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Chapter 1: Foundations of modern agricultural equipment and technological integration

1.1. Introduction to Agricultural Equipment

Until the end of the 19th century, agriculture in industrialized countries relied on men and animals. It was only after the introduction of fossil fuel-based mechanical energy sources that the first simple machines emerged, thereby increasing the productivity of agriculture. These machines, such as seeders and plows, were constructed for a long time with general specificity, without a particular adaptation to each culture. Only with the increase in work productivity and the improvement of the work process, did the cultivated species influence the design of the machines. The movement of mechanization in agriculture began in America and spread throughout the world. After the Second World War, many agrarian countries were encouraged to develop agricultural mechanization programs, allowing the import of equipment and the installation of local factories. Although the sector is now well-developed, with multinationals and local machines, the trend is still towards greater specialization of the equipment (Bechar & Vigneault, 2016; Liakos et al., 2018; Lowenberg-DeBoer & Erickson, 2019).

In recent years, a wave of technological integration has begun in the country. Robotics, computer, and electronic technology, as well as satellite positioning techniques, are increasingly incorporated into the various manufacturing processes. The increased use of data outside the controller, which is exchanged via the Internet, made these machines an integral part of that technological mix called Precision Agriculture. There is no more possible development of Precision Agriculture without the intervention of specialized machines at each stage of the production chain. We will focus on design-oriented solutions and technological applications for these advanced machines (Wolfert et al., 2017;Shamshiri et al., 2018)

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1.1.1. Overview of Agricultural Equipment

Agricultural Equipment: A critical aspect of modern agricultural activities for increased productivity. Work in agriculture needs the use of a host of different and varied input support services such as irrigation, power, improved technologies, and so on. Of all the services, farm power and mechanization are the most important input support services that help significantly increase the productivity of the various agricultural operations. In agriculture, besides human labor, the use of animals, power engines, and equipment need to be exploited for different farm operations. The different farm operations include soil preparation, intercultural operations, sowing, harvesting, threshing, land leveling, and so on. For all these operations, different types of agricultural equipment and machines are needed. Animal traction and power engines are the prime movers for most the farm field operations. In agriculture, various types and kinds of different equipment are used for different agricultural activities. These various types and kinds of agricultural equipment can primarily be broken down into equipment that is used for land preparation, sowing, intercultural operations, harvesting, threshing, and so on. Each of the activities mentioned above is further diversified based on the crops grown and varied modes of farming.

Agricultural equipment and machines can also primarily be categorized or classified based on use, mode of power, and driving parameters. Based on these parameters or categories of agricultural equipment, the various different and specific types of agricultural equipment and machines are further used in agricultural operations. Agricultural equipment is classified under primary tillage implements, secondary tillage implements, sowing and planting machines, fertilizer and manure application equipment, intercultural implements, harvesting implements, threshers, and so on. Based on the mode of power or type of propel, the various specific types of agricultural equipment are divided into human-powered equipment and machines, animal-powered tools and equipment, power engine-powered machines, and equipment for field operations in different types of crops.

1.2. Historical Development of Agricultural Tools

It is generally accepted, especially in the context of agricultural mechanization, that tools represent the first step of technological development following the insight, shaped by the forces of nature, that man is the master of all beings. Although tools date back to a time before there was a division of labor, one would have to wait for the division of labor, and with it, the cooperation of men with their like and with nature to evolve to a higher stage of development, to speak of implements or equipment. The preindustrial stage of food acquisition and processing has left us with very few agricultural tools. Scrapers, some bone and teeth, and a few flint specimens, all raised in a very rough manner, testify that Cro-Magnon man lived by hunting and fishing, and settled later by farming the land and breeding cattle. In Democritus' words, tools are man's second nature. It is challenging to identify the moment when man began to use tools deliberately, especially to build them. The contribution to agriculture of man's assistance to nature, executed with tools, has only begun to be clarified in ancient China with the discovery of agriculture during the third millennium BC and in the first millennium AD with the discovery of the plow by the Han dynasty.

Without agricultural products, providing food to permit, for one thing, population growth, specialization of products, and trade would be impossible. There are some signs of crops to be cultivated more than 10,000 years ago in the valley of the Nile. Similarly, from biblical texts, it is possible to conclude that agriculture must date back to a time very close to Adam. Hesperides were, according to the Greeks, paradisiacal gardens that provided citrus fruits all year round. But it was only the development of roots, used as spices, that made their trips worthwhile. In ancient Europe, fig trees were cultivated for their fruits, while vines were their means of exchange with the colonies along the Black Sea. Eventually, agriculture spread throughout Europe. In the British Isles, the Celts made agricultural tools of bronze and traded them with the Romans. These, hoping to find the Hesperides, would only settle for the vines.

