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Revolutionizing Agriculture: The Polyhouse Paradigm and AI Integration in Modern Farming Practices

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ABSTRACT

The global agricultural landscape has undergone a significant transformation, marked by the integration of technological innovations and modern farming practices. This review explores the latest agricultural solutions, examining their applications, limitations, and pivotal role in advancing crop development. The shift from traditional to modern agricultural practices is highlighted, showcasing the dynamic nature of the sector. The paper focuses on cutting-edge approaches like polyhouses, providing controlled environments to protect crops from adverse weather conditions and external threats. Complementary practices such as mulching, chemigation, agroecology, and hydroponics are explored for their unique advantages in achieving sustainable and efficient agricultural systems. A crucial aspect of modernization involves the strategic deployment of sensors for real-time monitoring of vital parameters like soil moisture, nutrient levels, and pest presence. Integrating sensor data with advanced technologies enables farmers to make informed, data-driven decisions, optimizing resource use and minimizing environmental impact. Recent technological advancements, including the Internet of Things (IoT), robotics, and Artificial Intelligence (AI), have revolutionized farming by introducing unprecedented changes in traditional approaches. This paradigm shift emphasizes smart and precision agriculture, leveraging innovative techniques and tools to enhance efficiency, productivity, and sustainability.

KEYWORDS

Artificial Intelligence (AI); Agriculture Shift; Polyhouse; Internet of Things (IoT); Robotics, Sensors

1. INTRODUCTION

To know about the transition from traditional farming practices to AI and IoT-based farming techniques, one should first know about the "Neolithic Revolution." The Neolithic Revolution was one of the most important periods in human history where humans transformed themselves from nomads, hunters, and gatherers to farmers who started growing their own food in 10,000 B.C. Since then, the agricultural sector has flourished, struggled, and made its way as an application of the Internet of Things and Artificial Intelligence [1].

The landscape of agriculture has undergone a radical metamorphosis in recent decades, marked by a dynamic fusion of cutting-edge technologies, innovative methodologies, and sustainable practices. This transformation is propelled by the urgent need to meet escalating global food demands while concurrently addressing pressing issues like climate change, limited resources, and environmental decline pose significant challenges. The evolution of modern farming practices transcends traditional boundaries, embracing a multifaceted approach that integrates scientific advancements with age-old agricultural wisdom. The review explores the amalgamation of technological innovations such as data-driven analytics, precision agriculture, the Internet of Things (IoT), and artificial intelligence (AI), elucidating their pivotal roles in optimizing agricultural processes. Additionally, this paper delves into the burgeoning realm of sustainable farming practices encompassing polyhouse, mulching, chemigation, vertical farming, hydroponics, agroforestry, and regenerative agriculture, highlighting their potential to harmonize productivity with environmental stewardship. The synthesis presented in this review strives to offer a thorough and inclusive examination of the present status of contemporary agriculture, navigating through its advancements, limitations, and potential pathways for global implementation. Ultimately, this exploration seeks not only to comprehend the transformation underway but also to offer insights into its implications for sustainable and resilient agricultural systems in the foreseeable future.

2. APPROACH DETAILS

Artificial Intelligence (AI) stands as a cornerstone of technological innovation which revolutionizes several anglesof our modern world. Rooted in the aspiration to replicate human cognitive abilities, Artificial Intelligence (AI) includes a wide range of methods and technologies aimed at empowering machines to execute tasks that have traditionally required human intelligence. Its evolution has traversed decades of research, innovation, and practical implementation, culminating in transformative applications across industries and disciplines. Artificial Intelligence integrated with agriculture represents a groundbreaking frontier in reshaping conventional farming methodologies. Moreover, AI-driven robotics and automation have transformed labor-intensive agricultural tasks, enhanced efficiency while mitigating labor shortages.From autonomous drones surveilling crops to smart harvesting machines equipped with computer vision, AI-powered tools are reshaping the landscape of farm operations. Furthermore, predictive models utilizing AI aid in forecasting market trends, managing supply chains, and reducing waste across the agricultural ecosystem. Crop monitoring is another area benefiting significantly from AI. Through image recognition and data analysis, machine learning algorithms facilitate the detection of crop diseases, pest infestations, and nutrient deficiencies. Early detection allows for targeted interventions, mitigating potential crop losses and reducing the reliance on chemical treatments.

