МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ЦЕНТРАЛЬНОУКРАЇНСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ
КАФЕДРА ІНОЗЕМНИХ МОВ

АНГЛІЙСЬКА МОВА

Методичні вказівки до практичних занять для здобувачів освіти другого (магістерського) рівня, спеціальність 208 “Агроінженерія”

Кропивницький 2024

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ЦЕНТРАЛЬНОУКРАЇНСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ
КАФЕДРА ІНОЗЕМНИХ МОВ

АНГЛІЙСЬКА МОВА

Методичні вказівки до практичних занять для здобувачів освіти другого (магістерського) рівня, спеціальність 208 “Агроінженерія”

Затверджено
на засіданні кафедри
іноземних мов
протокол № 1
від 29 серпня 2024 року

Кропивницький 2024

Методичні вказівки до практичних занять для здобувачів освіти другого (магістерського) рівня, спеціальність 208 “Агроінженерія”

Укладач: В.І. Миценко, - Кропивницький, ЦНТУ, 2024. – 25 с.

Автори: В.І. Миценко, завідувач кафедри іноземних мов, к.п.н., доцент
К. Б. Кармазіна, викладач кафедри іноземних мов

Рецензент: Соколовська О.М., к.філол.н., доцент кафедри МЕВ, ЦНТУ.

Методичні вказівки Призначені для здобувачів освіти 2-го рівня спеціальності “Агроінженерія”.

У цьому посібнику основну увагу звернено на розуміння специфіки лексико-граматичних засобів мовного стилю, вдосконалення навичок ознайомлювального, переглядового і вивчального читання літератури.

Тематика текстів не тільки забезпечує багатий лексико-граматичний навчальний матеріал, а й має велике пізнавальне значення.

Agricultural engineering, also known as **agricultural and biosystems engineering**, is the field of study and application of engineering science and designs principles for agriculture purposes, combining the various disciplines of mechanical, civil, electrical, food science, environmental, software, and chemical engineering to improve the efficiency of farms and agribusiness enterprises[1] as well as to ensure sustainability of natural and renewable resources.

An agricultural engineer is an engineer with an agriculture background. Agricultural engineers make the engineering designs and plans in an agricultural project, usually in partnership with an agriculturist who is more proficient in farming and agricultural science.
The first use of agricultural engineering was the introduction of irrigation in large scale agriculture in the Nile and the Euphrates rivers before 2000 B.C. Large irrigation structures were also present in Baluchistan and India before Christian era. In other parts of Asia, agricultural engineering was heavily present in China. In South America irrigation was practiced in Peru by the Incas and in North America by the Aztecs.

The Last Furrow by Henry Herbert La Thangue

The earliest plough was the ard or scratch-plough.

Settlers practiced irrigation in the vicinity of San Antonio in 1715, the Mormons practiced irrigation in Salt Lake Valley in 1847.
With growing mechanization and steam power in the Industrial Revolution, a new age in agricultural engineering began. Over the course of the Industrial Revolution, mechanical harvesters and planters would replace field hands in most of the food and cash crop industries. Mechanical threshing was introduced in 1761 by John Lloyd, Magnus Strindberg and Dietrich. Beater bar threshing machine was built by Andrew Meikle in 1786. A cast iron plow was first made by Charles Newbold between 1790 and 1796.
Old Style Sunshine Harvester found in Henty (wine) region of NSW Australia
James Smith constructed a mower in 1811. George Berry used a steam combine harvester in 1886. John Deere made his first steel plow in 1833. The two horse cultivator was first about 1861.

Fork hay tedder

The introduction of these engineering concepts into the field of agriculture allowed for an enormous boost in the productivity of crops, dubbed a "second agricultural revolution" which consisted of:
1. Shift from peasant subsistence-farming to cash-farming for the market
2. Technical changes of crop rotations and livestock improvement
3. Labour being replaced by machinery

In the 20th century, with the rise in reliable engines in airplanes, cropdusters were implemented to disperse pesticides. Benjamin Holt built a combine harvester powered by petrol in 1911. Erwin Peucker constructed bulldog tractors 1936. Deutz-Fahr produced the rotary hay tedder in 1961.
In the late 20th century, genetically modified foods (GMOs) were created, giving another large boost to crop yields and resistance to pests.

Agricultural machinery relates to the mechanical structures and devices used in farming or other agriculture. There are many types of such equipment, from hand tools and power tools to tractors and the farm implements that they tow or operate. Machinery is used in both organic and nonorganic farming. Especially since the advent of mechanised agriculture, agricultural machinery is an indispensable part of how the world is fed.

Agricultural machinery can be regarded as part of wider agricultural automation technologies, which includes the more advanced digital equipment and agricultural robotics. While robots have the potential to automate the three key steps involved in any agricultural operation (diagnosis, decision-making and performing), conventional motorized machinery is used principally to automate only the performing step where diagnosis and decision-making are conducted by humans based on observations and experience.

The Industrial Revolution

With the coming of the Industrial Revolution and the development of more complicated machines, farming methods took a great leap forward. Instead of harvesting grain by hand with a sharp blade, wheeled machines cut a continuous swath. Instead of threshing the grain by beating it with sticks, threshing machines separated the seeds from the heads and stalks. The first tractors appeared in the late 19th century.

Steam power

A German combine harvester by Claas

Power for agricultural machinery was originally supplied by ox or other domesticated animals. With the invention of steam power came the portable engine, and later the traction engine, a multipurpose, mobile energy source that was the ground-crawling cousin to the steam locomotive. Agricultural steam engines took over the heavy pulling work of oxen, and were also equipped with a pulley that could power stationary machines via the use of a long belt. The steam-powered machines were low-powered by today's standards but because of their size and their low gear ratios, they could provide a large drawbar pull. The slow speed of steam-powered machines led farmers to comment that tractors had two speeds: "slow, and damn slow".

Internal combustion engines

The internal combustion engine; first the petrol engine, and later diesel engines; became the main source of power for the next generation of tractors. These engines also contributed to the development of the self-propelled combine harvester and thresher, or the combine harvester (also shortened to 'combine'). Instead of cutting the grain stalks and transporting them to a stationary threshing machine, these combines cut, threshed, and separated the grain while moving continuously throughout the field.

Tractors

Tractors do the majority of work on a modern farm. They are used to push/pull implements—machines that till the ground, plant seeds, and perform other tasks. Tillage implements prepare the soil for planting by loosening the soil and killing weeds or competing plants. The best-known is the plow, the ancient implement that was upgraded in 1838 by John Deere. Plows are now used less frequently in the U.S. than formerly, with offset disks used instead to turn over the soil, and chisels used to gain the depth needed to retain moisture.

Combines

A John Deere cotton harvester at work in a cotton field

Combine is a machine designed to efficiently harvest a variety of grain crops. The name derives from its combining four separate harvesting operations - reaping, threshing, gathering, and winnowing—into a single process. Among the crops harvested with a combine are wheat, rice, oats, rye, barley, corn (maize), sorghum, soybeans, flax (linseed), sunflowers and rapeseed.

Planters

The most common type of seeder is called a planter, and spaces seeds out equally in long rows, which are usually two to three feet apart. Some crops are planted by drills, which put out much more seed in rows less than a foot apart, blanketing the field with crops. Transplanters automate the task of transplanting seedlings to the field. With the widespread use of plastic mulch, plastic mulch layers, transplanters, and seeders lay down long rows of plastic, and plant through them automatically.

A British crop sprayer by Lite-Trac

Sprayers

After planting, other agricultural machinery such as self-propelled sprayers can be used to apply fertilizer and pesticides. Agriculture sprayer application is a method to protect crops from weeds by using herbicides, fungicides, and insecticides. Spraying or planting a cover crop are ways to mix weed growth.

