic area without fixed fences. Other examples of tracking systems used on livestock farming are related to transport of animals. According to the Council Regulation (EC) No 1/2005 on the protection of animals during transport and related operations, it is required that any road vehicle undertaking long journeys transporting livestock must be equipped with a satellite tracking system. Enforcement officers use this as a tool for assessing compliance with the requirements of the Regulation.

5. Recommendations from Literatures

Under low emissions, socio-economic and technological factors will be more important for food security than climate factors. Under high emissions, climatic factors will be more important for food security than socio-economic and technological factors [19]. However, the most effective ways of combating food security will combine socio-economic and agro-climatic solutions.

Some solutions to be considered will include reduce Carbon emissions in the USA and Across the Globe. We already know that carbon emissions are a major threat to our climate. Since the industrial ages, we have depended on carbon-emitting machines and processes for economic, mobility, and domestic purposes. However, we must find alternative resources that are less toxic to our environment. Renewable energy, solar energy as opposed to petroleum products, and electric cars to replace oil or gas-based vehicles will help significantly reduce the accumulation of greenhouse gases and their effects on our atmosphere, lives, living conditions, and livelihoods. The USA is already working towards spending $370 billion to this effect [32]. There is also the need for more studies, reports, and outreach to farmers. There should be more studies and reports on climate change and expectations for short-term and long-term periods to help governments, organizations, and individuals develop innovative ideas to handle expected challenges from climate change. These studies and reports should be explained to farmers in rural areas via outreach programs to help boost productivity and food availability for food security purposes in the USA and elsewhere.

Financing Sustainable Agriculture in the USA and elsewhere will also be a huge contributor. Food security in countries with trade agreements with the USA adds to food security in the USA (since the USA can then make purchases to fill voids in case of food shortage). So, the USA should invest in Sustainable Agriculture both within the USA and other countries. This will help solve food problems in case of severe climatic changes. Furthermore, the advancement of technological solutions, artificial intelligence and remote sensing will go a long way in ensuring food security in different stages or processes associated with the food system. Technology improves farming techniques, conditions, and results.

Hence, it increases the production of safe and quality food items. Biotechnology also improves on nutrition needs of available food species. Technology can also help make storage and distribution equipment more effective as food become more durable and more easily distributed in case of climate disasters requiring logistic improvements to provide food security.

Considering future societal and environmental needs, the main challenge for US agriculture will be its ability to ensure a high level of production while improving the protection of natural resources. Precision agriculture is an information-based, decision-making approach to farm management designed to improve the agricultural process by precisely managing each step. In this manner, PA can provide a management approach optimizing both agricultural production and profitability—which is the key goal of most farming enterprises. Additionally, part of profitability can come from the reduced use of inputs (machinery, labour, fertilizer, chemicals, seeds, water, energy, etc.), leading to both cost savings and environmental benefits. Today, the technological infrastructure of precision agriculture is in place to support a wider implementation.

The support from governments and other public institutions can play an important role in a wider adoption of PA. But any decision from public bodies to further enable this adoption should take full account and advantage of any pre-existing commercial infrastructure. Although the possible use of precision technologies in managing the environmental side effects of farming and reducing pollution is appealing, the benefits provided to the environment have been little assessed with no quantified figures available. Some farmers state that improving the environmental aspects of their farm is an important element in deciding to adopt PA technology, but this most likely comes from their personal values and perceptions. An obvious next step is to have dedicated studies to quantify these environmental benefits since this is currently poorly documented. The benefits of higher profitability will be immediately seen at the farm level. In contrast, for the environmental situation, impacts will be manifest, not only at farm level, but also in the adjacent landscape (vegetation, streams, run-off areas) and they may take years to appear. Therefore, the idea of public good in a local or regional sense, rather than just benefit to an individual farm, is one that applies to the potential environmental benefits of adopting PA. Hence, the study of the potential benefits needs to add those from the broader scale to those accrued at the farm level.

Promoting precision agriculture through the CAP seems to be economically, environmentally, and even socially justifiable. However, further investigation and accompanying measures are necessary to avoid inappropriate technological push where PA is not likely to be successful, and to maximize the potential public benefit by focusing on specific farm types and farming practices. As discussed, support possibilities are available under Pillar II measures but since these require co-funding it is essential to have engagement and commitment of Member States through measures consistent with the intervention logic of their RDP. Successful adoption is expected to follow the phases of exploration, analysis, support, and execution. Involvement of MS in the first three phases is necessary before they are likely to endorse funds for execution.

6. Conclusion

In this paper, we investigated the prevalence of food insecurity in the United States and explored how precision agriculture can be a valuable tool in ensuring increased productivity, efficiency, and resources conservation. Whilst we found evidence of high adoption of precision agriculture, there are still challenges to the adoption of precision agriculture by farmers. These include cultural perception, lack of local technical expertise, infrastructure and institutional constraints, knowledge and technical gaps and high start-up costs within some cases a risk of insufficient return on the investment. Up to now, the private sector suppliers have been the clear driver of PA development and adoption.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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