Predictive analytics powered by AI models help farmers anticipate weather patterns, market trends, and crop behaviour. By analysing historical data and current variables, these models offer insights that aid decision-making regarding planting schedules, harvesting times, and crop selection. This forecasting capability enables farmers to adapt to changing conditions, optimise production, and mitigate risks. Autonomous intelligent systems and automation have also found their way into agriculture, streamlining labour- intensive tasks like harvesting, weeding, and sorting. Automatic vehicles and robots equipped with AI perform these tasks competently, reducing labour costs and increasing crop productivity. Moreover, these systems can operate around the clock, improving overall farm output. The optimization of supply chains is yet another area where AI plays a crucial role. By analysing data on demand patterns, transportation logistics, and market trends, AI helps in efficient distribution, ensuring that fresh produce reaches markets promptly while minimizing waste along the supply chain. Furthermore, AI contributes to agricultural research and development by accelerating genetic analysis and aiding in the development of disease-resistant and high-yield crop varieties. While AI offers immense potential in agriculture, challenges such as access to technology, and the infrastructure need in rural areas, data privacy concerns must be addressed for its widespread adoption. Nonetheless, AI continues to transform agriculture, offering innovative solutions to improve efficiency, sustainability, and food security on a global scale. The IoT is a transformative technology that interconnects everyday physical devices and objects, enabling them to collect, share, and utilize data over the Internet. These devices are embedded with sensors, connectivity, and software, allowing them to communicate and interact with each other without human intervention. The convergence of the Internet of Things (IoT) along with Machine Learning (ML) represents a powerful synergy that transforms industries, including agriculture, healthcare, manufacturing, and more. IoT devices generate vast amounts of data from interconnected sensors embedded in various devices, while ML algorithms process and analyze this data to extract valuable insights and enable informed decision-making. In agriculture, IoT sensors collect data on temperature, crop health, soil moisture, and humidity, among other parameters. ML algorithms leverage this data to create models for optimal irrigation schedules, disease detection in plants, and efficient resource utilization. By continuously learning from incoming data, ML algorithms can adapt and improve their predictions, leading to precision farming practices that maximize crop yields while minimizing resource wastage.

In IoT-driven agriculture, Machine Learning (ML) is applied using fundamental ML algorithms. These algorithms, such as Support Vector Machine (SVM), Naive Bayes, Discriminant Analysis, K-Nearest Neighbor, K-Means Clustering, Fuzzy Clustering, Gaussian Mixture Models, Artificial Neural Networks (ANN), decision-making systems, and deep learning techniques, play a fundamental role in improving and streamlining agricultural processes within IoT frameworks. These algorithms play essential roles in tasks such as predictive modeling for crop health, precision irrigation, disease detection, yield estimation, and smart resource allocation. They enable farmers to make data-driven decisions, automate crucial tasks, and derive actionable insights from the extensive data collected by IoT sensors, ultimately improving efficiency, productivity, and sustainability in agriculture [2]. The shift towards modern agricultural practices has seen the adoption of innovative techniques like polyhouses, marking a significant departure from traditional farming methods. Polyhouses, also known as greenhouse structures, revolutionize the way crops are cultivated by providing a controlled environment that shields plants from adverse weather conditions and external elements. These structures use materials like polyethylene or polycarbonate to create a sheltered space where temperature, humidity, and light levels can be regulated. Polyhouses offer several advantages over open-field farming. They extend the growing season by creating a conducive microclimate, allowing farmers to grow crops throughout the year regardless of external weather patterns. This controlled environment enables better management of water and nutrients, reducing water consumption and optimizing fertilizer use. Additionally, polyhouses provide protection against pests, diseases, and extreme weather events, leading to higher-quality yields and increased crop resilience.

The adoption of polyhouses represents a modern shift in agriculture, promoting sustainable practices by maximizing resource efficiency and minimizing environmental impact. These structures empower farmers to enhance productivity, improve crop quality, and ensure a more reliable and consistent supply of produce, contributing significantly to food security and economic stability in agricultural communities. Let's explore various farming methods and examine the evolution of agricultural practices over the past few decades.

3. TRADITIONAL FARMING PRACTICES

Traditional farming methods represent a collection of time-honored practices handed down through generations. They typically rely on manual labor, basic tools, and natural conditions for farming activities like tilling, planting, and harvesting, excluding the use of modern machinery. These approaches commonly incorporate natural fertilizers, crop rotation, and dependence on natural weather patterns for irrigation. These methods, deeply ingrained in local wisdom and heritage, have been the backbone of agriculture for ages. They prioritize a comprehensive farming approach that respects sustainability and aligns with nature. However, compared to modern agricultural techniques, they often face limitations in terms of efficiency and scalability.

3.1 Slash and Burn Technique

Slash-and-burn agriculture known as shifting cultivation or swidden cultivation, involves a farming method where land is cleared by cutting down vegetation, which is then burned before crops are planted. This practice allows farmers to create fertile land for cultivation by using the ash from the burned vegetation as a source of nutrients for the soil. After a few years of cultivation, the land is left fallow, allowing it to regenerate its fertility while farmers move to a new area to repeat the process. Critics, including Cramb (1989) and Tobing (1991), have disapproved of slash-and-burn agriculture, citing its lack of sustainability. Additionally, it has been identified as a major contributor to tropical deforestation, as highlighted by the World Resources Institute (WRI) in 1990. This method is often associated with challenges such as low crop yields and rapid soil degradation, as noted by El Moursi (1984) and Christanty (1986). Consequently, development initiatives commonly endorse continuous cropping systems as an alternative to slash-and-burn practices. Furthermore, many developing nations have launched institutional campaigns condemning all forms of slash-and-burn agriculture [3].