Balers and other agriculture implements

Farmer on a hay harvester in Switzerland

Planting crop hay balers can be used to tightly package grass or alfalfa into a storable form for the winter months. Modern irrigation relies on machinery. Engines, pumps and other specialized gear provide water quickly and in high volumes to large areas of land. Similar types of equipment such as agriculture sprayers can be used to deliver fertilizers and pesticides.

Besides the tractor, other vehicles have been adapted for use in farming, including trucks, airplanes, and helicopters, such as for transporting crops and making equipment mobile, to aerial spraying and livestock herd management.

The basic technology of agricultural machines has changed little in the last century. Though modern harvesters and planters may do a better job or be slightly tweaked from their predecessors, the combine of today still cuts, threshes, and separates grain in the same way it has always been done. However, technology is changing the way that humans operate the machines, as computer monitoring systems, GPS locators and self-steer programs allow the most advanced tractors and implements to be more precise and less wasteful in the use of fuel, seed, or fertilizer. In the foreseeable future, there may be mass production of driverless tractors, which use GPS maps and electronic sensors.

Agricultural automation
The Food and Agriculture Organization of the United Nations (FAO) defines agricultural automation as the use of machinery and equipment in agricultural operations to improve their diagnosis, decision-making, or performance, reducing the drudgery of agricultural work and improving the timeliness, and potentially the precision, of agricultural operations.

The technological evolution in agriculture has been a journey from manual tools to animal traction, then to motorized mechanization, and further to digital equipment. This progression has culminated in the use of robotics with artificial intelligence (AI). Motorized mechanization, for instance, automates operations like ploughing, seeding, fertilizing, milking, feeding, and irrigating, thereby significantly reducing manual labor. With the advent of digital automation technologies, it has become possible to automate diagnosis and decision-making. For instance, autonomous crop robots can harvest and seed crops, and drones can collect information to help automate input applications. Tractors, on the other hand, can be transformed into automated vehicles that can sow fields independently.

A 2023 report by the United States Department of Agriculture (USDA) revealed that over 50% of corn, cotton, rice, sorghum, soybeans, and winter wheat in the United States is planted using automated guidance systems. These systems, which utilize technology to autonomously steer farm equipment, only require supervision from a farmer. This is a clear example of how agricultural automation is being implemented in real-world farming scenarios.

Open source agricultural equipment

A self-propelled Apache Sprayer by Equipment Technologies

Many farmers are upset by their inability to fix the new types of high-tech farm equipment. This is due mostly to companies using intellectual property law to prevent farmers from having the legal right to fix their equipment (or gain access to the information to allow them to do it). In October 2015 an exemption was added to the DMCA to allow inspection and modification of the software in cars and other vehicles including agricultural machinery.
The Open Source Agriculture movement counts different initiatives and organizations such as Farm Labs which is a network in Europe, l'Atelier Paysan which is a cooperative to teach farmers in France how to build and repair their tools, and Ekylibre which is an open-source company to provide farmers in France with open source software (SaaS) to manage farming operations. In the United States, the MIT Media Lab's Open Agriculture Initiative seeks to foster "the creation of an open-source ecosystem of technologies that enable and promote transparency, networked experimentation, education, and hyper-local production". It develops the Personal Food Computer, an educational project to create a "controlled environment agriculture technology platform that uses robotic systems to control and monitor climate, energy, and plant growth inside of a specialized growing chamber". It includes the development of Open Phenom, an open source library with open data sets for climate recipes which link the phenotype response of plants (taste, nutrition) to environmental variables, biological, genetic and resource-related necessary for cultivation (input). Plants with the same genetics can naturally vary in color, size, texture, growth rate, yield, flavor, and nutrient density according to the environmental conditions in which they are produced.

Ergonomics, also known as **human factors** or **human factors engineering** (**HFE**), is the application of psychological and physiological principles to the engineering and design of products, processes, and systems. Primary goals of human factors engineering are to reduce human error, increase productivity and system availability, and enhance safety, health and comfort with a specific focus on the interaction between the human and equipment.

The field is a combination of numerous disciplines, such as psychology, sociology, engineering, biomechanics, industrial design, physiology, anthropometry, interaction design, visual design, user experience, and user interface design. Human factors research employs methods and approaches from these and other knowledge disciplines to study human behavior and generate data relevant to previously stated goals. In studying and sharing learning on the design of equipment, devices, and processes that fit the human body and its cognitive abilities, the two terms, "human factors" and "ergonomics", are essentially synonymous as to their referent and meaning in current literature.

The International Ergonomics Association defines ergonomics or human factors as follows:
Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design to optimize human well-being and overall system performance.

Human factors engineering is relevant in the design of such things as safe furniture and easy-to-use interfaces to machines and equipment. Proper ergonomic design is necessary to prevent repetitive strain injuries and other musculoskeletal disorders, which can develop over time and can lead to long-term disability. Human factors and ergonomics are concerned with the "fit" between the user, equipment, and environment or "fitting a job to a person" or "fitting the task to the man". It accounts for the user's capabilities and limitations in seeking to ensure that tasks, functions, information, and the environment suit that user.

To assess the fit between a person and the used technology, human factors specialists or ergonomists consider the job (activity) being done and the demands on the user; the equipment used (its size, shape, and how appropriate it is for the task), and the information used (how it is presented, accessed, and changed). Ergonomics draws on many disciplines in its study of humans and their environments, including anthropometry, biomechanics, mechanical engineering, industrial engineering, industrial design, information design, kinesiology, physiology, cognitive psychology, industrial and organizational psychology, and space psychology.

According to the International Ergonomics Association, within the discipline of ergonomics there exist domains of specialization. These comprise three main fields of research: physical, cognitive, and organizational ergonomics.

There are many specializations within these broad categories. Specializations in the field of physical ergonomics may include visual ergonomics. Specializations within the field of cognitive ergonomics may include usability, human–computer interaction, and user experience engineering.

Some specializations may cut across these domains: *Environmental ergonomics* is concerned with human interaction with the environment as characterized by climate, temperature, pressure, vibration, light. The emerging field of human factors in highway safety uses human factor principles to understand the actions and capabilities of road users – car and truck drivers, pedestrians, cyclists, etc. – and use this knowledge to design roads and streets to reduce traffic collisions. Driver error is listed as a contributing factor in 44% of fatal collisions in the United States, so a topic of particular interest is how road users gather and process information about the road and its environment, and how to assist them to make the appropriate decision. New terms are being generated all the time. For instance, "user trial engineer" may refer to a human factors engineering professional who specializes in user trials. Although the names change, human factors professionals apply an understanding of human factors to the design of equipment, systems and working methods to improve comfort, health, safety, and productivity.

Physical ergonomics
Physical ergonomics: the science of designing user interaction with equipment and workplaces to fit the user. Generally acceptable weights and positions during manual handling of loads Physical ergonomics is concerned with human anatomy, and some of the anthropometric, physiological, and biomechanical characteristics as they relate to physical activity. Physical ergonomic principles have been widely used in

the design of both consumer and industrial products for optimizing performance and to preventing / treating work-related disorders by reducing the mechanisms behind mechanically induced acute and chronic musculoskeletal injuries / disorders. Risk factors such as localized mechanical pressures, force and posture in a sedentary office environment lead to injuries attributed to an occupational environment. Physical ergonomics is important to those diagnosed with physiological ailments or disorders such as arthritis (both chronic and temporary) or carpal tunnel syndrome. Pressure that is insignificant or imperceptible to those unaffected by these disorders may be very painful, or render a device unusable, for those who are. Many ergonomically designed products are also used or recommended to treat or prevent such disorders, and to treat pressure-related chronic pain.

