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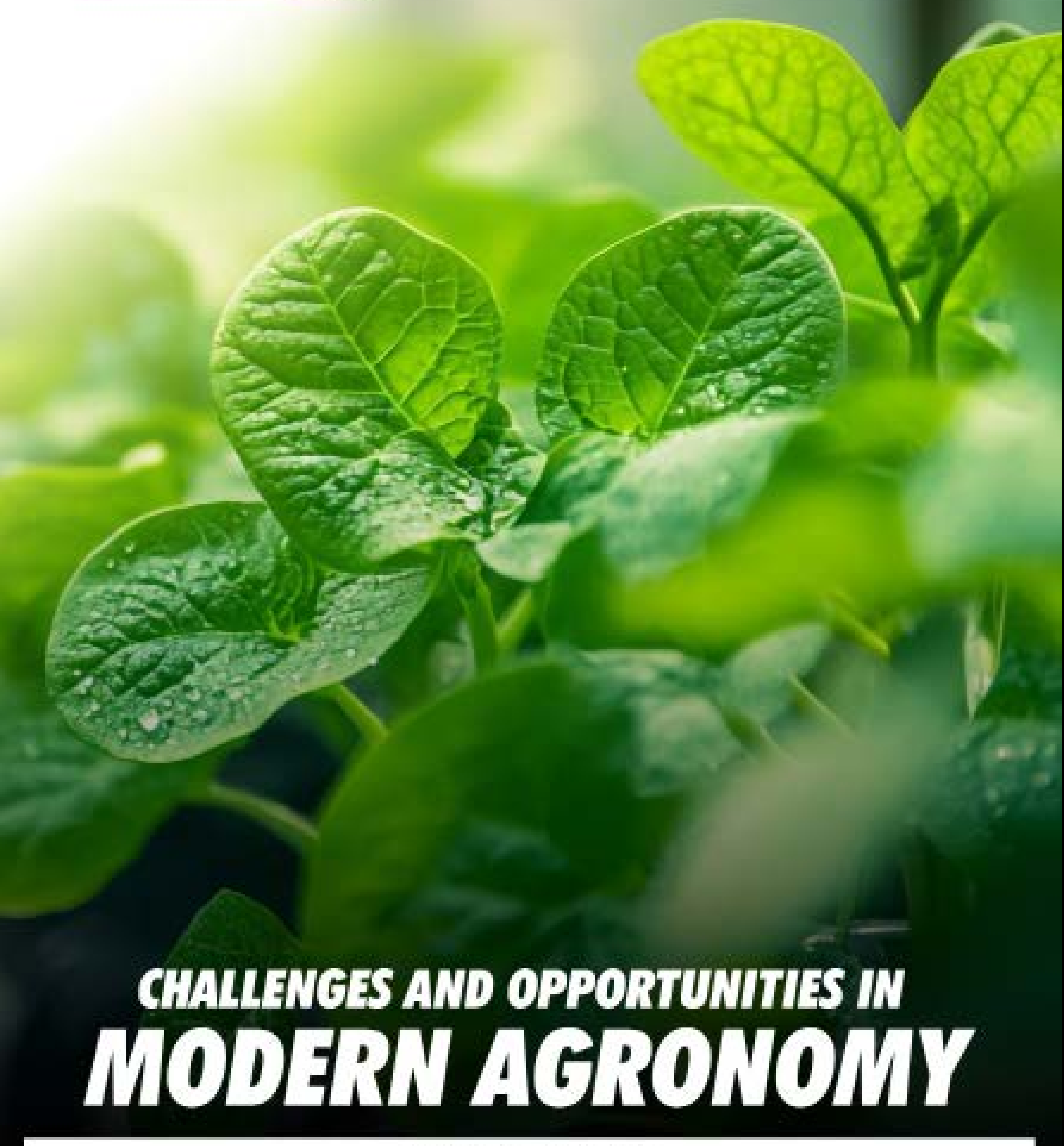

CHALLENGES AND OPPORTUNITIES IN MODERN AGRONOMY

MARCH 2026
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From the Desk of the Founder

At **Digital Agri News**, we understand that farming is not just a profession — it's a way of life. It is the heartbeat of our economy, the foundation of our food security, and the lifeline of millions of families. With this in mind, our mission is simple yet powerful: to bring timely, accurate, and actionable agricultural news right to your fingertips.