Fig. 1 Slash and Burn Technique

DISADVANTAGES OF SLASH AND BURN FARMING TECHNIQUE:

- Deforestation: Clearing land by slashing and burning vegetation leads to deforestation, which can result inthe loss of biodiversity, habitat destruction for wildlife, and disruption of ecosystems.

- Soil Degradation: Rapid soil degradation occurs due tothe burning of organic matter, which reduces soil fertility. This degradation can lead to decreased cropyields over time and hamper the land's ability to support agricultural activities.
- Loss of Nutrients: Although initially, the ash from burned vegetation provides nutrients to the soil, these benefits are short-lived. Continuous burning can deplete essential nutrients, making the land lessfertile.
- Environmental Impact: The practice contributes to airpollution and greenhouse gas emissions due to the release of carbon dioxide and other gases during burning. This can exacerbate climate change and affect air quality.
- Unsustainability: Slash-and-burn agriculture is not sustainable in the long term, as the cycle of clearingand abandoning land requires farmers to move to new areas once fertility diminishes, leading to further deforestation and land degradation.
- Erosion and Runoff: The removal of vegetation coverincreases the risk of soil erosion and runoff, which can lead to sedimentation in water bodies, affectingwater quality and aquatic ecosystems.

Addressing these disadvantages requires the adoption of more sustainable agricultural practices that prioritize soil conservation, biodiversity conservation, and responsible land use management to ensure the long-term health and productivity of agricultural landscapes.

3.2 Subsistence Farming

Subsistence farming is a form of agriculture in which farmers focus on cultivating crops and raising livestock primarily to fulfill the needs of their own families or the immediate local communities. The primary goal is to produce enough food to sustain the household's needs rather than generating surplus goods for sale in markets. Typically, subsistence farmers use small plots of land and employ traditional farming techniques, often relying on manual labor and simple tools rather than advanced machinery. This farming method is deeply intertwined with the local community's food security, as the produced food directly fulfills dietary requirements. Subsistence farming involves cultivating a diverse range of crops suited to the local climate and terrain, aiming to provide a balanced diet for the family.Subsistence farming, a practice prevalent before the rise of industrial agriculture, continues to endure in various regions globally, notably in parts of Asia, sub-Saharan Africa, and Latin America. Typically, subsistence farms are characterized by their small land sizes, often just a few hectares, and they rely on cultivating a diverse array of traditional landraces. These landraces represent locally adapted crop varieties, each possessing relatively low yield potential when considered as individual crops [4]. These farms prioritize growing crops that cater directly to thesustenance needs of the farming household or local community. Rather than focusing on high-yield single-crop cultivation, subsistence farmers often cultivate a mix of crops, such as grains, tubers, vegetables, and legumes. This diverse range of traditional landraces ensures a balanced dietand helps mitigate risks associated with crop failures due to pests, diseases, or adverse weather conditions. The choice of traditional landraces is guided by their adaptability to local environmental conditions, resilience to pests and diseases, and suitability to the local culinary and cultural preferences. While these landraces may have lower individual yield potential compared to modern high-yieldingvarieties, their cultivation leads to food security by ensuring a consistent food supply for the farming household. Overall, subsistence farming, with its reliance on small land holdings and cultivation of diverse traditional landraces, remains crucial for providing sustenance to rural communities in various parts of the world, preserving cultural heritage, and ensuring food security at the local level.

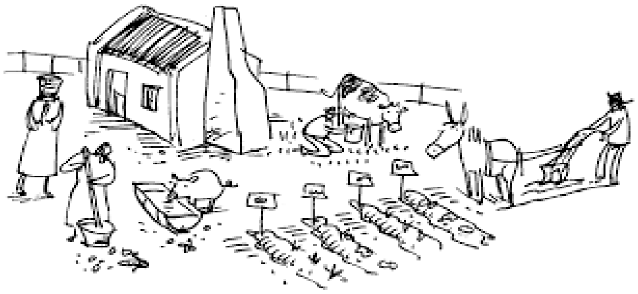


Fig. 2 Subsistence Farming

3.3 Crop Rotation

Crop rotation involves the systematic cultivation of different plant species in sequential order on a particular plot of land. In contrast, intercropping refers to the simultaneous cultivation of two or more crop species on the same land, while continuous monoculture involves the repetitive cultivation of a single species on the same land without rotation or variation in crops [5]. Crop rotations have been known to be essential for a long time. In 1888, scientists started explaining the role of legumes in rotations, while the University of Illinois and Kansas State College began rotation studies in 1876 and 1909, respectively. Before modern farming heavily relied on external inputs, crop rotations had various benefits, such as controlling pests (weeds, diseases, insects, and nematodes), reducing soil erosion, maintaining soil fertility, and boosting productivity. As farming increasingly depended on external inputs, some thought crop rotations would become less important. However, recent concerns about the environmental impact of chemical inputs, high use of purchased mineral fertilizers, soil erosion, uncertainty about the long-term effectiveness of external inputs, and declining yields have renewed interest in crop rotations [6].

