Chapter 14
Agricultural Mechanization and Food Security in Saudi Arabia

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Abstract Agricultural mechanization has evolved from the use of hand tools to draft animals, to motorized machinery, to digital equipment, and finally to robots using artificial intelligence. These improvements enhance productivity and improve the management of crops, livestock, aquaculture, and forestry. This, in turn, leads to better working environments, increased income, reduced labor-intensive work, and the creation of new rural business opportunities. The global population is growing rapidly and is projected to reach 8.5 billion individuals by 2030 and 9.7 billion by 2050. This poses a significant challenge for the agri-food industry, which must find ways to feed more people. Additionally, the loss of agricultural land due to urbanization and industrialization further emphasizes the need for efficient production methods Precision agriculture has the potential to be the solution. It is a management practice concerned with the precise application of agricultural inputs such as seeds, fertilizers, water, pesticides, and energy, with the ultimate objective of reducing the costs of such inputs, increase yield, improve returns, and mitigate the environmental risks of farming. Practicing of PA includes collection of data such as soil, crop and yield data, then processing them through computer models for the generation of prescription maps and finally precise application of the agricultural inputs through variable rate application devices installed in the agricultural implements. Saudi Arabia is the biggest country in the gulf region with a total area of about 2.3 million km^2 and a total population exceeding 28 million. The cultivable land in Saudi Arabia accounts for 1.6% of its total area resulting in 0.11 ha per capita arable land that is globally among the lowest ones. Saudi Arabia has been classified as "water stressed" country, and sever water scarcity is expected by the year 2050. The un-sustainable agricultural activities resulted in a rapid depletion of the non-replenish aquifers of the country. This situation necessitates changing the current farming practices so as to challenge food insecurity problems. To enhance

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its agricultural production to ensure food security Saudi Arabia needs to adopt the precision agriculture approach.

Keywords Agricultural mechanization · Enhancing productivity · Food security · Precision agriculture · Saudi Arabia and water scarcity

1 Introduction

Mechanization refers to the use of machinery and equipment, ranging from simple hand tools to advanced, motorized machinery, so as to perform agricultural operations (Sims et al. 2016). In the past, a significant amount of agricultural work relied on manual labor or the use of animals. However, in most countries around the world, this has changed due to the introduction of machines that require energy to function. Agricultural mechanization encompasses the choosing, operating, utilizing, and maintaining of mechanical devices and systems involved in agricultural operations and production, aiming to maximize the benefits for humans (Bello et al. 2021). That is to say to enhance the investment in mechanization technologies and their sustainable adoption, definite environmental, agricultural, social, and economic conditions have to be met (Ou et al. 2002). The incorporation of machines in farming since the industrial revolution has resulted in saving of manpower in agricultural practices. Agricultural mechanization is part of this technological development to reach automation in agriculture (FAO 2022a). The progression can be summarized as a move from using of hand tools to draft animals, to motorized machinery, to digital equipment, and finally to robots using artificial intelligence (AI) (FAO 2022b). These advancements increase productivity and ameliorate the management of crop, livestock, aquaculture, and forestry, resulting in a better working environments, improving revenues, reducing the workload in agriculture, and creating new rural business opportunities (FAO 2022b). In the present agricultural mechanization tractors, trucks, combine harvesting machines, various farm equipments, airplanes, helicopters, and drones for aerial application, and other vehicles were used.

When more power is supplied to agriculture, it is possible to achieve timeliness in agricultural operations and farm larger acreage to increase the agricultural production while preserving natural resources. This can be achieved by utilizing latest technologies that are less harmful to the environment, which lead to large produce and economically feasible farming process with less power used.

The fundamental requirements for humans to survive include food, clothing, and housing, with food being the most decisive factor for sustenance. Food is produced directly through primary agricultural production and is regarded as the most crucial of the three essential needs. Consequently, agriculture is a profession that saves lives (Bello 2012). Achieving food security means availability and affordability of enough, healthy and balanced nutrition at all times to every individual within a region or country, as stated by the FAO (1996).