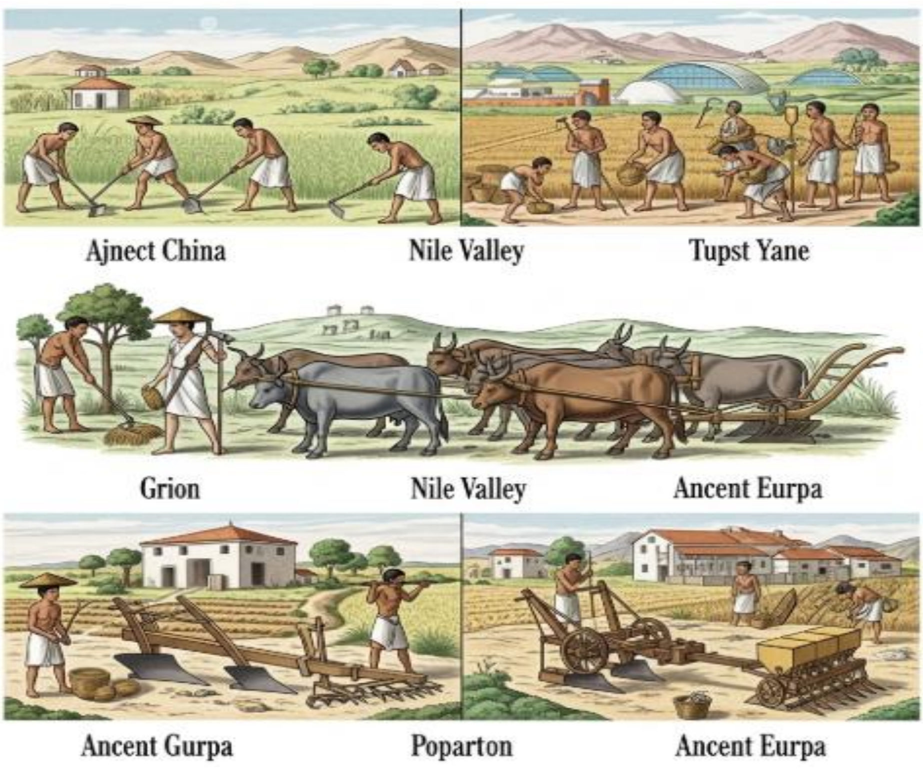

Fig 1 . 1 : The Evolution of Agricultural Tools and Human Progress

1.2.1. Evolution of Agricultural Implements Throughout History

In order to fully understand the technological integrations that take place in agricultural equipment, we must first present the historical process of the development of farming implements. For millennia, agriculture has been the foundation on which culture is built. The first tools for ground preparation, sowing, and agricultural product harvesting date from the beginning of humanity's sedentary lifestyle. The development of civilization led to the greater complexity of agricultural tasks, as corroborated by the necessity and invention of better and new implements. These implements were the reflection of progress: the durability and increase of production led to population growth and the subsequent need for greater development led to the introduction of innovations that facilitated agricultural tasks. Improvements in ground preparation, sowing, and harvesting were the most significant. New materials, knowledge of soil and plant behavior, advances in the knowledge of the weather, and the improvement of tasks related to fertilization, irrigation, and product conservation were just a few of the developments that allowed for improvements in production. The beginnings of agriculture are hazy. The Scientific Revolution considered agriculture's origins about ten thousand years ago, with the transition to a sedentary lifestyle and the domestication of the first animals and plants. As the earliest civilizations developed, new knowledge emerged in agriculture, and new tools of greater efficiency and development were required. The hinge from primitive agriculture to one of greater efficiency and complexity were the ancient civilizations of China and Mesopotamia. The process in which textile work began with spinning, weaving, and dyeing fibers led to a surplus in production and the development of tools for shoemaking, metallurgy, carpentry, and construction. This was the first division of labor, which allowed for the second group of specialists to work on the improvement and innovation of all tools, including agriculture.

1.3. Types of Modern Agricultural Equipment

Agriculture is one of the important indigenous sectors for the development of the national economy. The demand for food, textiles, and other agriculture-based industries has increased over the years along with the increase in population. To meet these requirements, agricultural production has been stepped up with the help of various mechanized implements and machines. The only way to achieve a high level of productivity is the mechanization of agriculture. Since ancient times, human beings have been continuously using various machines and implements for farming. With the advent of industry, various types of engines were invented which gave rise to tractors and other machines. These inventions have done away with hand labor and animal labor which were limited in use. Powerful engines and heavy machine tools have been developed to take the place of animal power. As a result of some experiments, modern developing countries have introduced tractors with machine tools powered by diesel engines. Specialized machines for different types of field operations have been devised for expansion. Tractors have enabled men to convert the untamed wilderness of earth into vast expanses of tilled fields with a speed and amplitude never before dreamed of. Tractors enable farmers to prepare the land more quickly in the spring and to do it better. With the increased use of crop rotation, farmers are replacing summer fallow with tillage of cover crops. It is not uncommon to find tractors used to reclaim lands that have been devastated by old-age neglect. Tractors are used to pull seeders and to drag harrows as the sugar beet, grain, and alfalfa crops develop. As the heavy loads of harvest creep, and finally run, bikes made possible the Sebring, the Gardner-Denver, and the plow sweep for ditching and for "picking" wheat. The job of planting was made easier in the days before the horseless carriage when mechanized planters dragged by horsepower continuously laid in the soil the rhythmically planted seeds until an entire field was done.

1.3.1. Tractors and Their Evolution

The tractor is one of the pivoting points of mechanized agriculture and has made a revolutionary change in agricultural operations and productivity. The root of the word tractor can be traced back to the Latin word trahere, meaning pull. Tractors take on many roles in agriculture from planting and harvesting to irrigation, cultivation, and transport. Tractors are not used for only field operations but also take on transporting agricultural products and installation of groundwater levels either directly or with appliances in rural gardens. The history of tractors is one steady evolution from animal power to steam, internal combustion engines to electric and hybrids, and crawlers to rubber-tired and eventually autonomous.

Tractors are among the most used agricultural equipment. The tractor, like any other agricultural machine, is a system of many components playing many roles i.e., a self-powered machine that provides a source of power for agriculture, as a work machine either as an engine or its attachment or as a power source providing energy to do work such as power generation. Tractors are considered the backbone of operation in the ever-improving efficiency of mechanized farming. The last decade saw a revival in tractor sales and the rapid growth was fuelled by the momentum of the introduction of new features, mainly electronics, and an emerging mix of tractors such as that of low-power segment demand to include features traditionally seen in higher HP tractors, increase in the creation of demand-pull from improved economic and agricultural growth, and storage and transportation facilitates. The growth was also driven by the use of modern high-yielding seeds hybrid crop technology and inundation and irrigation systems.

1.3.2. Harvesting Machinery

Agricultural productivity is most efficiently maximized when food and other raw material commodities are harvested and replaced in the shortest possible period. This is ideally pursued by mechanized equipment having sufficiently high throughput capacity to exceed the requirements of the production system while having large, sensitive, flexible capacity for soft handling and processing of the high-value fragile crop food product. Intensive efforts are placed within advanced industrial countries in mechanization programs to simplify and enhance the useful efficiency of root harvests, fruit harvesting, and grain crops. Specialized single-phase harvesting machines such as shelling machines, mobile grain dryers, and grain trucks are used as supplements.

The combine harvester is a powerful tractor-towed equipment unit that has displaced single-phase equipment in larger scale, price-insensitive mechanized harvesting of grain crops. The combine harvester successfully integrates field cutting, shredding, threshing, drying, handling, storage, and transport operations into an efficient flow of field crop material through a mobile processing system. The operating efficiencies of the combine strongly suggest the exploitation of the combination of field and harvest storage into the transport processing unit that will maximize user efficiency by properly sizing the unit. Mobile forage and silage harvesters occupy a unique niche within the mechanization systems by volumetrically supplementing crop transport units into on-farm feeding systems. Specialized self-propelled units are employed in cleaner deposits in the senescence stages of the growth cycle, malting barley, and oil seed crushing operations.