Fig. 3 Crop Rotation Technique

Conducting extended experiments proves valuable in evaluating the effects of crop rotation cycles on both production and environmental advantages, as well as potential limitations arising from diversification. This information plays a crucial role in developing more resilient cropping systems for northern agriculture. Some findings indicate that diverse crop rotations, incorporating cereals, oilseeds, and legumes, lead to increased yields in northern spring wheat production, particularly in reduced tillage systems. Analyzing factors such as yield quantity and quality, weed presence, plant diseases, and insect pests collectively contribute to a comprehensive understanding of the long-term impact of temporal diversification on cropping system performance. To optimize crop diversification in cereal production, special emphasis should be placed on the overall health of each plant species in the rotation, especially when considering the exclusion of soil tillage for pest control effects [7].

4. AGRICULTURE SHIFT

The shift in agriculture over recent decades reflects a transition from traditional, labour-intensive practices towards more technology-driven, efficient, and specialized methods. It signifies a move towards a more efficient, technology- driven, and sustainable approach that aims to address challenges such as food security, environmentalconservation, and economic viability in farmingcommunities.

4.1 Hydroponics

Hydroponics, an innovative and soil-less method of cultivating plants, has revolutionized traditional agriculture by offering a dynamic alternative for plant growth. This system involves the nourishment of plants through a nutrient- rich water solution, eliminating the need for soil while providing precise control over essential growth factors like nutrients, pH levels, and water distribution. By employing various hydroponic techniques such as deep-water culture, nutrient film, or aeroponics, this method maximizes resource efficiency, accelerates growth rates, and minimizes water usage. Its adaptability allows for year-round cultivation in diverse environments, offering opportunities for sustainable and controlled crop production, all while significantly reducing environmental impact. The integration of hydroponics in modern agriculture showcases a promising path toward ensuring food security, resource conservation, and agricultural sustainability. One of the standout features of hydroponics is its adaptability, enabling cultivation in various locations and climates throughout the year. By decoupling plant growth from natural soil conditions, hydroponics offers flexibility and resilience against environmental constraints, allowing for year-round production regardless of seasonal changes or limited arable land availability. Moreover, the controlled nature of hydroponic systems minimizes the risk of soil-borne diseases and pests, reducing the reliance on chemical pesticides. This sustainable approach to agriculture aligns with the growing global emphasis on environmentally friendly farming practices, promoting resource conservation and minimizing agricultural runoff. The integration of hydroponics into modern agriculture represents not just a technological advancement but a transformative shift toward more sustainable and efficient food production. Its potential to enhance food security, optimize resource utilization, and reduce the environmental footprint of farming makes hydroponics a promising cornerstone in the quest for a more sustainable future in agriculture.

Every hydroponic method relies on a nutrient solution to provide necessary elements to plant roots. Alongside nutrients, roots require a consistent oxygen supply. When roots lack oxygen, they are unable to uptake and transport vital substances to the remaining plants. These systems are categorized on the basis of how they provide nutrients and $O_2$to roots: either by classical hydroponics- aerating the solution with air maintaining roots intermittently submerged, or exposing roots entirely to air. In classical hydroponics, the nutrient solution can be pre-aerated and regularly replaced or continuously supplied with air throughout the plant's growth cycle. Alternatively, plants can grow on inert media like rockwool or clay pellets, where the media undergoes wet-dry cycles by periodically dripping or submerging in the nutrient solution. Aeroponics, on the other hand, involves spraying the nutrient solution onto roots to prevent them from drying out. This method ensures the roots have access to both nutrients and oxygen without constant submersion [8].

Fig. 4 Low-cost Hydroponic System

ADVANTAGES OF HYDROPONICS SYSTEM

- Hydroponic systems offer numerous advantages in modern agriculture. One key benefit lies in their efficient use of resources, notably water. These systems commonly use very less water than traditional soil-based farming methods, as water is redistributed and reused in the closed system, reducing wastage.
- Moreover, hydroponics allows for control over nutrient delivery to plants which leads to fastergrowth rates and higher yields. By providing nutrients directly to the roots in an easily absorbable form, plants can thrive in optimal conditions, resulting in healthier crops and increased productivity.
- Another advantage is the ability to cultivate plants in environments with limited arable land or poor soil quality. Hydroponic systems eliminate the reliance on fertile soil, enabling cultivation in urban settings,arid regions, or areas with contaminated or degradedsoil, expanding agricultural possibilities.
- Additionally, these systems reduce the risk of soil-borne diseases and pests, minimizing the necessity for herbicides or chemical pesticides and weedicides. This environmentally friendly approach aligns with sustainable farming practices, promotingcleaner and safer food production.

Overall, hydroponic systems offer a sustainable, resource-efficient, and adaptable method of cultivation, allowing for year-round production, improved crop quality, and enhanced agricultural sustainability.