2 The Role of Mechanization in Agriculture

Agricultural mechanization has the greatest impact on enhancing agricultural production by increasing farming efficiency, productivity, and profitability (Kumar 2017). Here are some ways in which agricultural mechanization contributes to increased agricultural production.

(a) Enhanced efficiency: Agricultural mechanization reduces the time and labor required for various farming operations such as land preparation, planting, and harvesting. This allows farm's tasks to be carried out more efficiently and quickly, leading to increased productivity and output.

(b) Improved crop quality: Mechanized farming equipment provides more precise control over various farming operations such as planting depth, spacing, and fertilizer application. This results in more accurate and consistent crop production, which can improve crop quality and yield.

(c) By utilizing mechanized farming equipment, the production capacity of farms can be increased. This is because such equipment can cover larger areas of land at a faster pace compared to manual labor. As a result, farmers are able to produce more crops in a shorter period of time. Moreover, this allows them to capitalize on beneficial weather and growing conditions (Kumar 2017).

(d) Improved crop resilience: Mechanized farming equipment can help farmers respond more quickly and effectively to weather or pest-related challenges. For instance, such equipment can be used to apply pesticides or fertilizers more precisely or harvest crops before they are damaged by weather events.

(e) Better market access: Mechanized farming equipment can help farmers produce crops that meet market demands for quality, quantity, and consistency. This allows them to sell their products at higher prices in local or global markets. Overall, the use of agricultural machinery can help farmers increase their productivity and profitability in farming. Additionally, it can improve the quality and resilience of their crops. However, it is important to recognize that adopting mechanized farming practices may require a substantial investment in equipment, infrastructure, and training, which could be difficult for some farmers. Agricultural mechanization has a significant impact on agricultural production and profitability. It involves using machines and equipment such as tractors, harvesters, and planters to replace human labor in various farming operations (Bello 2012). By utilizing mechanization, farmers can boost their productivity and efficiency since machines can complete tasks more rapidly and precisely than humans. This could result in higher yields and lower production costs, ultimately leading to increased profitability. Additionally, mechanization can help effectively manage crops and resources, resulting in precise and consistent application of fertilizers, pesticides, and herbicides. This can improve crop quality and reduce losses caused by pest infestations and disease outbreaks (FAO 2017). Moreover, agricultural mechanization can have positive effects on rural development. It can improve food security, create job opportunities, and enhance the living standards of farmers and their families. In conclusion, agricultural mechanization is a crucial tool for sustainable agricultural development, especially considering the growing global population and demand for food (FAO 2017). Below are some examples of research findings that explain the role of mechanization in agriculture. Xiaoshi and Wanglin (2022) conducted a study examining the effects of adopting various mechanized farming techniques (such as completely non-mechanized, partially mechanized, and fully mechanized) on land productivity in the People's Republic of China. Their findings revealed that implementing semi- and fully mechanized farming methods boosted land productivity, with the greatest impact occurring when applying the fully mechanized technique. Specifically, adopting the semi-mechanized system increased land productivity by 35.8%, while the fully mechanized one increased it by 67.2%.

Pingali and Binswanger (1984) conducted a review of 24 studies on labor usage in farms using animal draft power compared to those using tractors in Asia. Their findings showed changes in labor usage across different operations, as well as total labors involved and changes in their levels of use between operations. Of the total number studied, 22 were found to have use lower total labor/ha of crop production for farms using tractors as opposed to those relying on animal draft power. In 12 studies, labor use was reduced by 50% or more. The most significant decrease in labor use was observed in land preparation, where in all studies a reductions in labor input that exceeding 75% was reported.

Rice is a staple food in Bangladesh, which in its transplanting manual labor is used. According to Rao and Pradhan (1973) a delay in the transplanting process by one month can result in a crop yield reduction by 25%, and delaying it by two months can reduce the yield by up to 70%. As a result, mechanical transplanting can be viewed as a solution to this labor-intensive process. Islam et al. (2016) found that manual planting in Bangladesh requires approximately 123–150 man-hours per hectare, whereas when using four-row walking transplanters mechanical transplanting requires only 9–11 man-hours per hectare.