1.3.3. Irrigation Systems

Irrigation systems comprise an important subset of agricultural equipment. The development of special devices – the winged plow, the plow with smooth blades, the hoe – was aimed partially at providing surface irrigation of vegetable and fruit crops, trees, and shrubs. Cleaning up and digging out the canals and waterways – some of the oldest available water delivery devices – are done manually or mechanically. The changeover to contour irrigation methods is receiving much attention and would be simplified appreciably through the utilization of equipment outfitted with devices specially designed to dig canals and collect dirt. Water delivery to fields and crops is done primarily using pumps, which function on the basis of several different principles. Initially, these were lifting equipment, such as buckets or chains. These have been replaced gradually by machines that are able to lower water-pressure values or move them along from point to point. Most the modern pumps used for irrigating crops in developed countries are centrifugal pumps, either portable or set up at fixed points along main canals. Several different passages are used, including reversible axial turbines, and an appreciable amount of work has gone into constantly refining highly loaded machines such as tri-diaphragm pumps or screw pumps.

Drip irrigation systems are widely used for irrigating very valued crops, primarily in dry regions. Modern approaches to the fabrication of jets and fittings have made it possible to greatly reduce cost while increasing the service life of the equipment and lowering flow resistance coefficients appreciably. The delivery of water to fields is done mostly using pipes designed either to lay film in parallel ridges or pour small amounts of water into localized areas of soil in non-uniform fields. The relatively high cost of these systems means that they are most widely used in commercial agriculture for crops with high economic incomes. Considerable attention is being paid to the development of new centralized irrigation systems for crop-growing regions where there is high competition because of water scarcity.

1.3.4. Planting Equipment

Planting is the first operation determined at the start of the agricultural production cycle. The object of planting is to create reproductive structures of higher weed plants. The preparation of planting and the subsequent care of the growing crops during the vegetation period affect the efficiency of this operation. The essential elements of modern agricultural mechanization are transporting equipment, planting machines, and trailing units for planting. These plant-growing operations are carried out partially or entirely by machines. The most common are transplanting and sowing by machine, which ensures economical and high-quality planting.

In the process of planting, particular attention should be paid to the creation of the planting pattern, the volume of the sown area, and the creation of prepared germination conditions (necessary depth, compactness, and moisture). Today, machines and devices do not exist for the assumption that the capacity of planting with quality is higher than the soil processing preceding germination of crop seedlings. Modern mechanized planting of crops is a continuation of soil preparation under crop-worsening conditions. Preparing these conditions is possible under the special technological processes regulated by their morphometric parameters for each crop. Research has shown that increasing the sown area leading to excessive competitive conditions and overestimated hatching influences the final yields of grain crops. The machine-assisted recommendation for planting is significantly higher than those recommended for manual planting. The screening operations of planting machines and other machines are divided into further groups, seeders equipped for, machines functioning on two cycles, machines with working bodies developed for screening operations, and roller machines.

1.3.5. Soil Preparation Tools

Farming is performed on the soil. Without a healthy soil ecosystem, we cannot ensure a successful, usable harvest and a nutritionally rich and safe supply of food. Before planting a crop, the soil must be prepared through cultivation and tillage activities. Equipment used for soil preparation is known as primary tillage tools. These tools loosen the strip of upper soil layers so that the germinating roots can grow downwards and utilize the moisture and nutrients available there. Soil loosening also helps the rainwater to penetrate deep into soil layers to recharge the underground water and replenish the moisture reserves during dry periods. Primary tillage is important in clayey as well as sandy soils. For clayey soils, it is performed to break the mass of soil at great depth during the dry period, while for sandy soils, it is performed to help retain the moisture. Both sandy as well as clayey soils are further cultivated with secondary tillage tools to finish the job of pulverizing the soil for seedbed preparation. The seedbed must be well pulverized, leveled, and firm. A disturbed, loose seedbed would either bury the seed too deep in the soil so that it cannot germinate, or allow planting at uneven depths. It also takes away moisture from the seeds by capillary action.

In mechanical farming, the soil is prepared for sowing with the help of various tilling implements such as plows, harrows, cultivators, and rollers drawn by tractors. The size and design of this equipment depend upon the scale of farming operations, type, and condition of soil as well as the crop to be sown. Equipment for soil preparation is available in agricultural as well as custom-hiring markets. A farmer can purchase or hire different equipment for different activities related to soil preparation. Since soil preparation is a critical input before cultivating a crop, the farmer should try to choose equipment that is well-designed and constructed for the purpose. The dos and don’ts for using various types of tillage equipment are already well-studied and documented. Therefore, the limitations for making use of any equipment should be well understood for the quality effect of the work done using the equipment and for the safety, economy, and efficiency of its use.

1.4. Technological Innovations in Agriculture

Agriculture, in the past, has always been known as an industry that is strongly tied to the manual work of its workers. This aspect has important factors where each region's workforce differs. Not all countries are capable of providing an entire labor force, nor is it possible to leave an entire workforce to work the land because to allow for economic growth in a country, development in other areas must also be guaranteed. It is for this reason that the need for technology in this industry is crucial, and so in recent years, it has received a strong stimulus, mainly through technological innovations. These innovations have allowed for economic growth in both developed and developing countries, but tell a little story of how it all began.

In 1960, precision agriculture activities began to develop and guided in the 1970s by the first satellite programs, which existed only in military versions and later with the support of satellites for civilian purposes, allowed in the following years to obtain the greatest amount of information that could be used for a different management of the agricultural soil for crop purposes. The 1990s represented the beginning of the commercialization of agricultural machinery and equipment equipped with satellite devices for navigation and the beginning of the evolution of three-dimensional laser technologies for the creation of digital terrain model maps.

Precision agriculture allows farmers to meet the growing global demands for food, fiber, and fuel by increasing their productivity and harvesting more from the existing land base. No single tool can achieve all of these results. There is no golden hammer. Advanced or high-tech tools, such as lasers, sensors, and global positioning systems, help farmers produce more and better food with minimal chemicals, less water, and clean energy; and, do this by reducing emissions.