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Thank you for trusting us as your partner in this evolving journey. Together, let's cultivate awareness, embrace innovation, and nurture a sustainable future for generations to come.

Dr. Mukesh Narwal

Warm Regards
Dr. Mukesh Narwal
Founder, Digital Agri News

From the Desk of the Chief Editor

DR. ANKIT SAINI
Assistant Professor and Head
Department of Agronomy
Dr. KSG Akal College of Agriculture
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Greetings to all esteemed readers of Digital Agri News Magazine. We are pleased to present this issue, bringing together insightful articles on key challenges, innovations, and sustainable approaches shaping modern agriculture. This edition highlights pressing concerns such as climate change, shrinking land resources, soil degradation, and the growing demand for higher productivity. At the same time, it explores emerging opportunities including precision agriculture, climate-resilient crops, and advanced technologies that are transforming traditional farming into efficient and sustainable systems. Special emphasis has been given to eco-friendly solutions. Articles on mycoremediation demonstrate the potential of fungi in restoring contaminated soils, while discussions on biochar and biogenic materials showcase innovative methods for improving soil health, resource recovery, and carbon sequestration. We also feature cropping system strategies like mixed and relay cropping, which enhance resilience, optimize resource use, and support long-term sustainability. Overall, this issue reflects the integration of science, sustainability, and innovation. Our aim is to inspire farmers, researchers, students, and agri-entrepreneurs to adopt progressive practices and move towards a smarter, greener, and sustainable agricultural future.

Dr. Ankit Saini

Warm Regards
Editor-in-Chief
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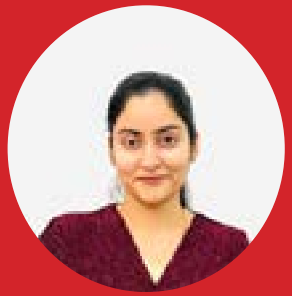

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FROM FARM TO FORK: ANTIBIOTIC USE IN POULTRY AND ITS IMPLICATIONS FOR HUMAN HEALTH AND THE ENVIRONMENT

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From Farm to Fork: Antibiotic Use in Poultry and Its Implications for Human Health and the Environment

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Introduction

In recent years, terms like “antibiotic-free chicken” and “safe poultry products” have become increasingly common in markets and among consumers. With growing awareness about food safety and health, people are beginning to question how poultry is produced and whether the use of antibiotics in farming poses any risks. Poultry meat, especially chicken, is one of the most widely consumed and affordable sources of animal protein globally, and its production has expanded rapidly to meet increasing demand. However, behind this rapid growth lies an important issue, the use of antibiotics in poultry production and its consequences for human health and the environment.

Why Are Antibiotics Used in Poultry?

Antibiotics have been an integral part of modern poultry production for decades. They are used primarily for three main purposes: treatment of diseases, prevention of infections, and improvement of growth and productivity.In intensive poultry farming systems, where large numbers of birds are raised in confined spaces, the risk of disease outbreaks is high. To prevent losses, farmers often use antibiotics not only to treat sick birds but also as a preventive measure. Additionally, antibiotics have historically been used at low levels in feed to enhance growth and improve feed efficiency, allowing birds to reach market weight faster.This practice contributed significantly to the success and expansion of the poultry industry, making chicken meat more affordable and accessible worldwide. However, over time, concerns have emerged about the long-term consequences of such widespread use.

The Growing Concern: What Is the Problem?

The major issue associated with antibiotic use in poultry is the development of antimicrobial resistance (AMR). This occurs when bacteria evolve and become resistant to antibiotics that were once effective in killing them.The extensive and sometimes inappropriate use of antibiotics in poultry production has created conditions that favor the development of resistant bacteria. These bacteria can survive antibiotic treatment and continue to multiply, making infections harder to treat in both animals and humans.Research shows that poultry farming is one of the significant contributors to the spread of antimicrobial resistance due to the scale of production and the frequent use of antibiotics.Importantly, this is not just an animal health issue, it has direct implications for human health.