4.2 Agroecology

Agroecology is a comprehensive approach to agriculture that integrates ecological principles with farming practices, with the goal of establishing resilient and sustainable food systems. At its essence, agroecology highlights the interdependence of ecological, social, and economic factors in the realm of agricultural production. By drawing inspiration from natural ecosystems, agroecology seeks to optimize agricultural productivity while simultaneously enhancing biodiversity, soil health, and ecosystem resilience. This approach encourages diverse farming techniques, like pest management, crop rotation, agroforestry etc. to create dynamic and self-regulating agricultural systems. Agroecology emphasizes local knowledge, fostering community engagement, and empowering farmers to co-create solutions that are adapted to their specific environmental and social contexts. By prioritizing the conservation of natural resources,promoting biodiversity, and reducing reliance on external inputs like synthetic fertilizers and pesticides, agroecology strives to foster sustainable agricultural practices that mitigate environmental degradation and climate change impacts. Ultimately, agroecology presents a vision for agriculture that not only addresses food security and nutritionbut also prioritizes environmental sustainability and social equity.

4.3 Chemigation

Chemigation is a farming technique that merges irrigation practices with the application of agricultural chemicals like fertilizers, pesticides, or herbicides. It involves injecting these substances directly into the irrigation system, allowing them to be distributed across fields alongside the water used for irrigation. This method provides precise and efficient delivery of chemicals, ensuring uniform distribution while potentially saving time and labour. However, proper maintenance, adherence to regulations, and careful monitoring are necessary to prevent environmental risks and ensure safe and effective chemical use.

Fig. 5 Chemigation Technique

Drip irrigation stands out as a highly effective technique for consistently providing water, and essential and enriched nutrients directly to the root zones of crops.

This method, known as drip chemigation, goes beyond mere irrigation by allowing the delivery of insecticides through the same system. This innovative approach has demonstrated remarkable success in controlling a diverse range of pests commonly encountered in crop production [9].

THE ADVANTAGES OF THE DRIP SYSTEM ARE :

- Efficient Resource Use: Drip delivery systems, whether for irrigation or content dissemination, enable targeted and precise distribution. In agriculture, they efficiently deliver water directly to plant roots, minimizing waste through evaporation. Similarly, in marketing, scheduled drip campaigns optimize content providing information or productsto the appropriate audience at the optimal moment., maximizing engagement and resource utilization.
- Consistency and Control: Drip systems ensure a consistent and controlled flow of resources or content. They maintain a steady schedule, which is crucial for plant health in irrigation and for engaging audiences with regular, well-timed communications in marketing.
- Precision Targeting: These systems allow for personalized and targeted delivery. In marketing, this means tailoring messages based on user behaviour or preferences. In agriculture, it involves delivering water exactly where it is needed, optimizing plant growth and yield.
- Reduced Waste and Maintenance: Drip systems minimize waste by delivering resources directly to the intended targets. In both irrigation and content distribution, this reduces unnecessary use or delivery, cutting down on waste and requiring less ongoing maintenance once the system is set up.
- Adaptability and Optimization: These systems are adaptable to changing needs and environments. They can be adjusted to accommodate shifting audience interests or changing plant requirements, optimizing results over time.
- Improved Efficiency and Results: Drip delivery often leads to better outcomes. In agriculture, plants receive the precise amount of water needed, resulting in healthier growth and improved yields. In marketing, drip campaigns often lead to higher engagement rates and conversions compared to bulk or one-time content delivery methods.

Overall, drip delivery systems offer efficient, targeted, and controlled distribution, resulting in better resource utilization, improved outcomes and reduced waste. Crops that benefit from the process of chemigation are as follows:

- Soybeans
- Orchard Fruits: Apples, Citrus, etc.
- Maize
- Potatoes
- Cotton
- Vegetables: Tomatoes, Peppers, etc.

Crops that don't grow from the process of chemigation areas follows:

- Certain Medicinal or herbal plants
- Shallow Rooted Crops
- Highly sensitive species
- Water Intolerant crops: Varieties of Cacti, Succulents, or plants adapted to arid conditions
- Crops requiring foliar application: Lettuce,grapefruits, lavender, min

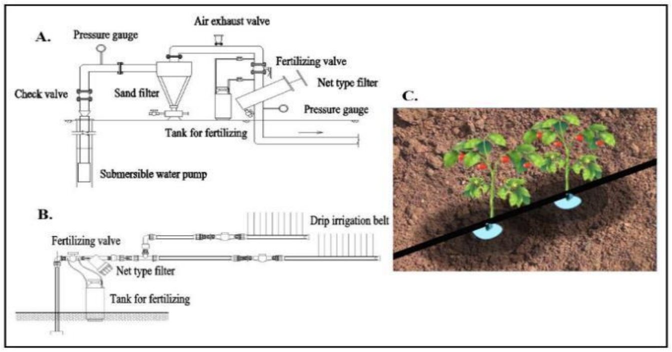


Fig. 5 The arrangement of the drip irrigation and fertilization system comprises several components: (A) depicting the main section or head of the drip irrigation setup, (B) illustrating the connection diagram of branches and capillaries within the drip irrigation system, and (C) demonstrating a layout of ground-based drip irrigation [10].

4.4 Mulching

Mulching is an age-old practice followed by several states in India itself. It is a fundamental technique of covering the soil with some substance (generally plastic/ dark polythene/ organic substances) to control soil moisture and improvement in soil condition.