Cotton production involves several methods such as land preparation, planting, weed control, spraying, and picking. Amongst all these methods, cotton picking is the most arduous, and labor-intensive operation. Mishra et al. (2023) conducted research and reviewed the current development in cotton harvesters, which are used for Indian cotton production. The researchers found that in India, multi-stage handpicking of cotton crops is common and typically involves about 500 man-hours/ha. Sandhar (1999) reported that, an adult can pick around 15–20 kg of seed cotton/day. Whereas, a single-row spindle-type picker can collect anywhere between 870–2180 kg/day.

Irrigation in India is characterized by low efficiency due to unleveled land. Aryal et al. (2015) conducted a study to investigate the influence of land leveling using laser technology, in reducing irrigation water losses resulting from highly undulating fields. In their study they compared two types of land leveling systems: Laser land leveling (LLL) that uses laser equipped drag buckets, and Traditional land leveling (TLL) that uses scrapers or leveling boards mounted to tractors or drawn by draft animals. The experiment was carried out in Indian states of, Haryana and Punjab, under three cropping systems: Rice–Wheat, Cotton-Wheat and Sugarcane-Wheat, potato, vegetables etc. They concluded that LLL minimizes the amount of water applied in irrigation and maximizes crop yields. Reduction in Irrigation duration in fields laserly leveled by 47–69 h/ha/season in rice and by 10–12 h per ha per season in wheat was observed and yields of wheat and rice were 7–9% and 7% higher, respectively, in comparison to ones that traditionally leveled. Minimized irrigation period means less energy use in agriculture which in turn minimize the emission of greenhouse gas from agricultural production. Consequently, more use of LLL assists in climate change alleviation. Moreover, using reduced amounts of water for irrigation creates opportunities to allocate the saved water for other purposes in the economy, such as addressing the demands of growing populations, industrial development, and urban expansion.

In Africa the traditional factors of labor force, agricultural land and livestock are the basis for the increase in agricultural production, with special emphasis on increasing the area under cultivation and the abundant use of labor (Djoumessi et al. 2020). As a result, there will be minimal or no improvement in the productivity of agricultural output for each unit of inputs. Enhancing productivity primarily depends on factors other than basic inputs, such as inventions, research and development, and rural infrastructure. Djoumessi (2021) conducted a study, on a sample consisting of 22 countries in the Sub-Saharan African region from 1996 to 2014 to examine the key factors influencing agricultural productivity, with a particular focus on agricultural innovations. Among the innovations that enhance productivity, it was observed that the components of fertilizer have a limited effect on agricultural productivity growth. In contrast, the use of pesticides and irrigation practices have a positive and significant effect on agricultural productivity. Regarding innovations that minimize cost or agricultural labor, the study indicates that the use of tractors and harvesting machines have a significant and important positive impact on agricultural productivity. Whereas threshing machines were found to have extremely low or non-existent effect on agricultural productivity in Sub-Saharan Africa.