Impact on Human Health

1. Transfer of Resistant Bacteria

One of the primary concerns is that antibiotic-resistant bacteria can be transmitted from poultry to humans. This transmission can occur through several pathways:

- Consumption of contaminated poultry meat
- Direct contact with live birds or farm environments
- Environmental exposure through soil and water

Bacteria such as *Escherichia coli, Salmonella*, and Campylobacter commonly associated with poultry have shown increasing resistance to antibiotics due to their exposure in farming systems.When these resistant bacteria infect humans, they can lead to illnesses that are more difficult to treat, requiring stronger or last-resort antibiotics.

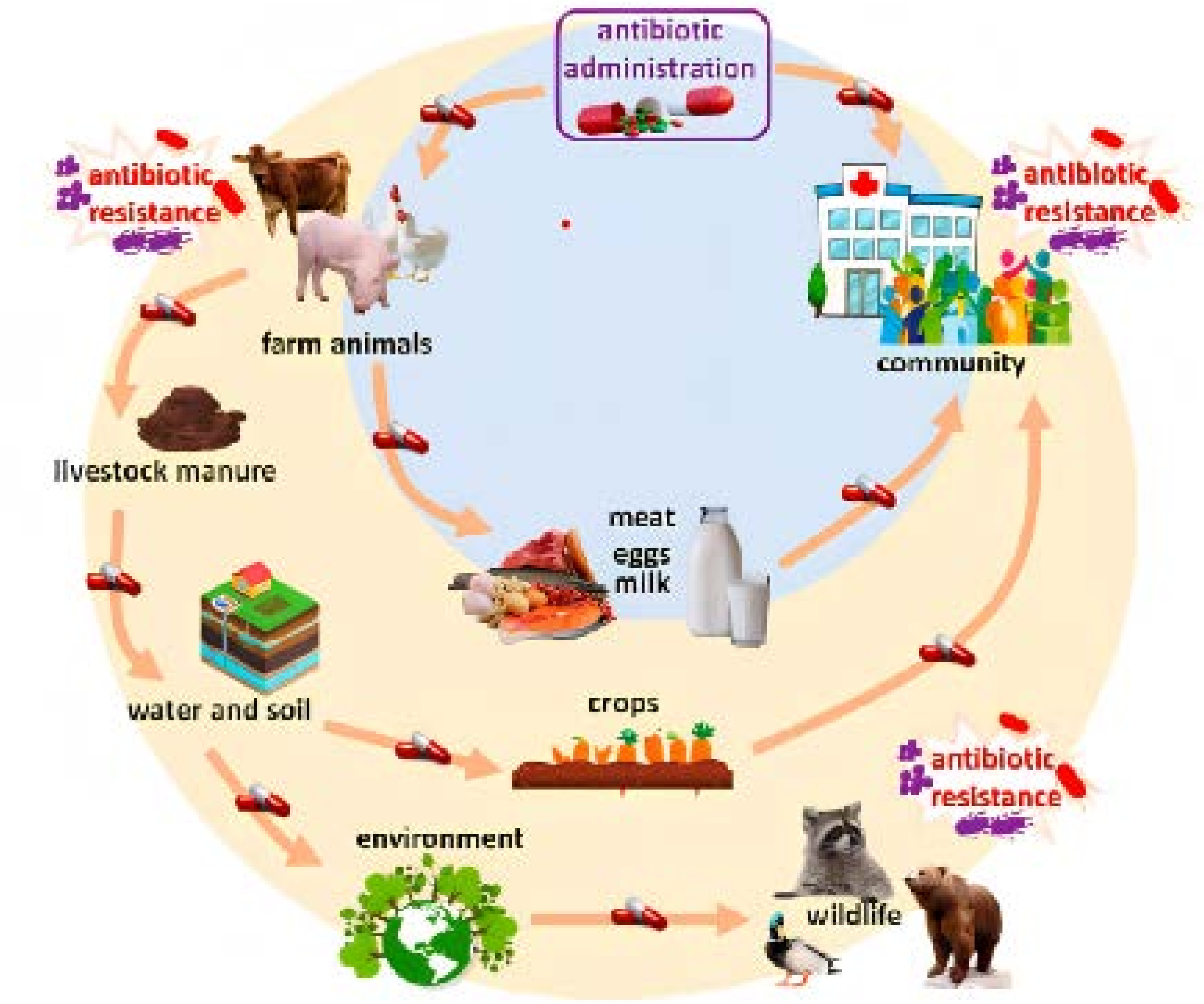

Figure 1:*Pathways of antibiotic resistance from animal production to humans and environment.*
Source: *Golowczyc & Gomez-Zavaglia (2024).*