The benefits of mulching are numerous:

- Moisture Retention: Mulch helps soil retain moisture by reducing evaporation. It shields the soilfrom direct sunlight, preventing rapid drying and maintaining a more consistent level of moisturearound plant roots.
- Weed Control: A dense mulch layer serves as an obstruction, preventing weed growth by blocking sunlight and impeding the germination of weeds. This diminishes the necessity for manual weeding and decreases the competition among plants fornutrients.
- Temperature Regulation: Mulch insulates the soil, moderating temperature extremes. In colderweather, it helps maintain soil warmth, while in hotter climates, it prevents excessive soil heating.
- Soil Improvement: Organic mulches gradually decompose, enriching the soil with nutrients as they break down. This enhances soil structure, fertility, and microbial activity.
- Erosion Prevention: Mulch acts as a protective layer, reducing soil erosion caused by wind or water runoff. It helps maintain soil integrity and prevents nutrient loss.

Pest Control: Some types of mulch, especially thosewith natural repellent properties, can deter certain pests and insects from reaching plants.

TABLE 1. Enhanced Vegetable Crop Yields Attributed to the

Utilization of Mulching [17] [18]

Crops	Field Type and Yield		
	Unmulched Yield (T/Ha.)	Mulched Yield(T/Ha.)	Increase in Yield(%)
Cauliflower	18.58	25.02	34.66
Brinjal	36.73	47.06	28.12
Okra	6.91	8.56	23.88
Cotton	1.67	2.22	24.77
Lentil	0.80	0.89	10.11
Wheat	7.24	7.79	7.06
Barley	3.77	4.27	11.70
French Beans	12.73	14.10	9.71
Chickpea	5.91	7.32	19.26
Cabbage	14.3	19.9	39.16

Utilizing straw mulching alongside wide-precision planting proves effective in offsetting decreased winter wheat grain yield and enhancing grain quality. Mulch materials minimize evaporation losses, thus improving soil water retention and aiding in weed reduction. Additionally, mulches promote root establishment, growth, and development [11].

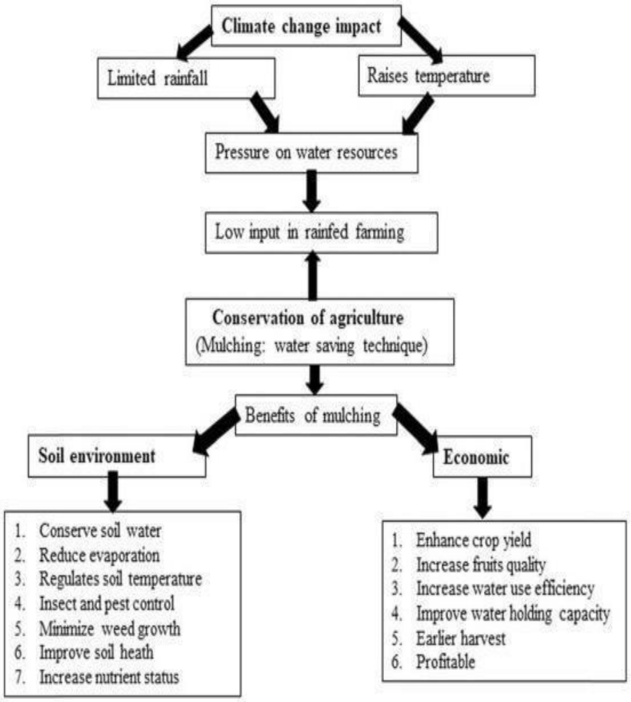


Fig. 5 A visual representation illustrating the relationship between the conservation of agriculture, climate dynamics and crop interactions [12]

Any system's dynamic range may be increased by using programmable gain. The practical range of a fixed gain instrumentation amplifier would be around 60dB [9,10,16]. To permit signal levels amplification in broad range then both high resolution (approx. about 0.4%) as well as wide-gain range (of about minimum 100 -1000) is required for programmable gain [4]. In data acquisition space, PG-IA are most crucial component which enables better signal to noise ratio performance as well as varied sensor sensitivities. Compact IC designing approaches may also be used to decrease parasitic and offer great matching, leading in better ac performance. Due to these benefits, if an integrated PGIA matches the design criteria, it is always suggested to employ it [7].

4.5 Polyhouse Farming

In the contemporary realm of agriculture, the demand for innovative, sustainable practices has never been pressing. Polyhouse farming is a technique that has garnered increasing attention for its ability to enhance crop productivity. The polyhouse once a testament to agricultural ingenuity nowstands as a beacon of sustainable farming practices, capable of withstanding the unpredictable climate. The implementation of IOT transforms these enclosed environments into a smart ecosystem, where data-driven decisions help in crop growth. The array of sensors and actuators deployed within the polyhouse ensures optimalconditions for plant growth and development.

It is also known as greenhouse farming, is a method ofgrowing plants in a controlled environment. It involves the use of structures made of transparent materials like polyethene or glass, allowing sunlight to enter while trapping heat inside. This controlled setting manages temperature,humidity, light exposure, and airflow, establishing ideal conditions conducive to the growth of plants throughout the year.