1.4.1. Precision Agriculture

Precision agriculture is a comprehensive farm organization that employs modern information technology to manage production inputs. Typically, the objective is to improve crop yield while minimizing costs and negative environmental impact. Precision farming utilizes advanced technology such as satellite imagery, yield monitors, soil mapping, and on-the-go fertilizer applicators; all these devices and technologies are used to conduct yield variability assessment, soil sampling, and variable-rate nutrient applications. Wireless communication devices such as GPS and cell phones generally assist precision farming technologies in their site-specific input recommendations. Precision agriculture is an advanced method to monitor crop agricultural activity by analyzing different factors that contribute to product development, such as soil moisture, humidity, temperature, and other environmental conditions. Primarily, satellite images are used to quantify crop growth and yield role to view farmers' precise fields.

Precision farming optimizes field-level management regarding crop farming. It refers to the methods of technology that achieve high yields while maintaining the environment within acceptable limits. It selects farming methods specific to the field, utilizing distinctions in growth, yield, and soil condition. It attains the detailed quantity of fertilizer application and irrigation issues. The word "precision" is derived from the Latin root "precisus," which means "cut off." Precision farming truly means "cutting off" coarseness to optimize returns while preserving the resource base for future generations.

Precision agriculture is generally regarded as a commercially viable application of information technology in agriculture. It has expanded rapidly across the cotton, corn, soybean, and sugarbeet sectors and represents the rapid prototype development phase of agriculture's information technology revolution. The automated measures are only as good as the integrated technology in the tractors and tillage equipment.

1.4.2. Drones in Farming

Drones have become an essential technology increasingly being explored for applications in farming. Organizations focusing on technology assessments are mainly funding the development of prototypes. Among the many original applications in agriculture for which unmanned aerial systems (UAS) have been tested are imaging problems, like phenotyping, germination assessments, topographical mapping, and water distribution research. A few companies also take to market drones that are claimed to perform these applications, however on a non-operational, research basis. Aspects of scouting and logistics, like monitoring and spraying, are the basis of three services offered by companies that utilize drones. Several companies market-adapted drone technologies that have been or can be tested in agriculture. It's still an example of two technologies to be integrated into drones, respectively: the data acquisition and the data evaluation phase.

Indirectly related to applied services, significant progress is made on three core product components. First of all, automatic vertical take-off and landing hybrids have become operational, thanks to advancements in technology, adaptations of the body partitions become more and more robust also for larger UAS. Secondly, research has been focused on the data acquisition and processing level. Until today, drones are operated carrying low-cost cameras for aerial imaging services on totally bare areas or are operated in the field, sensor-development is restricted to reinforced off-the-shelf cameras for image acquisition. The third aspect of technological advancement in georeferencing research has been mainly motivated by other usages than agricultural applications, like micro-mapping solutions for various industries. Drones will become integrated into farming if they prove to be capable of being small and light enough to work for scout-like objectives like long-lasting infrared detection and alert.

1.4.3. Automated Machinery

Technological advancements in industrial equipment and machine manufacturing also brought important innovations to agricultural equipment. Automated machinery has greatly improved field operations, enabling increased efficiency of field operations and ensuring timely implementation of agricultural practices. The monoculture of highly productive crops continuously increased the demand for machines capable of performing the same task hundreds of times within a season in the same farmland area. Factories specializing in agricultural equipment developed machines with higher productivity on specific field operations over the years. During the 1950s, the global industrial restructuring enabled by a series of events resulted in the very first large-scale manufacturing of tractors and combines, leading to the commercialization of equipment and the popularization of mechanization.

The development of automated equipment and its increased use in agricultural machinery resulted in the need to reduce the number of necessary operations and associated fixed costs. Thus, the two most important roles of decision-making systems were created. The first one is the decision to automate an operation, and the second one is the decision to select, develop, and adapt the machinery to the physical and economic needs of agriculture combined with the available resources, regarding a local climate, terrain, and soil quality. However, the equipment used in agriculture often has some limitations because of economics, social pressure, or physical restraints, which do not allow necessary improvements to be made in field operations. Improvement requires research and development of better decision-making systems, better machinery designed for mechanization, and more productive, suitable, and competitive agricultural policies.

The programming, symbols, images, and various colors that modern machinery is incorporating are modifying man's decision-making in important ways. Indeed, all the motor systems of a machine must be installed optimally, including the necessary automation and many sensors and monitoring systems that are being implemented. Rehabilitation is getting more and more complex. We can no longer lay under the machine and take it apart to replace a part; we have to know how to diagnose any breakdown and identify quickly which part of the overall automatisms has failed.

1.4.4. Data Analytics in Agriculture

Technological advancement is at the heart of the progress of modern portfolio management, which is able to process large amounts of data and independently manage substantial amounts. Data analytics have transformed agricultural decision-making, by increasing farmers' capacity to detect features and patterns in the landscape. Accordingly, the technology of big data applied to agriculture also facilitates collaboration to reduce risks and to better plan joint strategies. Digital agriculture has enabled exponential growth in the amount and variety of data used in the agricultural sector.

The increasingly vast and accessible data combined with advanced machine learning, artificial intelligence, and data analysis techniques support an increasing number of applications covering all phases of development, from selecting suitable seed varieties for each farm and crop production to supply chain management. These data-driven solutions foster a new era in farming and collaboration for food systems. Data for agriculture is a growing investment and specialization tool. The digitalization of agriculture is: collecting and exchanging a diverse range of data generated through the many opportunities of digital agriculture, analyzing the data, and creating services or products to be used by farmers, public administration agencies, and other players in the agriculture supply chain. Data contributes to the success of precision farming and its continuous monitoring of the health, quality, and yield of the crop. The success of these technologies and tools in this new era of digital agriculture can solve existing issues in data protection and preservation faced by the agricultural sector in recent years.

1.5. Sustainable Practices in Agriculture

Sustainable practices can accelerate the process of precision agriculture and promote agricultural environmental sustainability. Conservation tillage includes no-tillage, strip-tillage, ridge-tillage, mulch-tillage, and minimum-tillage. Today, 50% of the cropped land is under conservation tillage, growing 60% of the food. Conservation tillage is becoming highly mechanized, often involving the use of three to four interconnected implements and vehicles that carry out different functions such as surface shattering, soil loosening, residue displacement, and sowing/seeding/planting. Much work is needed to develop new equipment to make conservation tillage easier and more effective and reduce costs.