2. Antibiotic Residues in Poultry Products

Another important concern is the presence of antibiotic residues in poultry meat and products. These residues may occur when proper withdrawal periods are not followed before slaughter.Studies highlight that such residues can pose risks to consumers, including allergic reactions, toxicity, and disruption of the human microbiome. In developing countries, weak regulatory systems and lack of awareness have contributed to the persistence of this issue.

3. Reduced Effectiveness of Antibiotics

Perhaps the most serious long-term consequence is that overuse of antibiotics in animals can reduce their effectiveness in human medicine. Evidence suggests that resistant bacteria originating in animals can enter the human population through the food chain, contributing to a wider pool of resistance genes.This means that common infections in humans may become harder to treat, increasing the risk of complications, longer illness durations, and higher healthcare costs.

Environmental Impact

The impact of antibiotic use in poultry is not limited to animals and humans, it also affects the environment.A large proportion of antibiotics administered to animals is not fully metabolized and is excreted in active form through feces and urine. These residues enter the environment through poultry litter, which is often used as fertilizer in agricultural fields.As a result:

- Soil and water systems become contaminated
- Antibiotic residues accumulate in ecosystems
- Resistant bacteria spread beyond farm boundaries

This creates a cycle where resistance can develop and persist in the environment, eventually affecting both animals and humans.

Rising Awareness and Changing Trends

In recent years, there has been growing awareness among consumers, researchers, and policymakers regarding the risks associated with antibiotic use in poultry.Several countries have introduced regulations to restrict or ban the use of antibiotics as growth promoters. For example, European countries have taken significant steps to limit non-therapeutic antibiotic use in livestock production. Consumer demand for “antibiotic-free” or “organic” poultry products has also increased, encouraging producers to adopt alternative practices.However, despite these efforts, challenges remain, particularly in developing countries where regulatory frameworks may be weak and access to veterinary guidance is limited.

Alternatives to Antibiotics

With increasing restrictions on antibiotic use, the poultry industry has been actively exploring alternatives to maintain productivity and animal health.Research highlights several promising options:

- Probiotics and prebiotics to improve gut health
- Phytogenic additives (plant-based compounds) with antimicrobial properties
- Enzymes to enhance nutrient utilization
- Essential oils and herbal extracts
- Vaccination and improved biosecurity practices

Studies show that probiotics and phytogenic additives are among the most widely researched alternatives, indicating a shift toward more sustainable production systems.However, no single alternative can completely replace antibiotics. Instead, a combination of strategies is often required to achieve optimal results.