One of the most prevalent types of work-related injuries is musculoskeletal disorder. Work-related musculoskeletal disorders (WRMDs) result in persistent pain, loss of functional capacity and work disability, but their initial diagnosis is difficult because they are mainly based on complaints of pain and other symptoms. Every year, 1.8 million U.S. workers experience WRMDs and nearly 600,000 of the injuries are serious enough to cause workers to miss work. Certain jobs or work conditions cause a higher rate of worker complaints of undue strain, localized fatigue, discomfort, or pain that does not go away after overnight rest. These types of jobs are often those involving activities such as repetitive and forceful exertions; frequent, heavy, or overhead lifts; awkward work positions; or use of vibrating equipment. The Occupational Safety and Health Administration (OSHA) has found substantial evidence that ergonomics programs can cut workers' compensation costs, increase productivity and decrease employee turnover. Mitigation solutions can include both short term and long-term solutions. Short and long-term solutions involve awareness training, positioning of the body, furniture and equipment and ergonomic exercises. Sit-stand stations and computer accessories that provide soft surfaces for resting the palm as well as split keyboards are recommended. Additionally, resources within the HR department can be allocated to provide assessments to employees to ensure the above criteria are met. Therefore, it is important to gather data to identify jobs or work conditions that are most problematic, using sources such as injury and illness logs, medical records, and job analyses.

Innovative workstations that are being tested include sit-stand desks, height adjustable desk, treadmill desks, pedal devices and cycle ergometers. In multiple studies these new workstations resulted in decreased waist circumference and improved psychological well-being. However a significant number of additional studies have seen no marked improvement in health outcomes.

With the emergence of collaborative robots and smart systems in manufacturing environments, the artificial agents can be used to improve physical ergonomics of human co-workers. For example, during human–robot collaboration the robot can use biomechanical models of the human co-worker in order to adjust the working configuration and account for various ergonomic metrics, such as human posture, joint torques, arm manipulability and muscle fatigue. The ergonomic suitability of the shared workspace with respect to these metrics can also be displayed to the human with workspace maps through visual interfaces.

Cognitive ergonomics

Cognitive ergonomics is concerned with mental processes, such as perception, emotion, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system.[5][27] (Relevant topics include mental workload, decision-making, skilled performance, human reliability, work stress and training as these may relate to human–system and human–computer interaction design.) Epidemiological studies show a correlation between the time one spends sedentary and their cognitive function such as lowered mood and depression.

Organizational ergonomics and safety culture

Organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes. Relevant topics include human communication successes or failures in adaptation to other system elements, crew resource management, work design, work systems, design of working times, teamwork, participatory ergonomics, community ergonomics, cooperative work, new work programs, virtual organizations, remote work, and quality management. Safety culture within an organization of engineers and technicians has been linked to engineering safety with cultural dimensions including power distance and ambiguity tolerance. Low power distance has been shown to be more conducive to a safety culture. Organizations with cultures of concealment or lack of empathy have been shown to have poor safety culture.

Irrigation

Irrigation (also referred to as **watering of plants**) is the practice of applying controlled amounts of water to land to help grow crops, landscape plants, and lawns. Irrigation has been a key aspect of agriculture for over 5,000 years and has been developed by many cultures around the world. Irrigation helps to grow crops, maintain landscapes, and revegetate disturbed soils in dry areas and during times of below-average rainfall. In addition to these uses, irrigation is also employed to protect crops from frost, suppress weed growth in grain fields, and prevent soil consolidation. It is also used to cool livestock, reduce dust, dispose of sewage, and support mining operations. Drainage, which involves the removal of surface and sub-surface water from a given location, is often studied in conjunction with irrigation.

There are several methods of irrigation that differ in how water is supplied to plants. Surface irrigation, also known as gravity irrigation, is the oldest form of irrigation and has been in use for thousands of years. In sprinkler irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure water devices. Micro-irrigation is a system that distributes water under low pressure through a piped network and applies it as a small discharge to each plant. Micro-irrigation uses less pressure and water flow than sprinkler irrigation. Drip irrigation delivers water directly to the root zone of plants. Subirrigation has been used in field crops in areas with high water tables for many years. It involves artificially raising the water table to moisten the soil below the root zone of plants.

Irrigation water can come from groundwater (extracted from springs or by using wells), from surface water (withdrawn from rivers, lakes or reservoirs) or from non-conventional sources like treated wastewater, desalinated water, drainage water, or fog collection. Irrigation can be supplementary to rainfall, which is common in many parts of the world as rainfed agriculture, or it can be full irrigation, where crops rarely rely on any contribution from rainfall. Full irrigation is less common and only occurs in arid landscapes with very low rainfall or when crops are grown in semi-arid areas outside of rainy seasons.

The environmental effects of irrigation relate to the changes in quantity and quality of soil and water as a result of irrigation and the subsequent effects on natural and social conditions in river basins and downstream of an irrigation scheme. The effects stem from the altered hydrological conditions caused by the installation and operation of the irrigation scheme. Amongst some of these problems is depletion of underground aquifers through overdrafting. Soil can be over-irrigated due to poor distribution uniformity or management wastes water, chemicals, and may lead to water pollution. Over-irrigation can cause deep drainage from rising water tables that can lead to problems of irrigation salinity requiring watertable control by some form of subsurface land drainage.

Extent

In 2000, the total fertile land was 2,788,000 km^2 (689 million acres) and it was equipped with irrigation infrastructure worldwide. About 68% of this area is in Asia, 17% in the Americas, 9% in Europe, 5% in Africa and 1% in Oceania. The largest contiguous areas of high irrigation density are found in Northern and Eastern India and Pakistan along the Ganges and Indus rivers; in the Hai He, Huang He and Yangtze basins in China; along the Nile river in Egypt and Sudan; and in the Mississippi-Missouri river basin, the Southern Great Plains, and in parts of California in the United States. Smaller irrigation areas are spread across almost all populated parts of the world.

By 2012, the area of irrigated land had increased to an estimated total of 3,242,917 km^2 (801 million acres), which is nearly the size of India. The irrigation of 20% of farming land accounts for the production of 40% of food production.

Global overview

The scale of irrigation increased dramatically over the 20th century. In 1800, 8 million hectares globally were irrigated, in 1950, 94 million hectares, and in 1990, 235 million hectares. By 1990, 30% of the global food production came from irrigated land. Irrigation techniques across the globe includes canals redirecting surface water, groundwater pumping, and diverting water from dams. National governments lead most irrigation schemes within their borders, but private investors and other nations, especially the United States, China, and European countries like the United Kingdom, also fund and organize some schemes within other nations.

By 2021 the global land area equipped for irrigation reached 352 million ha, an increase of 22% from the 289 million ha of 2000 and more than twice the 1960s land area equipped for irrigation. The vast majority is located in Asia (70%), where irrigation was a key component of the green revolution; the Americas account for 16% and Europe for 8% of the world total. India (76 million ha) and China (75 million ha) have the largest equipped area for irrigation, far ahead of the United States of America (27 million ha). China and India also have the largest net gains in equipped area between 2000 and 2020 (+21 million ha for China and +15 million ha for India). All the regions saw increases in the area equipped for irrigation, with Africa growing the fastest (+29%), followed by Asia (+25%), Oceania (+24%), the Americas (+19%) and Europe (+2%).

Irrigation enables the production of more crops, especially commodity crops in areas which otherwise could not support them. Countries frequently invested in irrigation to increase wheat, rice, or cotton production, often with the overarching goal of increasing self-sufficiency.

Groundwater and surface water

Irrigation water can come from groundwater (extracted from springs or by using wells), from surface water (withdrawn from rivers, lakes or reservoirs) or from non-conventional sources like treated wastewater, desalinated water, drainage water, or fog collection.

While floodwater harvesting belongs to the accepted irrigation methods, rainwater harvesting is usually not considered as a form of irrigation. Rainwater harvesting is the collection of runoff water from roofs or unused land and the concentration of this.