Enhancing agricultural operational efficiency goes beyond being an effective approach to maximize farmers' revenue and improve the efficiency of the agricultural sector. Instead, it forms a fundamental basis of the rural revitalization strategy. Peng et al. (2022) conducted a study aimed to determine the extent of the impact of agricultural mechanization on farmers' agricultural production and income. The study used a Data collected from a field survey performed in Hubei Province among households during the year 2018. The survey gathered important information about households, including their natural and physical assets, production and working conditions, land transfer behavior, and farmers' awareness of policy. The study was conducted in the districts of Jianli and Qichun in Hubei Province, China, where the level of agricultural mechanization is 66.75%. This level closely matches the overall level of mechanization for land preparation, seeding, and harvesting of main crops in Hubei Province. Typically, researchers measure the level of agricultural mechanization by considering the amount of power or net value of machinery used. These indicators are suitable for assessing the level of mechanization in a specific region, but they are not applicable for evaluating mechanization at the individual farm level. Therefore, it would be more appropriate to use the calculation method employed by the Ministry of Agriculture and Rural Affairs. This method involves calculating a weighted average of machine farming, seeding, and harvesting rates at the farm level, with weights of 0.4, 0.3, and 0.3, respectively (Peng et al., 2021). This method not only provides an easy way to obtain the indicator but also accurately measures farmers' machinery usage behavior. Researchers have made the following discoveries: Firstly, the level of agricultural mechanization significantly impacts the cost of production, output value, revenue, and yield for all crop types. Increasing the mechanization level by one unit leads to cost increases of 0.74 units for all crops, 0.55 units for grain crops, and 5.51 units for cash crops. Moreover, the output values increase by 5.48 units for all crops, 8.42 units for grain crops, and 2.52 units for cash crops. The corresponding revenue increases are by 3.143 units for all crops, 5.479 units for grain crops, and 1.694 units for cash crops. Additionally, the rate of return experiences an increase of 1.22 units for all crops, 1.59 units for grain crops, and 0.44 units for cash crops. From a heterogeneity analysis perspective, a noticeable impact of the mechanization level threshold on income was observed, with a threshold estimated at 0.28 ha.

3 Precision Agriculture

The global population is growing quickly. According to the United Nations (2019), the number of people on Earth is estimated to reach 8.5 billion by 2030 and 9.7 billion by 2050. This presents a significant challenge for the agri-food industry as it tries to find ways to provide food for more people. The increase in urbanization and industrialization is leading to a decrease in available land, which is essential for agriculture. This means that there is a greater need for efficient production methods. Precision agriculture (PA) has the potential to be the solution (Mizik 2023).

Precision Agriculture (PA) is a management approach dealing with precise application of agricultural inputs such as seeds, fertilizers, water, pesticides, and energy. Its objective is to save agribusiness inputs, maximize yield, improve profitability, and mitigate the environmental risks of agricultural production. Precision Agriculture (PA), also called precision farming, encompasses three categories of advanced management technologies (Say et al. 2017), which are: First, there are several technologies used for data collection, such as soil sampling and field exploration, yield monitoring and mapping, the global navigation satellite positioning system (GNSS), remote sensing, as well as field and crop scouting. Second, there are technologies for processing this data and making decisions, which include Geographical Information Systems (GIS), software for agricultural mapping, economic analysis, geostatistics, and modeling. Lastly, there are technologies used for applying these findings directly on the field, such as variable rate application, section control, GNSS-based guidance, and agricultural robots.

In precision agriculture approach the agricultural inputs are applied at variable rates in the field according to the spatial and temporal variability of soil and crop. The Variable Rate Technology (VRT) is a system in which the inputs are applied at variable rates in the right time and place based on soil and crop variation (NESPAL 2005). VRT is used based on either map or sensor approach. In the map based VRT system, maps data of soil, crop and yield are collected then processed by computer crop/soil models and finally a control map is generated. A data card is used to copy the control map to a display/processor unit that is connected to a controller unit which are both installed in the tractor cabin. Finally the controller unit is connected to a variable rate device installed in the agricultural implement which apply inputs at variable rates (Belal et al. 2021). In the sensor based VRT technology, sensors are used in measuring characteristics of the soil and crop. Then the sensor readings are connected to a processor unit, for analysis. The analyzed data are then connected to a controller unit. The processor and controller units are both installed in the tractor cabin. Finally the controller unit is connected to a variable rate device installed in the agricultural implement which apply inputs at variable rates (Belal et al. 2021). Nowadays major agricultural equipment manufacturers incorporate precision variable rate capability as standard fittings.