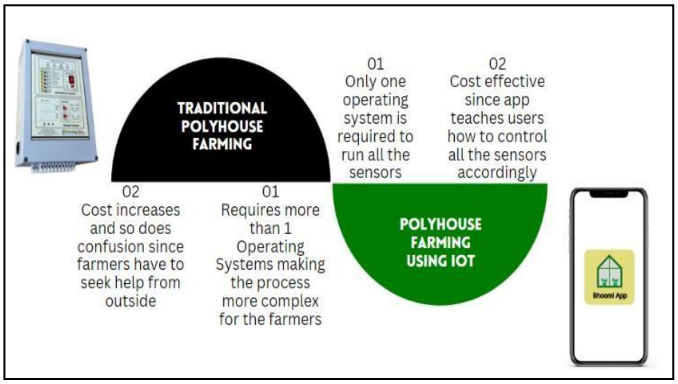


Fig. 6 Comparison between Hi-Tech and Contemporary Polyhouses

Polyhouse farming integrated with IoT (Internet of Things) technology revolutionizes traditional agricultural practices by employing a network of interconnected devices to monitor and manage various aspects of the polyhouse environment. Within the polyhouse, strategically positionedIoT sensors collect immediate data on vital elements including soil moisture, humidity, temperature, light intensity, and CO_2 levels. This data is then transmitted to a central system or the cloud for analysis and interpretation.

TABLE 2. Size and Investment Pattern of Polyhouses (Rs.)

[11], [14]

Investments	**Land size in square meters**		
	100	250	500
The cost of a polyhouse (approximately)	88000	192500	434000
The cost of Drip and the Fogger (approximately)	12500	23750	47600
Structure costs for average unit size	539206 (<2000 sq. m)	943930 (2000-4000 sq. m)	1855098 (>4000 sq. m)
The total cost of polyhouse	100500	216250	481600
Land preparation cost	379331 (<2000 sq. m)	616940 (2000-4000 sq. m)	1173028 (2000-4000 sq. m)
Complete support (80%)	80400	173000	385280
Farmer's Investment(20%)	20100	43250	96320
Total Investment costs	1429148 (<2000 sq. m)	2322360 (2000-4000 sq. m)	4364336 (2000-4000 sq. m)

TYPES OF POLYHOUSES:

- Naturally ventilated polyhouses:

  The naturally ventilated polyhouse addresses challenges related to ventilation and humidity, specifically tailored for hot and humid climates. This is achieved through strategically positioned fixed openings situated at the center of each arch of the structure, spanning both the length and breadth, ensuring comprehensive ventilation on all four sides.

Fig. 7 A Naturally Ventilated Polyhouse

- Even span polyhouses:

  An even-span polyhouse is a type of greenhouse structure characterized by a uniform roof slope and a symmetrical design. It consists of two equal-width bayswith a central ridge that runs along the length of the structure. This design offers balanced light distribution,efficient utilization of space, and ease of construction and maintenance due to its uniformity and standardized components. The even-span polyhouse is versatile, allowing for the cultivation of various crops while providing a controlled environment for optimal growth and protection against external weather conditions.

- Un even span polyhouses:

This polyhouse variant is built on uneven or hilly landscapes, featuring roofs of varying widths that accommodate the side slopes of hills. However, its usage has declined in modern times due to its limited adaptability to automation processes [13].

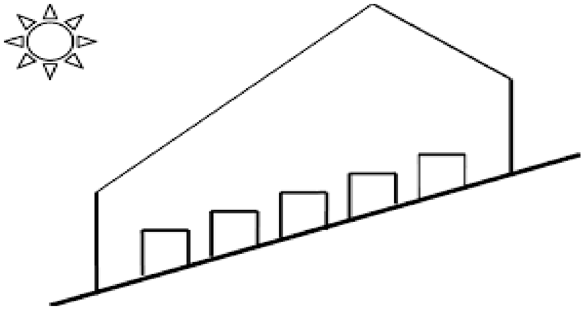


Fig. 8 An Uneven Span Polyhouse

- Plastic Mulches

Plastic mulch serves as a tool in plasticulture, mirroring the function of traditional mulch by suppressing weed growth and conserving water in both crop cultivation and landscaping. Some variations of plastic mulch additionally function as a barrier, retaining methyl bromide—a potent fumigant and ozone-depleting substance—in the soil.

Fig. 8 A Plastic Mulch

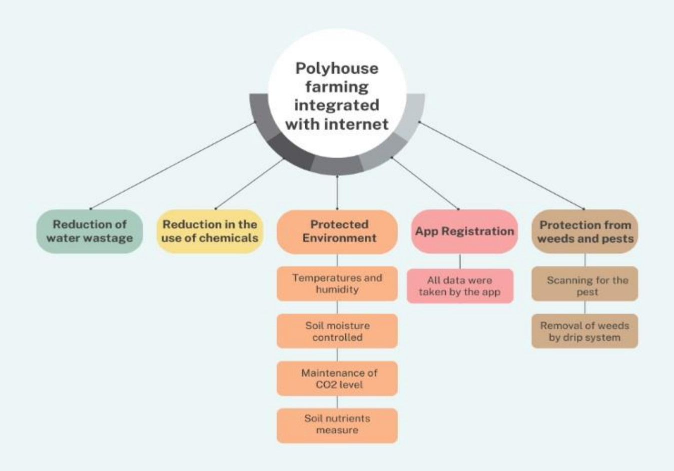
There are several other types of polyhouses as well based on different shapes, sizes, characteristics and the crops grown in them [13] [14]:

- Ridge and furrow polyhouses
- Saw tooth polyhouses
- Quonset Greenhouses
- Gothic Arch Greenhouses
- Polyhouses for active heating
- Polyhouses for active cooling
- Wooden framed structures
- Pipe-framed structures
- Truss framed structures
- Fully climate-controlled polyhouses
- Plastic low tunnels

4.6 Polyhouse using IoT- The Polyhouse for today

An IoT-based polyhouse integrates Internet of Things (IoT) technology into its operations, transforming traditional greenhouse structures into smart, interconnected systems.This innovation involves embedding sensors, actuators, and monitoring devices within the polyhouse infrastructure to gather real-time data on various environmental factors like temperature, humidity, soil moisture, light intensity, and ventilation [15]. These sensors collect information that is then transmitted and analyzed through a central IoT platform. By leveraging IoT, farmers can remotely monitor and controlthe polyhouse environment using smartphones or computers. Automated systems can adjust climate controls, irrigation schedules, and nutrient delivery based on preset parameters or data-driven insights. For instance, if sensors detect a deviation in temperature or moisture levels, the IoT system can trigger actions like adjusting ventilation or initiating irrigation to maintain optimal conditions for crop growth. Additionally, IoT-based polyhouses facilitate data-driven decision-making by providing valuable insights into crop health, resource usage, and environmental conditions. This technology enables predictive analytics, allowing farmers to anticipate potential issues and optimize crop production moreefficiently. Overall, this integration of IoT into polyhouse operations enhances efficiency, precision, and yield while reducing resource wastage and manual labor [19, 20]. The conditions within the polyhouse can be managed from a remote laboratory. These polyhouses serve as acclimatization facilities for plants transported from other locations, as well as for those needing relocation to their ultimate destinations. These controlled environments are suitable for cultivating various crops, including tomatoes, peppers, broccoli, and off-season crops like cucumbers. Furthermore, the polyhouses can be utilized for the acclimatization of plants produced through plant tissue culture [15].

Fig. 9 Polyhouse with internet



4.6 Generative Artificial Intelligence

Generative AI is a subset of AI that focuses on content creation, often in the form of images, text, music, or even videos, that are original and not directly copied from existingexamples [16]. This technology involves algorithms that learn patterns and structures from large datasets and then generatenew content based on this learned information. Generative AI's ability to simulate and predict complex agricultural scenarios holds immense promise in improving crop yields, sustainability, and resilience in the face of evolving environmental challenges. However, its implementation requires large and diverse datasets, advanced computational resources, and collaboration between researchers, farmers, and technologiststo ensure its effective and ethical use in agriculture. The adoption of visual signals within horticulture has emerged as a focal point, encompassing a rich array of data types such as 2D images, 3D point clouds, videos, and hyperspectral images. These visual cues have become invaluable in advancing sophisticated computer vision systems tailored specifically for various applications within horticulture. They serve as crucial tools enabling the monitoring of plant growth dynamics, identification of pests and diseases, estimation of yield and produce quality, and even streamlining the harvesting process. The creation of deep learning-driven computer vision systems for horticulture faces unique hurdles that are not typically encountered in other industries. One major challenge involves the limited availability of top-tier datasets essential for effective training and improving deep learning algorithms. This scarcity impedes the full potential of these systems, requiring innovative solutions to navigate these unique hurdles and harness the full capabilities of computer vision in optimizing horticultural practices [16].

5. CONCLUSION

In conclusion, traditional farming methods, rooted in historyand local practices, pose challenges such as inefficiency dueto manual labor, susceptibility to weather uncertainties, and lower yields compared to modern, technology-driven approaches. The labor-intensive nature of traditional farminglimits scalability, hindering its ability to meet the demands of a growing population and making it vulnerable to pests, diseases, and adverse weather events. The integration of Artificial Intelligence (AI) into farming represents a transformative era, offering advancements in efficiency, productivity, and sustainability. AI-driven technologies, including machine learning algorithms and automated machinery, empower farmers to make informed decisions, optimize resource management, and enhance crop yields. AI applications in precision agriculture, crop monitoring, and autonomous machinery enable a more precise and data-driven approach, reducing environmental impact and maximizing land utilization. Polyhouse technology, enhanced by AI, allows real-time monitoring and control of environmental variables, optimizing conditions for crop growth. Machine learning algorithms analyze data for insights into crop health, disease detection, and yield prediction, facilitating proactive management strategies. Despite the benefits, challenges suchas accessibility and scalability must be addressed for the widespread acceptance and enduring success of these contemporary agricultural methods. The collective review of polyhouse technology and its integration with modern farming signifies a paradigm shift, converging technological advancements, sustainable practices, and precisionagriculture.

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