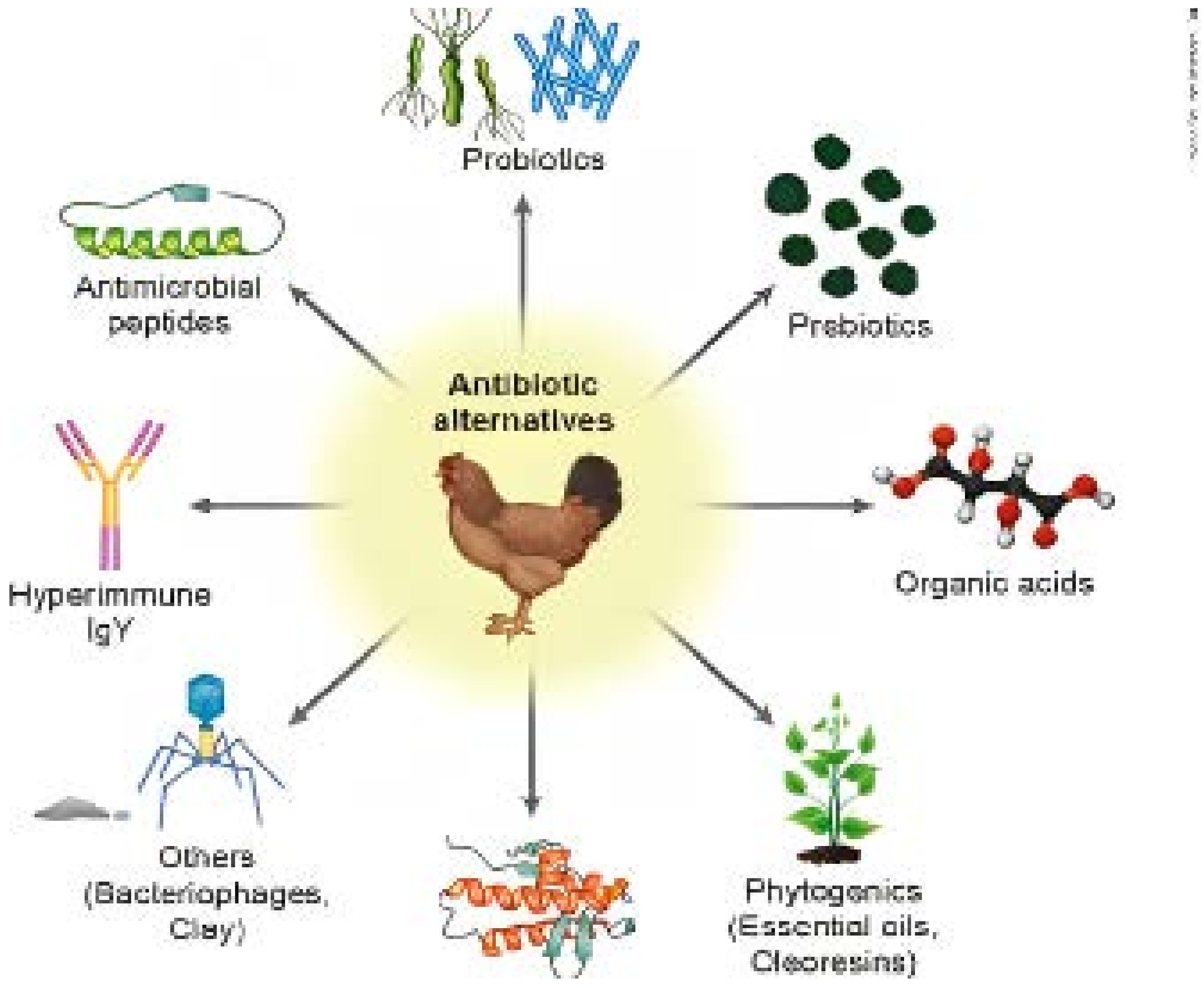

Figure 2:ALTERNATIVES TO ANTIBOTIC GROWTH PROMOTERS Source: Benison Media. (2023). Alternatives to antibiotic growth promoters. Retrieved from https://benisonmedia.com/alternatives-to-antibiotic-growth-promoters/

Challenges in Reducing Antibiotic Use

Despite the availability of alternatives, reducing antibiotic use in poultry production is not straightforward. Several challenges exist:

- Economic pressure on farmers to maintain productivity and profitability
- Lack of awareness and training among farmers
- Easy availability of antibiotics without strict regulation
- Inconsistent implementation of policies

Additionally, once resistance develops, it can persist in the system even after antibiotic use is reduced, making it difficult to reverse the problem.