Organic farming emphasizes the use of natural bio-organic materials and the avoidance of synthetic fertilizers and pesticides. This further draws attention to soil quality and functions reliant upon biological activity. Organic farming makes agriculture highly sustainable in terms of its effects on the environment and its future. At present, the demand for organic products is being met mostly through imports, as domestic supply is only about 10%. Meeting organic production targets will require major investments in organic inputs and equipment. A present potential for significant growth exists for organic fertilizers, which account for only about 4% of total fertilizer use.

Most irrigation is very inefficient with up to 60% of the water loss due to evaporation, with much of the remainder lost to soil evaporation and water runoff. Technologies are now available to reduce water loss through the use of mulch covers, which reduce evaporation losses, and earthen bunds or furrows surrounding land to reduce runoff. However, the wide-scale application of such water conservation technologies has been and continues to be hampered by high labor costs. An increase in crop yields requires greater investment in specialized capital equipment and increased inputs for rapid production response.

1.5.1. Conservation Tillage

Tillage is a crucial practice for crop production expansion where due to crop residue deterioration or soil conditioning needs, multiple operations are required. However, excessive tillage of the soils has contributed to their degradation and loss of fertility because natural processes are lessened. This problem prompted the use of conservation tillage systems that minimize soil physical and chemical disturbances. Depending on the residue retention quantity, conservation tillage can be subdivided into minimum tillage, no-till, or ridge tillage. These systems have undoubted advantages, such as slowing soil erosion processes, moisture storage, improving soil structure, carbon and nitrogen cycling, increasing organic matter and nitrogen in nature, and favoring biological activity and diversity.

Fig 1 . 2 : Conservation Tillage: Nurturing Soil Health for Sustainable Agriculture

Soil tillage advances have led to the emergence of specific machinery for major soil functions during tillage, preparation, and establishment of crops, such as primary tillage, secondary tillage, and planting machines. However, new options for machines and equipment are being developed because they haven't gained the anticipated popularity because of soil and crop residue conditions imposed by the purpose and location of the machinery that is applied in conservation tillage. These machines are equipped with systems to regulate working depth and soil loosening intensity, enabling the machine to be used in different tillage systems. In general, they are equipped with pneumatic at the entrance and hydraulic at the exit. Research is focusing on reducing energy requirements and transferring energy from petroleum to renewable energy from biomass. Various equipment is available for carrying out the different tasks in the established minimum tillage method in the crop area during the crop's vegetative cycle and for not disturbing the soil surface.

1.5.2. Organic Farming Equipment

Organic farming is an alternative farming system that avoids the use of synthetic fertilizers, insecticides, fungicides, herbicides, and other chemicals and relies on crop rotations, manure and compost additions, pest control using insects, plant species diversity, etc. Organic farming equipment is different from conventional equipment in the following ways: Organic farms use cover crops, and their incorporation requires special equipment. Organic farmers may grow long-stemmed crops like mustard and buckwheat in wide rows, and their incorporation requires other than conventional mulching equipment. Organic farmers may wish to utilize thin stems and fibrous root crops in mixtures in wide rows, and their conversion to mulch via shredding and subsequent incorporation would require special equipment. Organic farms have difficulties managing weeds, and their maturing during crop growing season requires the installation or incorporation of tools that can function without harming the crop.

Tines that can eliminate all weeds may be used between both conventional tobacco rows, which use black plastic mulch, and organic sweet potatoes, which use no plastic mulch; also functioning as a transfer board, the indehiscence tines on the frame of a transfer board convey soil to the dike base. Since both crops are planted with paper mulch planters, tobacco, and sweet potatoes can be raised with shallow, timed beatings of the soil surface from a rotary hoe implemented with frosting tines, driving rods from a tractor to augment the eccentric power of one or more wheels; high ridges can be observed between the two crops approximately 10 days after planting. The ridges can be retained until sweet potatoes are ready for harvesting.

1.5.3. Water Conservation Technologies

Agriculture is a major consumer of our water resources. It accounts for about 30 to 60 percent of freshwater utilization across the world. Cropping is a process that disturbs the natural water cycle by using precipitation, depleting underground water, and making the water unfit for consumption through chemical fertilizer pollution. Consequently, agriculture is under pressure to ensure food production with minimum utilization of freshwater resources. The best way to solve various problems in water management for sustainability is to introduce new technologies or modify the existing ones.

The introduction of modern technologies in irrigation and drainage management, rainfed agriculture, and water management in watersheds is essential to reduce the demand for water, raise irrigation efficiency and water-use efficiency, increase the promotion and utilization efficiency of rainfall, and seek sustainable solutions for water management. Modern practices and technologies aim to address the water problems facing agriculture and ensure food production while ensuring water productivity. The technologies, which are generally adopted at different stages of large- and small-scale irrigation projects, are incorporated in some of our traditional surface, ground, and rainfall management strategies to cultivate crops using minimum water. Depending upon the need, increased efficiency and effectiveness of water management can be adopted at different levels of agricultural activity throughout the world in a decentralized manner.

Irrigation scheduling clarifies a specific period during which crop requirements of water should be realized. The growing season is divided into stages. Based upon these stages, the required durations of the irrigation are decided either for surface irrigation, sprinkler irrigation, or farm ponds. The periods preferably should match the dry phase of the stage. This activity can be undertaken on the basis of soil moisture criteria, plant indicator methods, or weather indicators. The scheduling of irrigation is a management requirement, which can also be applied to rainfed farming at appropriate stages to secure desired yields. The management also can be secured through the proper selection of crops to be grown against a climate.