Below are a few examples of precision agriculture practices:

Tillage is the mechanical disturbance of soil for the creation of favorable conditions for crop growth. Hence tillage practicing create good aeration and absorbing capacity in soil, moreover it helps in pest control by eliminating their habitat (Aditya 2023). In conventional agriculture uniform depth tillage is practice throughout the field, hence it is called conventional tillage (CT). There are several drawbacks associated with this technique. Firstly, from an economic point of view, unnecessarily disturbing of soil in areas in which the soil structure and condition is unessential is wasting of time and energy (Keskin et al. 2011). Secondly, tilting the soil to incorrect depth can lead to damaging of soil structure, specifically by smearing wet plastic soil (Gill and Berg 1967), resulting in the formation of a non-permeable layer that hinders plant root growth and negatively impacts yield. Lastly, unsuitable tillage practices may make the soil vulnerable to erosion, causing nutrients to be lost to the environment through leaching and runoff rather than being retained in the soil and available for plants. Soil erosion and soil organic matter depletion are among the biggest sustainability challenges for CT. The adoption of Conservation Tillage (CVT) practices can address these issues and therefore contribute to sustainable farming systems (Bista et al. 2017). CVT stands for any tillage or farming method that aims to reduce erosion caused by water or wind by ensuring that plant residue covering at least 30% of the soil surface after planting (Gorucu and Keskin 2010). However, CVT is not recommended for soils with compaction issues. A third approach called variable-depth tillage (VDT) or precision tillage has emerged as an alternative technology. VDT focuses on optimizing the physical properties of soil in places only where tillage is necessary, by performing tillage at specific depths. This technology has been proven to reduce costs, labor, fuel consumption, and energy requirements. To successfully implement the VDT system, it is important to accurately determine and map the penetration resistance of soil spatially and at different depths throughout the soil profile. Meselhy (2021) conducted a field experiment to evaluate the effectiveness of the technology by measuring the depth of tillage based on soil penetration resistance at various depths. The experiment was carried out in five areas, each representing a different method of preparing the soil for planting: no-tillage (CVT), tillage at a uniform depth of 25 cm, tillage at a uniform depth of 35 cm, tillage at a uniform depth of 45 cm (all representing CT), and variable-depth tillage (VDT), which is also known as precision tillage. The study aimed to measure various factors including the rate at which fuel is consumed (FCR), the actual capacity of the field for planting (AFC), the power needed for the process (PR), the specific energy used (SE), the costs of operating (OC), the resistance of the soil to penetration (SPR), and the amount of sorghum produced (SY). The results demonstrated the presence of a compacted layer of soil between depths of 25 and 35 cm. Consequently, the VDT system was applied at a tillage depth of 35 cm. Around 47% of the entire field area needed to be prepared for planting. The findings indicated that the VDT system reduced FCR, PR, and OC by approximately 35%, 35%, and 23% respectively, compared to the UDT system. In contrast, AFC increased by about 21% for the VDT system compared to UDT. When it comes to the amount of sorghum produced, there was a 53% increase for the VDT system compared to UDT at a tillage depth of 25 cm, while decreases of approximately 8% and 11% were observed for the VDT system compared to UDT at tillage depths of 35 cm and 45 respectively. In the conventional agriculture the soil is uniformly managed, regardless of the local spatial variability of its characteristics; such a practice may exacerbate its degradation process (Jie et al. 2002). The impact of intense human activity on agricultural soils worldwide is a matter of great concern. Extensive research, such as the study conducted by Jie et al. (2002), has estimated that about 40% of agricultural soils across the globe are currently facing serious degradation problems. The annual loss of agricultural soils due to advanced degradation, is estimated at 12 million hectares. This loss of arable land has a profound impact on global food production and security; as a result annual 20 million tons of grains is anticipated as a reduction in productive capacity (Rickson et al. 2015). To alleviate the soil degradation problems the soil should be delineated to zones which are homogeneous in their properties and managed accordingly regarding the application of agricultural inputs with the ultimate intent of increasing crop and soil productivity. Oliveira et al. (2019) conducted an experiment in two fields situated in the district of Planaltina, state of Goiás, Brazil. Field 1 (F1) encompasses 312 ha and has an average elevation of 1068 m. Field 2 (F2), which is located 5 km away from the first field, covers an area of 297 ha and has an average elevation of 1000 m. In the two fields the forest was cleared during the 1980s for agricultural purposes, with conventional farming practices involving plowing and disking to cultivate grain crops. Starting from 1995, a system of no-tillage was practiced, in which a soybean–corn were grown in a rotation in summer followed by fallow in winter. After 2007, an intercropping pattern involving maize-brachiaria was introduced for the management of soil cover and livestock. Their study had two main objectives. The first objective was the delineation of the homogeneous management zones (HMZs) employing the multivariate analysis approach. The second objective was the assessing the impact of uniformly managing soil on the physical–hydraulic attributes of the delineated HMZ. The HMZ represented soil spatial variability at the mineralogy level. The delineation of the management zones involved three steps. First, soil samples were collected from the fields and laboratory analysis was performed. Second, statistical analyses were carried out, and the HMZ were defined. Third, spatial distribution of the HMZ in the field was confirmed and location of soil profiles and sample collection for soil quality analysis was selected. The HMZ were determined based on the physical attributes of the soil, such as bulk density and structural porosity. In fields where the soil spatial variability exhibited greater homogeneity (F1), the physical attributes were used. In fields where the variability was more complex (F2), the HMZ were defined based on chemical attributes. When examining uniform management, it was observed that in F1, a significant decrease in structural porosity occurred in 46% of the 312 ha. In F2, there was a more pronounced decrease in structural porosity, affecting 26% of the area, while an increase in bulk density was observed in another 24% of the surface layer (0.00–0.30 m). The experimental findings support the hypothesis that uniformly managing soil can exacerbate its degradation and potential erosion. Conversely, dividing the field into homogeneous management zones (HMZs) can lead to more appropriate and sustainable soil management practices.