Treated or untreated wastewater

Irrigation with recycled municipal wastewater can also serve to fertilize plants if it contains nutrients, such as nitrogen, phosphorus and potassium. There are benefits of using recycled water for irrigation, including the lower cost compared to some other sources and consistency of supply regardless of season, climatic conditions and associated water restrictions. When reclaimed water is used for irrigation in agriculture, the nutrient (nitrogen and phosphorus) content of the treated wastewater has the benefit of acting as a fertilizer. This can make the reuse of excreta contained in sewage attractive.

The irrigation water can be used in different ways on different crops, such as for food crops to be eaten raw or for crops which are intended for human consumption to be eaten raw or unprocessed. For processed food crops: crops which are intended for human consumption not to be eaten raw but after food processing (i.e. cooked, industrially processed). It can also be used on crops which are not intended for human consumption (e.g. pastures, forage, fiber, ornamental, seed, forest and turf crops).

In developing countries, agriculture is increasingly using untreated municipal wastewater for irrigation – often in an unsafe manner. Cities provide lucrative markets for fresh produce, so they are attractive to farmers. However, because agriculture has to compete for increasingly scarce water resources with industry and municipal users, there is often no alternative for farmers but to use water polluted with urban waste directly to water their crops.

There can be significant health hazards related to using untreated wastewater in agriculture. Municipal wastewater can contain a mixture of chemical and biological pollutants. In low-income countries, there are often high levels of pathogens from excreta. In emerging nations, where industrial development is outpacing environmental regulation, there are increasing risks from inorganic and organic chemicals. The World Health Organization developed guidelines for safe use of wastewater in 2006, advocating a ‘multiple-barrier' approach wastewater use, for example by encouraging farmers to adopt various risk-reducing behaviors. These include ceasing irrigation a few days before harvesting to allow pathogens to die off in the sunlight; applying water carefully so it does not contaminate leaves likely to be eaten raw; cleaning vegetables with disinfectant; or allowing fecal sludge used in farming to dry before being used as a human manure.

Drawbacks or risks often mentioned include the content of potentially harmful substances such as bacteria, heavy metals, or organic pollutants (including pharmaceuticals, personal care products and pesticides). Irrigation with wastewater can have both positive and negative effects on soil and plants, depending on the composition of the wastewater and on the soil or plant characteristics.

Other sources

Irrigation water can also come from non-conventional sources like treated wastewater, desalinated water, drainage water, or fog collection.

In countries where humid air sweeps through at night, water can be obtained by condensation onto cold surfaces. This is practiced in the vineyards at Lanzarote using stones to condense water. Fog collectors are also made of canvas or foil sheets. Using condensate from air conditioning units as a water source is also becoming more popular in large urban areas.

As of November 2019 a Glasgow-based startup has helped a farmer in Scotland to establish edible saltmarsh crops irrigated with sea water. An acre of previously marginal land has been put under cultivation to grow samphire, sea blite, and sea aster; these plants yield a higher profit than potatoes. The land is flood irrigated twice a day to simulate tidal flooding; the water is pumped from the sea using wind power. Additional benefits are soil remediation and carbon sequestration.

Competition for water resources

Until the 1960s, there were fewer than half the number of people on the planet as of 2024. People were not as wealthy as today, consumed fewer calories and ate less meat, so less water was needed to produce their food. They required a third of the volume of water humans presently take from rivers. Today, the competition for water resources is much more intense, because there are now more than seven billion people on the planet, increasing the likelihood of overconsumption of food produced by water-thirsty animal agriculture and intensive farming practices. This creates increasing competition for water from industry, urbanisation and biofuel crops. Farmers will have to strive to increase productivity to meet growing demands for food, while industry and cities find ways to use water more efficiently.

Successful agriculture is dependent upon farmers having sufficient access to water. However, water scarcity is already a critical constraint to farming in many parts of the world.

There are several methods of irrigation. They vary in how the water is supplied to the plants. The goal is to apply the water to the plants as uniformly as possible, so that each plant has the amount of water it needs, neither too much nor too little. Irrigation can also be understood whether it is *supplementary* to rainfall as happens in many parts of the world, or whether it is '*full* irrigation' whereby crops rarely depend on any contribution from rainfall. Full irrigation is less common and only happens in arid landscapes experiencing very low rainfall or when crops are grown in semi-arid areas outside of any rainy seasons.

Surface irrigation

Basin flood irrigation of wheat

Surface irrigation, also known as gravity irrigation, is the oldest form of irrigation and has been in use for thousands of years. In *surface* (*furrow, flood,* or *level basin*) irrigation systems, water moves across the surface of agricultural lands, in order to wet it and infiltrate into the soil. Water moves by following gravity or the slope of the land. Surface irrigation can be subdivided into furrow, *border strip or basin irrigation*. It is often called *flood irrigation* when the irrigation results in flooding or near flooding of the cultivated land. Historically, surface irrigation is the most common method of irrigating agricultural land across most parts of the world. The water application efficiency of surface irrigation is typically lower than other forms of irrigation, due in part to the lack of control of applied depths. Surface irrigation involves a significantly lower capital cost and energy requirement than pressurised irrigation systems. Hence it is often the irrigation choice for developing nations, for low value crops and for large fields. Where water levels from the irrigation source permit, the levels are controlled by dikes (levees), usually plugged by soil. This is often seen in terraced rice fields (rice paddies), where the method is used to flood or control the level of water in each distinct field. In some cases, the water is pumped, or lifted by human or animal power to the level of the land.

Surface irrigation is even used to water urban gardens in certain areas, for example, in and around Phoenix, Arizona. The irrigated area is surrounded by a berm and the water is delivered according to a schedule set by a local irrigation district.

A special form of irrigation using surface water is spate irrigation, also called floodwater harvesting. In case of a flood (spate), water is diverted to normally dry river beds (wadis) using a network of dams, gates and channels and spread over large areas. The moisture stored in the soil will be used thereafter to grow crops. Spate irrigation areas are in particular located in semi-arid or arid, mountainous regions.

Micro-irrigation

Micro-irrigation, sometimes called **localized irrigation**, **low volume irrigation**, or **trickle irrigation** is a system where water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it. Traditional drip irrigation use individual emitters, subsurface drip irrigation (SDI), micro-spray or micro-sprinklers, and mini-bubbler irrigation all belong to this category of irrigation methods.

Drip irrigation

Drip irrigation, also known as microirrigation or trickle irrigation, functions as its name suggests. In this system, water is delivered at or near the root zone of plants, one drop at a time. This method can be the most water-efficient method of irrigation, if managed properly; evaporation and runoff are minimized. The field water efficiency of drip irrigation is typically in the range of 80 to 90% when managed correctly. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation, and is also the means of delivery of fertilizer. The process is known as fertigation.

Deep percolation, where water moves below the root zone, can occur if a drip system is operated for too long or if the delivery rate is too high. Drip irrigation methods range from very high-tech and computerized to low-tech and labor-intensive. Lower water pressures are usually needed than for most other types of systems, with the exception of low-energy center pivot systems and surface irrigation systems, and the system can be designed for uniformity throughout a field or for precise water delivery to individual plants in a landscape containing a mix of plant species. Although it is difficult to regulate pressure on steep slopes, pressure compensating emitters are available, so the field does not have to be level. High-tech solutions involve precisely calibrated emitters located along lines of tubing that extend from a computerized set of valves.

Sprinkler irrigation

In *sprinkler* or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. A system using sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a *solid-set* irrigation system. Higher pressure sprinklers that rotate are called *rotors* and are driven by a ball drive, gear drive, or impact mechanism. Rotors can be designed to rotate in a full or partial circle. Guns are similar to rotors, except that they generally operate at very high pressures of 275 to 900 kPa (40 to 130 psi) and flows of 3 to 76 L/s (50 to 1200 US gal/min), usually with nozzle diameters in the range of 10 to 50 mm (0.5 to 1.9 in). Guns are used not only for irrigation, but also for industrial applications such as dust suppression and logging.