1.6. Economic Impact of Agricultural Technology

Economic growth in developed nations as a direct result of agricultural and agricultural machinery technology advancement relative to that of underdeveloped nations indicates the degree of importation of technology from developed to underdeveloped nations and its deployment relative to those nations' developmental stages. The lowest technology economic sectors in developed economies continue to be agriculture and food production, and the machinery base for technology deployment in these sectors has been the lowest of any industrial sector. Farming balance sheets are characterized by net farm income from both crop and livestock operations disappearing due to off-farm job income and capital and resource management problems. Labor efficiency in farming continues to grow and is leading to demand for basic farming products that can be efficiently produced and processed, meaning crop origins for biofuels and quality food to supply a global hungry market. Three major issues continue to major discussions at the government and industry level over their potential effects on the agricultural economy of developed and underdeveloped economies. These issues are both the total market size as it relates to the effect of technological integration into farming and food production and the domestic and global market direction for agriculture from high levels of conversion from oil to biodiesel and gas to ethanol.

The second issue is the need for on-farm capital investment for in-field technology pairing and equipment and crop infrastructure investment to speed the quasi-factory processing chain of turn-around time to market supply windows. This area is of general interest in that much of the increasing, enhancing food cuisine flavor quality demand from 3rd and 4th generation immigrant ethnic groups, in both developed and developing economies, is approaching and matching the consumption food demand of bordering undeveloped economies. The third issue is the ongoing voluntary and involuntary demand entering the global food equation for the increased use of bioengineered food products to reduce food spoilage and associated storage costs.

1.6.1. Cost-Benefit Analysis

Cost-benefit analysis (CBA) is a method that is widely used to select and justify the adoption of specific agricultural technology. The CBA starts with the assumption that a decision maker seeks to maximize economic welfare by selecting the most preferred alternative from all possible options. This is the principle of optimization. The optimal decision is determined by estimating the overall economic costs and benefits of each of the alternatives being considered. The alternative with the lowest estimated costs or the greatest net benefits is selected. The basic principles of CBA are outlined in the following sections. We focus on simple cases with non-recurrent or annualized costs and benefits. There are also specialized criteria that can be used to guide selection.

In essence, the costs and benefits of an alternative are what is given up (the costs) and what is received in return (the benefits) for taking the action associated with that alternative. Costs less benefits is the "net present value," abbreviated as "NPV." In economic analysis, costs and benefits are measured in monetary terms. Following established accounting principles, costs must include not only the explicit, nominal payments made for undertaking the action, such as the purchase price of a tractor and its operation and maintenance costs but also implicit costs, such as the production loss incurred from using the tractor on the owner’s farm. Benefits must likewise account for the relevant income effects, such as the reduction in joules of food energy provided free of charge to the owner of the tractor by other farm family members in the absence of tractor use.

1.6.2. Market Trends and Equipment Demand

The discussions in the first part of this book have centered on criteria for determining the relative merit of techniques of more complex technology transfer. They possess the special significance and advantages in horizontal technology packets that allow them to stimulate rapid agricultural development in nations facing an acute shortage of resources needed to finance a costly transformation of their agricultural sectors. While the more conventional approach may have more appeal to those agencies that have made large investments in research or the promotion of expensive transfer projects, the merit of an orderly phased transition in the technologies transferred, from the simple improvement of traditional techniques to the more sophisticated techniques of advanced nations, should not be ignored.

We turn now to the problems associated with the shifting demand for agricultural products and consider the consequences of these changes for the supply and demand for agricultural capital. It is our view that as they occur, and are shown in these earlier parts of the book, the forces involved in the ongoing forces in demographic transition, technological change, and economic development are pushing economies towards market-driven demand for increased agricultural efficiency, can easily outpace decreases in the capital/labor ratio response. It follows that the ratio of rental to capital values should move in the opposite direction, thereby stimulating rapid capital deepening in agriculture and perhaps generating some overshoot of the economic values of capital stock in the short run. The market demand for equipment is the amount of equipment that would be purchased in a period at different price and rental value expectation levels. In many cases, this demand is negative for economic values, which fall below the threshold for damage repair or replacement cost values. For these periods reversing wrong estimates of rental value and excess demand involves rent cost-based investment patterns that are quite different from the roles of the market in determining investment decisions in the two other sectors. We will explore some of these additional demand models when we relate short-run demand projections to a description of the market structure typically found in equipment.

1.7. Challenges in Agricultural Equipment Adoption

While there is a transition towards newer technologies in agricultural machinery, there are still many traditional systems being used around the world. The reasons for this slow transition are very context-specific and vary from nation to nation, region to region, and also from farmer to farmer. For many farmers, their traditional equipment is more than just a way of doing business; it holds a nostalgic place in their culture, and they are proud of it. However, for many others, the most current challenge is financial, and upgrading to newer generations comes with a financial burden that they cannot sustain. For smallholders in emerging economies, the sheer price of precision implementations is a significant barrier and they even sometimes choose to not adopt certain precision applications that could potentially increase their productivity or reduce cost simply because the equipment available for them to utilize is prohibitively expensive.

In the years 2011 to 2012, much of the investment in agricultural equipment went to machinery targeting the commercial market, which led to specialization in larger equipment and larger components due to economies of scale and higher margins for manufacturers. This pursuit of volume has led to a shortage in capacity for service providers to enable smallholders of other developing economies to have access to precision agriculture. While there are companies globally that are making specialized lower-cost, better entry-level precision agricultural equipment, there are still concerns about the timeliness of service and the ability of farmers to be able to utilize them efficiently. Precision agriculture requires training and education at all levels from companies, farmers, and employees to utilize and reap the maximum socio-economic returns. Formal and informal training are critical in ensuring that any skill gaps and labor shortages are being filled.

1.7.1. Financial Barriers

Investment in modern agricultural technology represents a high opportunity cost for producers and brings few immediate benefits. Current expenditure on mechanization is often the largest payment on an annual budget, representing on average over 30 percent of total annual costs. Lease and hire businesses have been concentrating on tractors and primary tillage implements. Large-size tractor and implement combination hire is said to be cost-effective for certain operations, but minimum tillage operations in areas with moisture constraints require the use of specialist equipment. Providing this service is not economically viable at current rates of hire and the difficulties of amortizing such an investment mean these implements may not be readily available shortly. It is doubtful that any rapid or drastic technological changes will materialize in underdeveloped countries shortly. At best, this will mean an influx of tractors converting to a 'service center' pattern of activity with little benefit at the farm level. Small farmers who have low investments and few vehicles to support an implement hast enable a rapid expansion of mechanized agriculture which is well past the states of correction.