One of the main benefits of precision agriculture is the improvement of resource allocation for agricultural inputs. Variable Rate Seeding (VRS) is considered as an accurate agricultural technology that can perfectly meter the seeding rate based on variables such as soil properties, terrain, meteorological conditions, and other factors (Šarauskis et al. 2022). VRS can adjust the desired seeding rate for each zone in the field according to the site-specific data layers of soil texture, soil electrical conductivity, pH, and yield maps. Remote sensing technology or other data that identifies yield-determinant factors can then be used to determine the optimal sowing method for each field area, allowing farmers to optimize crop density and achieve the highest agricultural and economic results. Currently, different proximal and remote sensor systems, contact and contactless device, mapping, and VRS modeling technologies are utilized to identify the variability of soil and crop. By implementing VRS practices, farmers are able to properly manage their farm risks and focus more on investing in parts of the farm that are potentially productive (Šarauskis et al. 2022).

Chivenge et al. (2022) conducted a review of the advances made in research on the Site Specific Nutrient Management (SSNM) approach, a precision farming method used in rice, maize, and cassava cropping patterns for small-scale farmers in Sub-Saharan Africa (SSA). Findings demonstrated that employing the SSNM technique leads to an increase in both yield and profitability, as well as improved nutrient utilization efficiency. In SSA, rice and maize crops yielded 24% and 69% more, respectively, when grown using SSNM compared to conventional farmer practices. Alternatively, yield increases of 11 and 4% were observed when comparing SSNM to the typical locally recommended fertilizer application method.

Yield monitoring in agriculture is an essential practice that provides farmers with valuable information about their crop production. It involves the use of advanced technologies, such as sensors and GPS systems, to measure and record crop yields during harvesting. Accurate yield data helps farmers make informed decisions regarding crop management, resource allocation, and future planning. By understanding the variations in yield across different areas of their fields, farmers can identify factors influencing yield variability, such as soil fertility, irrigation, or pest problems. This information enables them to adjust their practices accordingly, optimize inputs, and improve overall productivity. Yield monitoring allows farmers to assess the performance of different crop varieties, hybrids, or management practices. By comparing yield data from different fields or trials, farmers can identify the most productive areas or practices and replicate them in future seasons. It also helps in evaluating the effectiveness of specific treatments, such as new fertilizers, pesticides, or irrigation techniques, by quantifying their impact on crop yield.