Sprinklers can also be mounted on moving platforms connected to the water source by a hose. Automatically moving wheeled systems known as *traveling sprinklers* may irrigate areas such as small farms, sports fields, parks, pastures, and cemeteries unattended. Most of these use a length of polyethylene tubing wound on a steel drum. As the tubing is wound on the drum powered by the irrigation water or a small gas engine, the sprinkler is pulled across the field. When the sprinkler arrives back at the reel the system shuts off. This type of system is known to most people as a "waterreel" traveling irrigation sprinkler and they are used extensively for dust suppression, irrigation, and land application of waste water.

Other travelers use a flat rubber hose that is dragged along behind while the sprinkler platform is pulled by a cable.

Center pivot

Center pivot irrigation is a form of sprinkler irrigation utilising several segments of pipe (usually galvanized steel or aluminium) joined and supported by trusses, mounted on wheeled towers with sprinklers positioned along its length. The system moves in a circular pattern and is fed with water from the pivot point at the center of the arc. These systems are found and used in all parts of the world and allow irrigation of all types of terrain. Newer systems have drop sprinkler heads as shown in the image that follows.

As of 2017 most center pivot systems have drops hanging from a U-shaped pipe attached at the top of the pipe with sprinkler heads that are positioned a few feet (at most) above the crop, thus limiting evaporative losses. Drops can also be used with drag hoses or bubblers that deposit the water directly on the ground between crops. Crops are often planted in a circle to conform to the center pivot. This type of system is known as LEPA (Low Energy Precision Application). Originally, most center pivots were water-powered. These were replaced by hydraulic systems (*T-L Irrigation*) and electric-motor-driven systems (Reinke, Valley, Zimmatic). Many modern pivots feature GPS devices.

Irrigation by lateral move (side roll, wheel line, wheelmove)

A series of pipes, each with a wheel of about 1.5 m diameter permanently affixed to its midpoint, and sprinklers along its length, are coupled together. Water is supplied at one end using a large hose. After sufficient irrigation has been applied to one strip of the field, the hose is removed, the water drained from the system, and the assembly rolled either by hand or with a purpose-built mechanism, so that the sprinklers are moved to a different position across the field. The hose is reconnected. The process is repeated in a pattern until the whole field has been irrigated.

This system is less expensive to install than a center pivot, but much more labor-intensive to operate – it does not travel automatically across the field: it applies water in a stationary strip, must be drained, and then rolled to a new strip. Most systems use 100 or 130 mm (4 or 5 inch) diameter aluminum pipe. The pipe doubles both as water transport and as an axle for rotating all the wheels. A drive system (often found near the centre of the wheel line) rotates the clamped-together pipe sections as a single axle, rolling the whole wheel line. Manual adjustment of individual wheel positions may be necessary if the system becomes misaligned.

Wheel line systems are limited in the amount of water they can carry, and limited in the height of crops that can be irrigated. One useful feature of a lateral move system is that it consists of sections that can be easily disconnected, adapting to field shape as the line is moved. They are most often used for small, rectilinear, or oddly-shaped fields, hilly or mountainous regions, or in regions where labor is inexpensive.

Lawn sprinkler systems

A lawn sprinkler system is permanently installed, as opposed to a hose-end sprinkler, which is portable. Sprinkler systems are installed in residential lawns, in commercial landscapes, for churches and schools, in public parks and cemeteries, and on golf courses. Most of the components of these irrigation systems are hidden under ground, since aesthetics are important in a landscape. A typical lawn sprinkler system will consist of one or more zones, limited in size by the capacity of the water source. Each zone will cover a designated portion of the landscape. Sections of the landscape will usually be divided by microclimate, type of plant material, and type of irrigation equipment. A landscape irrigation system may also include zones containing drip irrigation, bubblers, or other types of equipment besides sprinklers.

Although manual systems are still used, most lawn sprinkler systems may be operated automatically using an irrigation controller, sometimes called a clock or timer. Most automatic systems employ electric solenoid valves. Each zone has one or more of these valves that are wired to the controller. When the controller sends power to the valve, the valve opens, allowing water to flow to the sprinklers in that zone.

There are two main types of sprinklers used in lawn irrigation, pop-up spray heads and rotors. Spray heads have a fixed spray pattern, while rotors have one or more streams that rotate. Spray heads are used to cover smaller areas, while rotors are used for larger areas. Golf course rotors are sometimes so large that a single sprinkler is combined with a valve and called a 'valve in head'. When used in a turf area, the sprinklers are installed with the top of the head flush with the ground surface. When the system is pressurized, the head will pop up out of the ground and water the desired area until the valve closes and shuts off that zone. Once there is no more pressure in the lateral line, the sprinkler head will retract back into the ground. In flower beds or shrub areas, sprinklers may be mounted on above ground risers or even taller pop-up sprinklers may be used and installed flush as in a lawn area.

Hose-end sprinklers

Hose-end sprinklers are devices attached to the end of a garden hose, used for watering lawns, gardens, or plants. They come in a variety of designs and styles, allowing you to adjust the water flow, pattern, and range for efficient irrigation. Some common types of hose-end sprinklers include:
Oscillating Sprinklers: These spray water back and forth in a rectangular or square pattern. They are good for covering large, flat areas evenly.

Impact (or Pulsating) Sprinklers: These create a rotating, pulsating spray, which can cover a circular or semi-circular area. They are useful for watering large lawns.
Stationary Sprinklers: These have a fixed spray pattern and are best for smaller areas or gardens.
Rotary Sprinklers: These use spinning arms to distribute water in a circular or semi-circular pattern.
Traveling Sprinklers: These move along the hose path on their own, watering as they go, ideal for covering long, narrow spaces.
Each type offers different advantages based on garden size and shape, water pressure, and specific watering needs.

Subirrigation

Subirrigation has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone. Often those systems are located on permanent grasslands in lowlands or river valleys and combined with drainage infrastructure. A system of pumping stations, canals, weirs and gates allows it to increase or decrease the water level in a network of ditches and thereby control the water table.

Subirrigation is also used in the commercial greenhouse production, usually for potted plants. Water is delivered from below, absorbed by upwards, and the excess collected for recycling. Typically, a solution of water and nutrients floods a container or flows through a trough for a short period of time, 10–20 minutes, and is then pumped back into a holding tank for reuse. Sub-irrigation in greenhouses requires fairly sophisticated, expensive equipment and management. Advantages are water and nutrient conservation, and labor savings through reduced system maintenance and automation. It is similar in principle and action to subsurface basin irrigation.

Another type of subirrigation is the self-watering container, also known as a sub-irrigated planter. This consists of a planter suspended over a reservoir with some type of wicking material such as a polyester rope. The water is drawn up the wick through capillary action. A similar technique is the wicking bed; this too uses capillary action.

Negative impacts frequently accompany extensive irrigation. Some projects which diverted surface water for irrigation dried up the water sources, which led to a more extreme regional climate. Projects that relied on groundwater and pumped too much from underground aquifers created subsidence and salinization. Salinization of irrigation water in turn damaged the crops and seeped into drinking water. Pests and pathogens also thrived in the irrigation canals or ponds full of still water, which created regional outbreaks of diseases like malaria and schistosomiasis. Governments also used irrigation schemes to encourage migration, especially of more desirable populations into an area. Additionally, some of these large nationwide schemes failed to pay off at all, costing more than any benefit gained from increased crop yields.

Overdrafting (depletion) of underground aquifers: In the mid-20th century, the advent of diesel and electric motors led to systems that could pump groundwater out of major aquifers faster than drainage basins could refill them. This can lead to permanent loss of aquifer capacity, decreased water quality, ground subsidence, and other problems. The future of food production in such areas as the North China Plain, the Punjab region in India and Pakistan, and the Great Plains of the US is threatened by this phenomenon.

The environmental impact of irrigation relates to the changes in quantity and quality of soil and water as a result of irrigation and the subsequent effects on natural and social conditions in river basins and downstream of an irrigation scheme. The effects stem from the altered hydrological conditions caused by the installation and operation of the irrigation scheme.