Financial assistance is often provided through grants, subsidies, low interest rates, and other easily accessible payments. We can identify a number of possible steps that a developing country might take to create the kinds of incentives that would induce farmers to invest in new technology. From a strictly practical standpoint, the means and the methods available will differ greatly depending on the size, the makeup, and the prevailing policies and practices of such investment industries in the developing country.

In most developing countries a very high percentage of total savings comes from the public sector and institutional savings. To some extent, it allows for these considerations that were the slowest to orient. This reluctance has been amended since most developed countries have succeeded in setting a good example and by showing how much a country can gain, both in terms of economic growth and export potential, as a result of its investment support.

1.7.2. Training and Education Needs

Training is a fundamental activity within the educational process both for students in the classroom and for professionals in companies. It is a basic need in any sector of the economy. Training and education in, by, and for the AG sector, before and after the BOT revolution, are stratospherically important in those countries with a structure/agricultural policy based on productivity: good, the best, and at a good price. South Africa is a paradigmatic case. The productivity of the AG sector is a key factor in the economy: its fall puts the country at risk of being declared a failed state. For the productive matrix of any country, the conditions of the AG sector have a double impact: on the national economy and the ground.

The BOT revolution transforms the AG sector and the relations of the AG sector with the other sectors of the economy. Training must also change. No country can afford not to work for or be satisfied with the educational system it has to train future professionals or those who are already working to advance knowledge within the AG sector: standards, regulations, private or public responsibility, in Universities, Vocational Training Centers, Public Administration Services and Companies. Companies must also have the capacity, the economic resources, and the knowledge and accept the responsibility to train their workers to be modified by the BOT revolution. Not everyone has, nor will they have the ability, the courage to place people and resources in training.

1.7.3. Infrastructure Limitations

Infrastructure limitations are perhaps the biggest challenge in modernizing international agricultural sectors, both in developed and developing countries. For many countries, it's road networks or bridges that restrict equipment size and weight. Making equipment work properly usually entails engineering decisions. However increasing the allowable axle loads, extra-wide implements and machines, wider tires or tracks, and auxiliary hitching for pulling bigger loads change the requirement for suitable roads and bridges in agricultural areas. Such engineering decisions aren't just financial decisions; they also depend on the availability of resources.

World development agencies and a few universities have developed and occasionally updated road design procedures used primarily outside of the United States. Those procedures clearly illustrate the dependency of design allowable axle loads or implement widths on the frequency of use, proximity to centers of activity, local subgrade resources, and local water content and drainage conditions. Many graduate work and major highway departments have incorporated the concept of critical loads for highway subgrades. That concept explains the reason large machines aren't used for final planting or harvest.

That is true in both developed and developing countries, but where specific road design procedures have been used outside of the United States, the lower average axle loads applied to roads have often been a major justification for lifting allowable axle loads from those identified in American publications. Although not a justification for not using modern equipment, such procedures suggest that modern equipment may well be optimally designed for American conditions, and the United States may need to be especially careful about allowable equipment dimensions and weights. Paved highways are part of the developed world economic infrastructure, which American agriculture built and has helped protect and promote.

1.8. Future Trends in Agricultural Equipment

The agriculture industry is currently in the middle of a twilight phase during which highly technological solutions enter into place. These solutions in combination with completely different psychological attitudes will completely delocalize the conception and construction of equipment in all territories of the globe, while the industry itself concentrates even more and specializes in the mass production of high-added value equipment. The values of innovation, selective production, eco-design, and constructive modularity become common to agriculture, automotive, and aeronautics, creating a tight bond association between agriculture and agro-food, structuring European territories around centers of agricultural excellence.

Smart Farming Solutions

During this period of transition, several specific solutions already exist that apply for instance: Variable Rate Application, Variable Rate Irrigation, and Variable Rate Seeding. However, the evolutions are still quite limited. And most parameters have been identified. But we are still in a phase of exploratory R&D. The number of tractors and services equipped with smart farming capabilities is multiplied, both in terms of installed capacity and use per equipment.

In addition to service, millions of tractors will have deployed smart farming services in the US in 2030. The autonomous tractor equipped with a camera sensor promises in or near term to revolutionize the connection of the farm to the field. Connected, electric, and autonomous equipment seemed a realistic development prospect not too late. A huge evolution should be proposed by 2030. The services and the sensors will make autonomous driving of the tractor straightforward. Should, therefore, propose a connected tractor, a tractor programmed for a needs-driven task and highly secure so that action is guaranteed. The equipment will then be equivalent to intelligent tools designed for specific tasks in fields and available in sufficient volume to be rented with appropriate guarantees. Beyond the heavy equipment, miniaturized robotic vehicles equipped with tools such as robotic arms or small implements will further simplify and re-skill the operations we are used to. These tools will automatically intervene in these areas around the house and other urban areas.

1.8.1. Smart Farming Solutions

The world today must feed over 9 billion human beings and it must do it using the most sustainable resources to preserve biodiversity and ecosystems. Also, to respect the environment and consumers with a healthy diet based on products free from excess chemicals, fertilizers, etc. Precision agriculture, accurate farming, and smart farming are not just buzzwords today. They encompass multiple aspects of modern life and agricultural economics, from sustainability reduction of the environmental impact to effective and efficient logistics. In smart farming solutions inclusive of most physical agriculture aspects, vehicles and equipment represent a key component. Therefore, their development must be oriented to become real tools available for smart farming and not just hi-tech machines. In developing future equipment, IoT, precision location, data collecting, and management, and hardly seen for soil condition determination and field management.

Planting, management, treatment with sanitizing, fertilizer or watering products, harvesting, tilling, transporting, storing, and remediating crops must be carefully defined according assessment seriously the economic conditions. Predictive models are fully implemented as technology pushes to maintain access to smart farming tools even within an accessible and reduced budget. Use blockchain technologies to secure, with great attention and protection the farmer's final integrated solution. Combining herein robotic companies or agricultural field players appeal to complete and effective platforms. Fertilization, crop growth, monitoring, and even qualitative and quantitative evaluation come from a common goal-oriented platform. In this sector, the level of automation is reduced and generally concentrated in some specific test phases like crop evaluation. However, the potential is very high as long as the route from R&D to the market proposal can be as short and cost-effective as possible.