Regarding precision agriculture yield monitoring is considered a fundamental component, which aims to maximize productivity while minimizing inputs and environmental impact. It provides the necessary data for site-specific management, allowing farmers to tailor their actions to the specific requirements of various areas within a field. By mapping yield variations, farmers can create prescription maps for variable rate application of inputs, such as fertilizers or seeds, optimizing their usage and reducing costs.

Accurate yield data is crucial for financial planning and analysis in agriculture. It allows farmers to estimate their production revenue, evaluate the profitability of different crops or fields, and make informed decisions regarding marketing, storage, or crop insurance. Yield data, combined with input cost information, helps farmers assess the return on investment (ROI) for different inputs or practices, facilitating better financial management.

When it comes to harvesting grain using combine harvesters, yield monitors can measure the weight of grain and the area harvested either load by load or area by area. This capability allows the operator to obtain real-time measurements of the total accumulated grain weight, harvested area, and average yield directly in the field. These data can be exported to a PC using numerous yield monitors, where they can be saved in nonvolatile memory for additional analysis or printing using specialized software packages or common word-processing and spreadsheet software. When linked to a global positioning system receiver, yield monitors can provide the necessary data needed to generate yield maps (Banus 2015). Yield mapping also helps decision-makers and farmers identify different productive zones within the field. This information enables them to evaluate whether using different planting populations will lead to higher revenue on their application. Farmers or producers use the yield map of the previous crop to estimate the fertilizer application rate, considering the nutrients depleted from the soil during the previous crop season (Das et al. 2018; Risius 2014; de Oliveira et al. 2019).

4 Agricultural Mechanization in Saudi Arabia

The Kingdom of Saudi Arabia is situated in the western part of the Asian continent and is the largest among the Arab countries, covering an approximate area of 2.3 million square kilometers. It shares borders with the Red Sea on the western side and the Persian Gulf on the eastern side. The population of the kingdom surpasses 28 million, with its capital city being Riyadh. The terrain of Saudi Arabia consists of large deserts, dry mountains, a central plateau, shrubs, and patches of fertile soil found in oases and basins. There are no permanent rivers or lakes, and the prevailing climate is typically desert, characterized by scorching daytime temperatures and very low temperatures at night. While rainfall is scarce, some destructive flash floods resulting from heavy rains have been witnessed in recent years (GFRAS 2023).

The Kingdom has only 1.6% of its total land area suitable for cultivation. As a result, the amount of land available for farming per person is very limited, estimated at 0.11 ha (World Bank 2018). This is regarded as one of the lowest rates worldwide. The economy of Saudi Arabia mainly depends on petroleum. However, the government has dedicated billions of dollars to enhance and modernize its agricultural industry, even though it is challenging due to the harsh desert conditions and limited water resources. Despite the significant costs, impressive progress has been achieved in agriculture within the country. Primary crops cultivated in Saudi Arabia include cereals like wheat, sorghum, barley, and millet. Moreover, a range of vegetables like tomatoes, watermelons, eggplants, potatoes, cucumbers, peppers, and onions are grown. Additionally, fruits such as dates, citrus fruits, mangoes, and grapes are cultivated as well. Finally, alfalfa and Rhodes are grown as fodder crops (GFRAS 2023).

According to the Agricultural Statistics Publication, fresh dairy products achieved self-sufficiency at a rate of 121% in Saudi Arabia in 2021, followed by table eggs at a rate of 112%, while fish reached 40%. Dates ranked first in plant resources, with a self-sufficiency rate of 118% and a local production of 1,565 thousand tons for 2021, while the self-sufficiency of tomatoes was 77% and onions was 52%. The total amount of agricultural imports for the year 2021 in Saudi Arabia was 20,037 thousand tons, with grains accounting for 42.5% of it. The total quantity of exports for the same year was 2,652 thousand tons, of which 23.5% was dairy products, eggs, natural honey (Agricultural Statistic Publication 2021).

Saudi Arabia has been classified as "water stress" and is expected to encounter a severe water scarcity by the year 2050 (Falkenmark et al. 2009). Baig et al. (2019) stated that the country's non-replenish aquifers are being rapidly depleted due to the adoption of unsustainable agricultural practices. This situation highlights the clear necessity for achieving self-sufficiency in food production.