Amongst some of these problems is the depletion of underground aquifers through overdrafting. Soil can be over-irrigated due to poor distribution uniformity or management wastes water, chemicals, and may lead to water pollution. Over-irrigation can cause deep drainage from rising water tables that can lead to problems of irrigation salinity requiring watertable control by some form of subsurface land drainage. However, if the soil is under-irrigated, it gives poor soil salinity control, which leads to increased soil salinity with the consequent buildup of toxic salts on the soil surface in areas with high evaporation. This requires either leaching to remove these salts or a method of drainage to carry the salts away. Irrigation with saline or high-sodium water may damage soil structure owing to the formation of alkaline soil.

Technical challenges

Irrigation schemes involve solving numerous engineering and economic problems while minimizing negative environmental consequences. Such problems include:

- Ground subsidence (e.g. New Orleans, Louisiana)
- Underirrigation or irrigation giving only just enough water for the plant (e.g. in drip line irrigation) gives poor soil salinity control which leads to increased soil salinity with consequent buildup of toxic salts on soil surface in areas with high evaporation. This requires either leaching to remove these salts and a method of drainage to carry the salts away. When using drip lines, the leaching is best done regularly at certain intervals (with only a slight excess of water), so that the salt is flushed back under the plant's roots.
- Overirrigation because of poor distribution uniformity or management wastes water, chemicals, and may lead to water pollution.
- Deep drainage (from over-irrigation) may result in rising water tables which in some instances will lead to problems of irrigation salinity requiring watertable control by some form of subsurface land drainage. For example in Australia, over-abstraction of fresh water for intensive irrigation activities has caused 33% of the land area to be at risk of salination.
- Drainage front instability, also known as viscous fingering, where an unstable drainage front results in a pattern of fingers and viscous entrapped saturated zones.
- Irrigation with saline or high-sodium water may damage soil structure owing to the formation of alkaline soil.
- Clogging of filters: algae can clog filters, drip installations, and nozzles. Chlorination, algaecide, UV and ultrasonic methods can be used for algae control in irrigation systems.
- Complications in accurately measuring irrigation performance which changes over time and space using measures such as productivity, efficiency, equity and adequacy.
- Macro-irrigation, typical in intensive agriculture, where also are used agrochemicals, often causes eutrophication.

Precision agriculture (**PA**) is a farming management strategy based on observing, measuring and responding to temporal and spatial variability to improve agricultural production sustainability. It is used in both crop and livestock production. Precision agriculture often employs technologies to automate agricultural operations, improving their diagnosis, decision-making or performing. The goal of precision agriculture research is to define a decision support system for whole farm management with the goal of optimizing returns on inputs while preserving resources.
Among these many approaches is a phytogeomorphological approach which ties multi-year crop growth stability/characteristics to topological terrain attributes. The interest in the phytogeomorphological approach stems from the fact that the geomorphology component typically dictates the hydrology of the farm field.

The practice of precision agriculture has been enabled by the advent of GPS and GNSS. The farmer's and/or researcher's ability to locate their precise position in a field allows for the creation of maps of the spatial variability of as many variables as can be measured (e.g. crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K, and others).[10] Similar data is collected by sensor arrays mounted on GPS-equipped combine harvesters. These arrays consist of real-time sensors that measure everything from chlorophyll levels to plant water status, along with multispectral imagery. This data is used in conjunction with satellite imagery by variable rate technology (VRT) including seeders, sprayers, etc. to optimally distribute resources. However, recent technological advances have enabled the use of real-time sensors directly in soil, which can wirelessly transmit data without the need of human presence.

Precision agriculture has also been enabled by unmanned aerial vehicles that are relatively inexpensive and can be operated by novice pilots. These agricultural drones can be equipped with multispectral or RGB cameras to capture many images of a field that can be stitched together using photogrammetric methods to create orthophotos. These multispectral images contain multiple values per pixel in addition to the traditional red, green blue values such as near infrared and red-edge spectrum values used to process and analyze vegetative indexes such as NDVI maps. These drones are capable of capturing imagery and providing additional geographical references such as elevation, which allows software to perform map algebra functions to build precise topography maps. These topographic maps can be used to correlate crop health with topography, the results of which can be used to optimize crop inputs such as water, fertilizer or chemicals such as herbicides and growth regulators through variable rate applications.

History

Precision agriculture is a key component of the third wave of modern agricultural revolutions. The first agricultural revolution was the increase of mechanized agriculture, from 1900 to 1930. Each farmer produced enough food to feed about 26 people during this time. The 1960s prompted the Green Revolution with new methods of genetic modification, which led to each farmer feeding about 156 people. It is expected that by 2050, the global population will reach about 9.6 billion, and food production must effectively double from current levels in order to feed every mouth. With new technological advancements in the agricultural revolution of precision farming, each farmer will be able to feed 265 people on the same acreage.

Overview

The first wave of the precision agricultural revolution came in the forms of satellite and aerial imagery, weather prediction, variable rate fertilizer application, and crop health indicators. The second wave aggregates the machine data for even more precise planting, topographical mapping, and soil data.
Precision agriculture aims to optimize field-level management with regard to:

- crop science: by matching farming practices more closely to crop needs (e.g. fertilizer inputs);
- environmental protection: by reducing environmental risks and footprint of farming (e.g. limiting leaching of nitrogen);
- economics: by boosting competitiveness through more efficient practices (e.g. improved management of fertilizer usage and other inputs).

Precision agriculture also provides farmers with a wealth of information to:

- build up a record of their farm
- improve decision-making
- foster greater traceability
- enhance marketing of farm products
- improve lease arrangements and relationship with landlords
- enhance the inherent quality of farm products (e.g. protein level in bread-flour wheat)

Prescriptive planting

Prescriptive planting is a type of farming system that delivers data-driven planting advice that can determine variable planting rates to accommodate varying conditions across a single field, in order to maximize yield. It has been described as "Big Data on the farm." Monsanto, DuPont and others are launching this technology in the US.

Principles

Precision agriculture uses many tools but here are some of the basics: tractors, combines, sprayers, planters, diggers, which are all considered auto-guidance systems. The small devices on the equipment that uses GIS (geographic information system) are what makes precision agriculture what it is. You can think of the GIS system as the “brain.” To be able to use precision agriculture the equipment needs to be wired with the right technology and data systems. More tools include Variable rate technology (VRT), Global positioning system and Geographical information system, Grid sampling, and remote sensors.

Geolocating

Geolocating a field enables the farmer to overlay information gathered from analysis of soils and residual nitrogen, and information on previous crops and soil resistivity. Geolocation is done in two ways

- The field is delineated using an in-vehicle GPS receiver as the farmer drives a tractor around the field.
- The field is delineated on a basemap derived from aerial or satellite imagery. The base images must have the right level of resolution and geometric quality to ensure that geolocation is sufficiently accurate.

Variables

Intra and inter-field variability may result from a number of factors. These include climatic conditions (hail, drought, rain, etc.), soils (texture, depth, nitrogen levels), cropping practices (no-till farming), weeds and disease. Permanent indicators—chiefly soil indicators—provide farmers with information about the main environmental constants. Point indicators allow them to track a crop's status, i.e., to see whether diseases are developing, if the crop is suffering from water stress, nitrogen stress, or lodging, whether it has been damaged by ice and so on. This information may come from weather stations and other sensors (soil electrical resistivity, detection with the naked eye, satellite imagery, etc.). Soil resistivity measurements combined with soil analysis make it possible to measure moisture content. Soil resistivity is also a relatively simple and cheap measurement.