A Balanced Perspective

It is important to note that antibiotics themselves are not the problem, the issue lies in their misuse and overuse. When used responsibly under veterinary supervision, antibiotics play a crucial role in maintaining animal health and preventing disease outbreaks. Eliminating antibiotics completely without proper alternatives could compromise animal welfare and food security. Therefore, the focus should be on:

- Judicious use of antibiotics
- Improved management practices
- Better regulation and monitoring

Conclusion

The use of antibiotics in poultry production has played a vital role in meeting the global demand for affordable animal protein. However, its widespread and sometimes inappropriate use has led to significant concerns regarding antimicrobial resistance, human health risks, and environmental contamination.Poultry production represents a critical link between animal agriculture and public health, highlighting the importance of a “One Health” approach, where human, animal, and environmental health are considered together. Moving forward, sustainable poultry production will depend on a balanced strategy that combines responsible antibiotic use, adoption of effective alternatives, stronger regulations, and increased awareness among all stakeholders.Ultimately, protecting the effectiveness of antibiotics is not just a scientific challenge, it is a shared responsibility that affects farmers, consumers, policymakers, and society as a whole.

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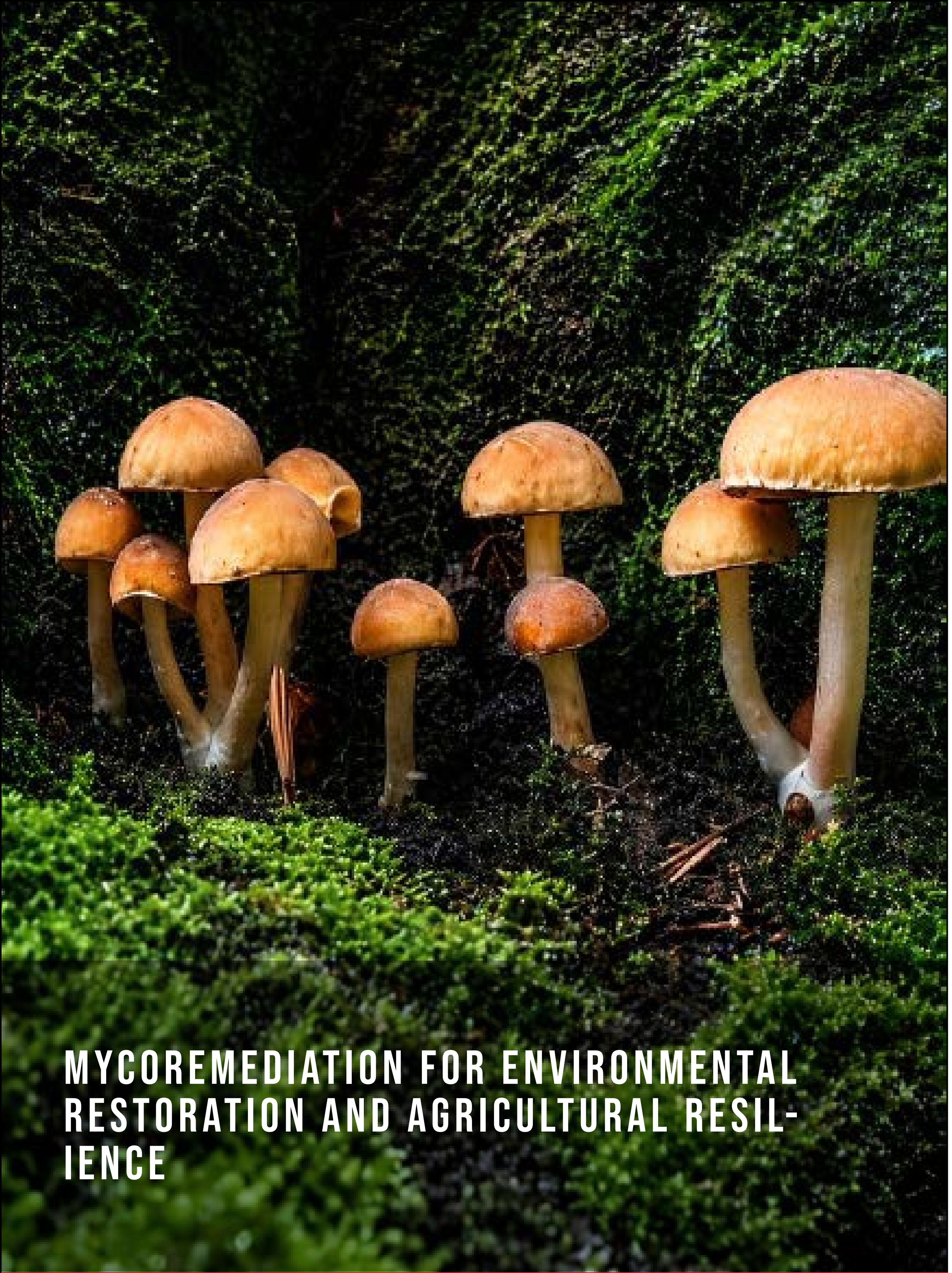