1.8.2. Integration of AI and Robotics

Though it is common for nearly every industry to employ some level of automation, farming is still catching up to what is possible. The research and implementation of autonomous equipment is a major part of the future of improved farming. Artificially intelligent machines are currently relegated to field monitoring, which allows for another level of physical automation on behalf of the farmer. The next step is the introduction of complete automation that allows a robotic machine to think not just about how to perform a task but also allows it to react entirely on its own. These machines would need to be able to think through a complicated web of tasks, like planting and watering crops, and be able to respond to changes in their environment. Fully autonomous farming machines are passed through developmental stages, including semi-automated machines. These machines currently implement a variety of autonomous aspects, but a human needs to be present in case the machine needs outside assistance. Some functions already have produced machines available for sale, such as autonomous weeding robotics. However, machines that focus on complete autonomous thinking are still in development and require years of more focused research before becoming commercially available.

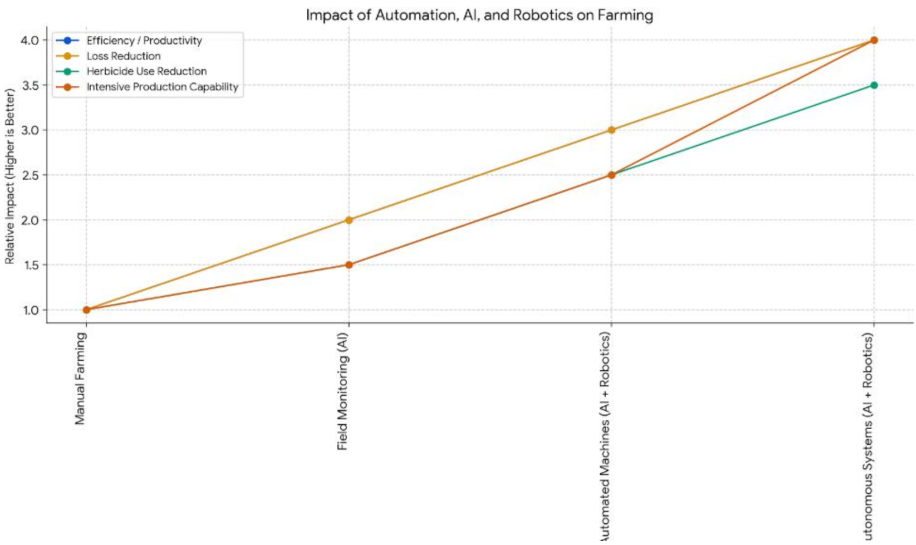

Fig 1 . 3 : Impact of Automation, AI, and Robotics on Farming

The addition of AI acts as a catalyst for the effectiveness of automation in farming, creating solutions to various problems down the road. An even larger meaningful impact on the future of farming, however, is the integration of robotics and AI together with the development of full autonomy. These improvements are aimed at experiencing the minimum burden with regard to essential operations such as reduction in losses and in the use of herbicides. Furthermore, through periodic monitoring without expressing either bias or fatigue, the autonomous system using AI and robotics can be expected to make intensive production possible. Considering all these statements, the future of production involves a high-level collaboration between AI and robotics resulting in autonomous systems that can operate round-the-clock without any human intervention.

1.9. Conclusion

Over the course of history, mankind has developed a suite of agricultural machines that provide the necessary support for completing modern-day production. Most of the fundamental functions and core engineering principles have not changed much, although some of the technologies supporting these machines have improved tremendously. In particular, electronic and data-based systems are now used to support many of the main functions that assist agriculture and/or improve its efficiency. Although the necessary increase in agricultural productivity to support a growing and increasingly wealthy global population has become bound up with the pressures to improve the environmental sustainability of farming practices, socially responsible engineering techniques, which connect product lifecycle and sustainability, have become important in addressing agricultural issues. Technological integration provides the techniques that support this product lifecycle and sustainability assessment and will be an important driver of future machine development. This text has been somewhat deterministic about how agricultural equipment may evolve, in terms of how hierarchical Layered product groups branch out from tiers of Layers of basic components with basic functions. At the core level, machines have key functions associated with the fundamental activities and mechanized processes that are present within each Layer of the Layered product. At any one time, machine requirements are modified by specific combinations and augmentations of these core factors, as society imposes its own needs and standards that influence design choices for new equipment, be it for Crop Establishment, Crop Care, Crop Harvesting, or Crop Processing. The hope is that this design template helps machine design engineers consider the full range of physical and analytical attributes relevant to designing future intelligent agricultural machines, be they tractors, sprayers, cultivators, or drills, to undertake the processes needed for successful Crop-based Food Systems, despite the accelerating impact of product and social change.

1.9.1. Summary and Future Outlook for Agricultural Equipment Evolution

This essay provides an overview of agricultural equipment's historical evolution, considering the connection between their technological advancements and the social and economic boundaries faced. The entire evolution happened on technological micro and β-processes, aiming to supply the population's food demand, which used to increase from generation to generation and, currently, is more linked to the population's well-being.

For a long time, agricultural revolution participation in social and economic development was slow. Contrarily, the Industrial Revolution occurred at a fast pace, leading to gaps between production technologies. In this way, since micro-processes are assisted by macro-processes, agriculture faced gaps driven by social and economic constraints, starting from, first, food unavailability and then moving to food inaccessibility, until the 20th century.

In the past century, evolution errors and/or fluctuations caused technological discontinuities in micro-processes with evolutions pulling on through the use of methods and equipment able to satisfy, in association with the whole economy, the sudden population growth's needs. Simultaneously, discontinuities in macro-processes also occurred from the Industrial to the Technological Revolution. After World War II, for a long period, the entire economy became more regulatory than typical on micro-discontinuities, enabling on-demand availability, the connection between the growth of the population, people's well-being, and the capacity of production, no longer as a goal, rather a tool for these activities to be continuously interconnected.

Currently, as the entire economy goes towards being more regulatory; food and well-being unavailability become a transition between phases in this trajectory. In the Agricultural Sector, technological pushing appears to be more flexible now, given the Digital Revolution, allowing small and large-scale actors to create solutions more rapidly. During a transition period, customized solutions integrated into the goods supply chain and into the market will appear. Enabling better offering and choice, aiming for optimization of production systems, also supplies the path for enlarging capacity, distribution, and safety of offering as a tool to make the Income Growth objective possible.

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