Strategies

Using soil maps, farmers can pursue two strategies to adjust field inputs:

- Predictive approach: based on analysis of static indicators (soil, resistivity, field history, etc.) during the crop cycle.
- Control approach: information from static indicators is regularly updated during the crop cycle by:
- sampling: weighing biomass, measuring leaf chlorophyll content, weighing fruit, etc.
- remote sensing: measuring parameters like temperature (air/soil), humidity (air/soil/leaf), wind or stem diameter is possible thanks to Wireless Sensor Networks and Internet of things (IoT)
- proxy-detection: in-vehicle sensors measure leaf status; this requires the farmer to drive around the entire field.
- aerial or satellite remote sensing: multispectral imagery is acquired and processed to derive maps of crop biophysical parameters, including indicators of disease. Airborne instruments are able to measure the amount of plant cover and to distinguish between crops and weeds.

Decisions may be based on decision-support models (crop simulation models and recommendation models) based on big data, but in the final analysis it is up to the farmer to decide in terms of business value and impacts on the environment- a role being takenover by artificial intelligence (AI) systems based on machine learning and artificial neural networks.

It is important to realize why PA technology is or is not adopted, "for PA technology adoption to occur the farmer has to perceive the technology as useful and easy to use. It might be insufficient to have positive outside data on the economic benefits of PA technology as perceptions of farmers have to reflect these economic considerations."

Implementing practices

New information and communication technologies make field level crop management more operational and easier to achieve for farmers. Application of crop management decisions calls for agricultural equipment that supports variable-rate technology (VRT), for example varying seed density along with variable-rate application (VRA) of nitrogen and phytosanitary products.[28]

Precision agriculture uses technology on agricultural equipment (e.g. tractors, sprayers, harvesters, etc.):

- positioning system (e.g. GPS receivers that use satellite signals to precisely determine a position on the globe);
- geographic information systems (GIS), i.e., software that makes sense of all the available data;
- variable-rate farming equipment (seeder, spreader).

Usage around the world

The concept of precision agriculture first emerged in the United States in the early 1980s. In 1985, researchers at the University of Minnesota varied lime inputs in crop fields. It was also at this time that the practice of grid sampling appeared (applying a fixed grid of one sample per hectare). Towards the end of the 1980s, this technique was used to derive the first input recommendation maps for fertilizers and pH corrections. The use of yield sensors developed from new technologies, combined with the advent of GPS receivers, has been gaining ground ever since. Today, such systems cover several million hectares.

In the American Midwest (US), it is associated not with sustainable agriculture but with mainstream farmers who are trying to maximize profits by spending money only in areas that require fertilizer. This practice allows the farmer to vary the rate of fertilizer across the field according to the need identified by GPS guided Grid or Zone Sampling. Fertilizer that would have been spread in areas that don't need it can be placed in areas that do, thereby optimizing its use.

Around the world, precision agriculture developed at a varying pace. Precursor nations were the United States, Canada and Australia. In Europe, the United Kingdom was the first to go down this path, followed closely by France, where it first appeared in 1997–1998. In Latin America the leading country is Argentina, where it was introduced in the middle 1990s with the support of the National Agricultural Technology Institute. Brazil established a state-owned enterprise, Embrapa, to research and develop sustainable agriculture. The development of GPS and variable-rate spreading techniques helped to anchor precision farming management practices. Today, less than 10% of France's farmers are equipped with variable-rate systems. Uptake of GPS is more widespread, but this hasn't stopped them using precision agriculture services, which supplies field-level recommendation maps.

While digital technologies can transform the landscape of agricultural machinery, making mechanization both more precise and more accessible, non-mechanized production is still dominant in many low- and middle-income countries, especially in sub-Saharan Africa. Research on precision agriculture for non-mechanized production is increasing and so is its adoption. Examples include the AgroCares hand-held soil scanner, uncrewed aerial vehicle (UAV) services (also known as drones), and GNSS to map field boundaries and establish land tenure. However, it is not clear how many agricultural producers actually use digital technologies.

Precision livestock farming supports farmers in real-time by continuously monitoring and controlling animal productivity, environmental impacts, and health and welfare parameters. Sensors attached to animals or to barn equipment operate climate control and monitor animals' health status, movement and needs. For example, cows can be tagged with the electronic identification (EID) that allows a milking robot to access a database of udder coordinates for specific cows. Global automatic milking system sales have increased over recent years, but adoption is likely mostly in Northern Europe, and likely almost absent in low- and middle-income countries. Automated feeding machines for both cows and poultry also exist, but data and evidence regarding their adoption trends and drivers is likewise scarce.

The economic and environmental benefits of precision agriculture have also been confirmed in China, but China is lagging behind countries such as Europe and the United States because the Chinese agricultural system is characterized by small-scale family-run farms, which makes the adoption rate of precision agriculture lower than other countries. Therefore, China is trying to better introduce precision agriculture technology into its own country and reduce some risks, paving the way for China's technology to develop precision agriculture in the future.

Economic and environmental impacts

Precision agriculture, as the name implies, means application of precise and correct amount of inputs like water, fertilizer, pesticides etc. at the correct time to the crop for increasing its productivity and maximizing its yields. Precision agriculture management practices can significantly reduce the amount of nutrient and other crop inputs used while boosting yields. Farmers thus obtain a return on their investment by saving on water, pesticide, and fertilizer costs.

The second, larger-scale benefit of targeting inputs concerns environmental impacts. Applying the right amount of chemicals in the right place and at the right time benefits crops, soils and groundwater, and thus the entire crop cycle. Consequently, precision agriculture has become a cornerstone of sustainable agriculture, since it respects crops, soils and farmers. Sustainable agriculture seeks to assure a continued supply of food within the ecological, economic and social limits required to sustain production in the long term. A 2013 article tried to show that precision agriculture can help farmers in developing countries like India.

Precision agriculture reduces the pressure of agriculture on the environment by increasing the efficiency of machinery and putting it into use. For example, the use of remote management devices such as GPS reduces fuel consumption for agriculture, while variable rate application of nutrients or pesticides can potentially reduce the use of these inputs, thereby saving costs and reducing harmful runoff into the waterways.
GPS also reduces the amount of compaction to the ground by following previously made guidance lines. This will also allow for less time in the field and reduce the environmental impact of the equipment and chemicals.
Precision agriculture produces large quantities of varied sensing data which creates an opportunity to adapt and reuse such data for archaeology and heritage work, enhancing understanding of archaeology in contemporary agricultural landscapes.

Emerging technologies
Precision agriculture is an application of breakthrough digital farming technologies. Over $4.6 billion has been invested in agriculture tech companies—sometimes called agtech.

Robots
Self-steering tractors have existed for some time now, as John Deere equipment works like a plane on autopilot. The tractor does most of the work, with the farmer stepping in for emergencies. Technology is advancing towards driverless machinery programmed by GPS to spread fertilizer or plow land. Autonomy of technology is driven by the demanding need of diagnoses, often difficult to accomplish solely by hands-on farmer-operated machinery. In many instances of high rates of production, manual adjustments cannot sustain. Other innovations include, partly solar powered, machines/robots that identify weeds and precisely kill them with a dose of a herbicide or lasers.
Agricultural robots, also known as AgBots, already exist, but advanced harvesting robots are being developed to identify ripe fruits, adjust to their shape and size, and carefully pluck them from branches.

Drones and satellite imagery
Drone and satellite technology are used in precision farming. This often occurs when drones take high quality images while satellites capture the bigger picture. Aerial photography from light aircraft can be combined with data from satellite records to predict future yields based on the current level of field biomass. Aggregated images can create contour maps to track where water flows, determine variable-rate seeding, and create yield maps of areas that were more or less productive.