Saudi Arabia possesses an annual groundwater availability of 3850 m^3, while surface water amounts to 1300 m^3 per year, which subject to variation based on annual rainfall. The anticipated sum of renewable water resources in Saudi Arabia amount to approximately 500 km^3, 340 km^3 of that amount is economically viable for extraction. It is estimated that Saudi Arabia's water consumption stands at an average of 24 billion cubic meters per year (Faridi and Sulphey 2019). As stated by Al-Hussayen (2007), the agricultural sector accounts for the majority of this consumption with 88%, then municipalities with 9% and the industrial sector with approximately 3%.

According to ESCAP (2013), it is projected that water availability will decrease in the future, while the global demand for water in agriculture is expected to increase by around 19% by 2050. As a result, in terms of food security, water scarcity is becoming a more significant determining factor than land scarcity, as stated by Brown and Funk

(2008). Considering the unique circumstances in Saudi Arabia, attaining sustainable food security requires the adoption of advanced agricultural technologies that can improve productivity, as stated by Fiaz et al. (2018).

Saudi Arabia is confronted with numerous challenges in guaranteeing food security because of its scarcity of water resources, extreme temperatures, and a growing population (Falkenmark et al. 2009 and Baig et al. 2019). The implementation of agricultural mechanization can aid in overcoming these obstacles by enhancing agricultural productivity, enhancing efficiency, and lowering labor expenses. Saudi Arabia needs to adopt a precision agriculture approach and practices such as site-specific nutrient management, variable rate irrigation, and precision planting can be adopted to enhance agricultural production and ensure food security.

Precision irrigation can effectively address the problem of water scarcity in Saudi Arabia of Saudi Arabia. Precision irrigation technology involves using irrigation moisture sensors that provide instantaneous data on moisture content of soil, thereby aiding management of irrigation decisions (Dubois et al. 2021). Several types of soil moisture sensors, including capacitance, resistance, and time-domain reflectometry (TDR) sensors, are available and can be installed in the field. These sensors monitor the moisture content of soil over time by connecting to a data logger. The information collected from these soil moisture sensors, along with weather forecast data and evapotranspiration models, is utilized in predictive irrigation systems to anticipate future soil moisture levels and help make decisions regarding irrigation management (Yartu et al. 2022). This involves analyzing the data using machine learning algorithms such as linear regression, logistic regression, decision trees, random forest, and neural networks. After analyzing the aforementioned data and considering factors like weather conditions, crop growth stage, and soil characteristics, recommendations are provided regarding irrigation scheduling, the appropriate amount of water to apply, and the intervals at which irrigation should occur. This precision irrigation system can effectively apply water as needed, thus improving irrigation efficiency and addressing the issue of water scarcity. In general, adopting modern technologies and investing in agricultural infrastructure to enhance agricultural productivity and ensure a steady food supply for its population can help Saudi Arabia improve food security and bolster its economy through agricultural mechanization.

5 Conclusion and Prospects

The Kingdom of Saudi Arabia possesses the second-largest proven petroleum reserves and the fourth-largest measured natural gas reserves. Currently, Saudi Arabia holds the position of the world's largest exporter of petroleum, earning it the title of a petrostate in Western media. In 2016, the Saudi government introduced the Saudi Vision 2030 program with the goal of diminishing reliance on oil and expanding the diversity of its economic resources. As a result, there has been growth in the industrial sector, which has had an impact on the availability of agricultural labor. To address the issue of labor scarcity caused by industrialization, the Kingdom should enhance the level of agricultural mechanization in order to achieve food security. Considering the limited arable land in relation to the total land area, implementing precision agriculture methods and practices like variable rate seeding and site-specific nutrient management would be necessary to boost agricultural production and ensure food security. Additionally, the Kingdom of Saudi Arabia is also confronted with the challenge of water scarcity, which can be mitigated through the adoption of precision irrigation techniques.

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