The Internet of things
The Internet of things is the network of physical objects outfitted with electronics that enable data collection and aggregation. IoT comes into play with the development of sensors and farm-management software. For example, farmers can spectroscopically measure nitrogen, phosphorus, and potassium in liquid manure, which is notoriously inconsistent. They can then scan the ground to see where cows have already urinated and apply fertilizer to only the spots that need it. This cuts fertilizer use by up to 30%. Moisture sensors in the soil determine the best times to remotely water plants. The irrigation systems can be programmed to switch which side of tree trunk they water based on the plant's need and rainfall.
Innovations are not just limited to plants—they can be used for the welfare of animals. Cattle can be outfitted with internal sensors to keep track of stomach acidity and digestive problems. External sensors track movement patterns to determine the cow's health and fitness, sense physical injuries, and identify the optimal times for breeding. All this data from sensors can be aggregated and analyzed to detect trends and patterns.

As another example, monitoring technology can be used to make beekeeping more efficient. Honeybees are of significant economic value and provide a vital service to agriculture by pollinating a variety of crops. Monitoring of a honeybee colony's health via wireless temperature, humidity and CO_2 sensors helps to improve the productivity of bees, and to read early warnings in the data that might threaten the very survival of an entire hive.

Smartphone applications

Smartphone and tablet applications are becoming increasingly popular in precision agriculture. Smartphones come with many useful applications already installed, including the camera, microphone, GPS, and accelerometer. There are also applications made dedicated to various agriculture applications such as field mapping, tracking animals, obtaining weather and crop information, and more. They are easily portable, affordable, and have high computing power.

Machine learning

Machine learning is commonly used in conjunction with drones, robots, and internet of things devices. It allows for the input of data from each of these sources. The computer then processes this information and sends the appropriate actions back to these devices. This allows for robots to deliver the perfect amount of fertilizer or for IoT devices to provide the perfect quantity of water directly to the soil. Machine learning may also provide predictions to farmers at the point of need, such as the contents of plant-available nitrogen in soil, to guide fertilization planning. As more agriculture becomes ever more digital, machine learning will underpin efficient and precise farming with less manual labour.

Vocabulary

1. automobile (motor-car або motor vehicle) - автомобіль
2. nuclear energy - ядерна енергія
3. advancement - успіх розповсюдження
4. efficient (або effective) - ефективний, з високим ККД
5. thermal powered road vehicle - автомобіль з тепловим двигуном
6. benzine (gasoline или petrol) - бензин
7. expansion - розширення
8. versatility - різносторонність застосування
9. partial - частковий
10. Impediment перешкода
11. lorry англ. (або truck амер.) - вантажівка
12. to scale - підніматися
13. steep gradient - крутий схил
14. to stick in mud - загрузнути в багні
15. to negotiate - проходити
16. sharp curve - крутий поворот
17. applicable - який застосовується
18. a vast variety of purposes - різноманітне призначення
19. design - конструкція
20. passenger car - легковий автомобіль
21. host - більшість
22. special service - спеціальне призначення
23. ambulance або emergency medical aid car - машина швидкої допомоги
24. fire-brigade - пожежна команда
25. emergency technical repair machine - автомобіль технічної швидкої допомоги
26. dump-car - самоскид
27. tank зд. автоцистерна
28. liquids of various description - різноманітні рідини
29. milk tank молочна цистерна
30. oil tank цистерна для нафтопродуктів
31. city motor bus - міський автобус
32. interurban bus - автобус міжміського призначення
33. to win a part - вибороти собі місце

34. short (тут) - близький
35. long distance - делекого проходження
36. passenger traffic - пасажирські перевезення
37. to effect - виконувати
38. vehicle - транспортний засіб
39. to win ... in - придбати більше
40. speed - швидкість
41. safety - безпека
42. materially - значно
43. motor-launch - катер
44. are responsible for (тут) - служать для
45. not to be forgotten - потрібно згадати
46. internal-combustion engine - двигун внутрішнього згоряння
47. motor-cycle - мотоцикл
48. to cater for - обслуговування
49. to map out - позначати
50. the automotive industry - машинобудування
51. increased speed - збільшення швидкості
52. enhanced safety - підвищення безпеки
53. driver - водій, шофер
54. streamlining - надання кузову обтічної форми
55. to apply to - звертатися
56. to stand out with particular prominence - особливо виділятися
57. fine lines - красиві лінії
58. finishing - обробка
59. comfortable - комфортний, зручний
60. convenient for servicing - зручний (в обслуговуванні або для обслуговування)
61. dynamic and economic characteristics технічні і економічні показники
62. "Grand Prix" (фр.) - Великий приз
63. exhibition - виставка
64. four-stroke cycle - чотирьохтактний
65. carburettor - карбюратор
66. overhead valves - поверхове розміщення клапанів
67. cylinder bore - діаметр циліндра
68. piston stroke - хід поршня
69. displacement - робочий об'єм
70. compression ratio - ступінь стискання
71. lubricating system - система змазки
72. forced lubrication - змазування під тиском
73. splash lubrication - змазування розбризкуванням
74. fuel system - система живлення, система подачі пального
75. to be equipped - бути оснащеним
76. downdraft carburettor - карбюратор з падаючим потоком
77. air filter - повітряний фільтр
78. muffler - глушник
79. octane number - октанове число
80. cooling system - система охолодження
81. fluid - рідинний
82. closed type - замкнута система (охолодження)
83. forced circulation - примусова циркуляція
84. storage battery - акумулятор
85. V - вольт

86. A-hr - ампер-година
87. ebonite block - ебонітовий корпус
88. generator - генератор
89. W = watt ват
90. current regulator - регулятор сили струму
91. voltage regulator - регулятор напруги
92. ignition - запалення
93. distributor - розподільник запалювання
94. centrifugal - центробіжний,
95. vacuum regulator - вакуумний регулятор
96. hand octane selector - ручний октан-коректор
97. head lights - фари
98. electric engagement of drive - електричне ввімкнення привода
99. lorry (або freight-carrying truck) - вантажівка
100. traditional road-going lorry - звичайна вантажівка
101. long distance heavies - тягач для далеких перевезень
102. short-run operation - робота з коротким пробігом
103. construction site - будівельним майданчик
104. forest - estates лісорозробки
105. to range - варіюватися
106. to-be of paramount importance - мати вірішальне значення
107. to fill the need - відповідати вимогам
108. whenever - в тих випадках коли
109. loading time - час або срок завантаження
110. unloading time - час або строк розвантаження
111. load - вантаж
112. container - контейнер
113. cross-country vehicle - всюдихід
114. trailer - причеп
115. tractor - тягач
116. to be under way - в роботі

References

1. https://en.wikipedia.org/wiki/Agricultural_engineering
2. "Agricultural and Biosystems Engineering | Professional Regulation Commission". *prc.gov.ph*. Retrieved 2021-05-01.
3. Brown, R.H. (ed). *CRC handbook of engineering in agriculture.* Boca Raton, FL.: CRC Press. ISBN 0-8493-3860-3.
4. Field, H. L., Solie, J. B., & Roth, L. O. *Introduction to agricultural engineering technology: a problem solving approach*. New York: Springer. ISBN 0-387-36913-9.
5. Stewart, Robert E. *Seven decades that changed America: a history of the American Society of Agricultural Engineers, 1907-1977*. St. Joseph, Mich.: ASAE. OCLC 5947727
6. The State of Food and Agriculture 2022 – Leveraging agricultural automation for transforming agrifood systems. Rome: Food and Agriculture Organization of the United Nations (FAO). 2022. doi:10.4060/cb9479en. ISBN 978-92-5-136043-9.
7. McBratney, A., Whelan, B., Ancev, T., Future Directions of Precision Agriculture. Precision Agriculture, 6, 7-23.
8. Whelan, B.M., McBratney, A.B., Definition and Interpretation of potential management zones in Australia, In: Proceedings of the 11th Australian Agronomy Conference, Geelong, Victoria.
9. Howard, J.A., Mitchell, C.W., Phytogeomorphology. *Wiley*.

АНГЛІЙСЬКА МОВА

Методичні вказівки до практичних занять для здобувачів освіти другого (магістерського) рівня, спеціальність 208 “Агроінженерія” – ЦНТУ, 2024, – 25 с.