MYCOREMEDIATION FOR ENVIRONMENTAL RESTORATION AND AGRICULTURAL RESILIENCE

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Mycoremediation for Environmental Restoration and Agricultural Resilience

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Abstract

The rapid expansion of industrial activities and modern agricultural practices has significantly increased environmental contamination, leading to the accumulation of toxic substances like heavy metals, pesticides and persistent organic pollutants in soil and water systems. Traditional remediation methods, although widely used, are often costly, energy-demanding and can negatively impact natural ecosystems. In contrast, mycoremediation has gained attention as a sustainable and environmentally compatible approach that harnesses the natural capabilities of fungi to restore polluted environments. Fungi function as efficient decomposers through mechanisms such as extracellular enzyme-mediated degradation, intracellular transformation of toxic compounds and adsorption or accumulation of heavy metals. Several fungal genera, including Aspergillus, Penicillium, Fusarium and Trametes, have shown remarkable efficiency in degrading diverse contaminants. The utilization of fungal biomass, such as spent mushroom substrate, further enhances its applicability in field conditions. Moreover, recent developments in areas such as fungal-assisted nanoparticle synthesis and mol-

-cular tools like gene editing have expanded the scope and effectiveness of this technology. Although certain challenges related to environmental variability and large-scale implementation remain, ongoing advancements suggest that mycoremediation has strong potential as a reliable and eco-friendly solution for long-term environmental management.

Key words: Mycoremediation, Environmental pollution, Heavy metals, Extracellular enzymes Ligninolytic fungi Sustainable remediation

Introduction

With the world's population on the rise and cities growing fast, both land and water ecosystems are being affected by more and more pollution. Because we have relied on conventional farming and let industries run wild, soils and groundwater are packed with heavy metals, synthetic pesticides, and stubborn pollutants that simply do not disappear (Kumar et al., 2021). Traditional clean-up techniques, like digging up contaminated dirt or burning off toxins, cost a fortune, use tons of energy, and wreck the natural communities of microbes living in the soil (Liu, 2025). So, if we want a cleaner environment that lasts, mycoremediation is coming forward as a wiser, environmentally friendly alternative. Fungi, with all their powerful enzymes, break down, capture or utterly remove harmful substances. This approach belongs to the category of "green" biotechnology and it's more than just gentler on the environment as it adapts well to larger scales, is budget-friendly and genuinely aids in restoring soil vitality, ensuring farming is better prepared for the future (Kuppan et al., 2024). Mycoremediation possesses the introduction of particular fungus, also referred to as "bioremediation fungi" or "mycofilters," into the contaminated sites.

Mechanism of Mycoremediation:

The remarkable effectiveness of fungi in environmental remediation stems from their evolutionary function as nature's foremost decomposers. Fungi serve as nature's primary decomposers and they're incredibly effective because they've spent millions of years breaking things down. Their methods for detoxifying pollutants can be generally categorized into three biological processes.:

First, there's what happens outside the cell i.e., the **extracellular enzymatic degradation**, fungi produce extremely effective enzymes that break down tough chemicals like pesticides or oil spills. These ligninolytic enzymes, like laccase and various peroxidases, decompose complex toxins within the environment itself. That which remains is less complex, less toxic compounds, sometimes simply carbon dioxide and water (Daassi et al., 2025).

Afterwards arrives the inside job that is the **intracellular biotransformation.** If toxic compounds penetrate the fungal cell, the fungus activates rapidly. Recent transcriptomic studies show fungi significantly increase certain protective proteins and specialized enzymes (like haloalkane dehalogenases) when they're stressed by chemicals. This lets them break down nasty pollutants from the interior outward, cutting apart toxic bonds and making the invaders harmless (Ali et al., 2025).

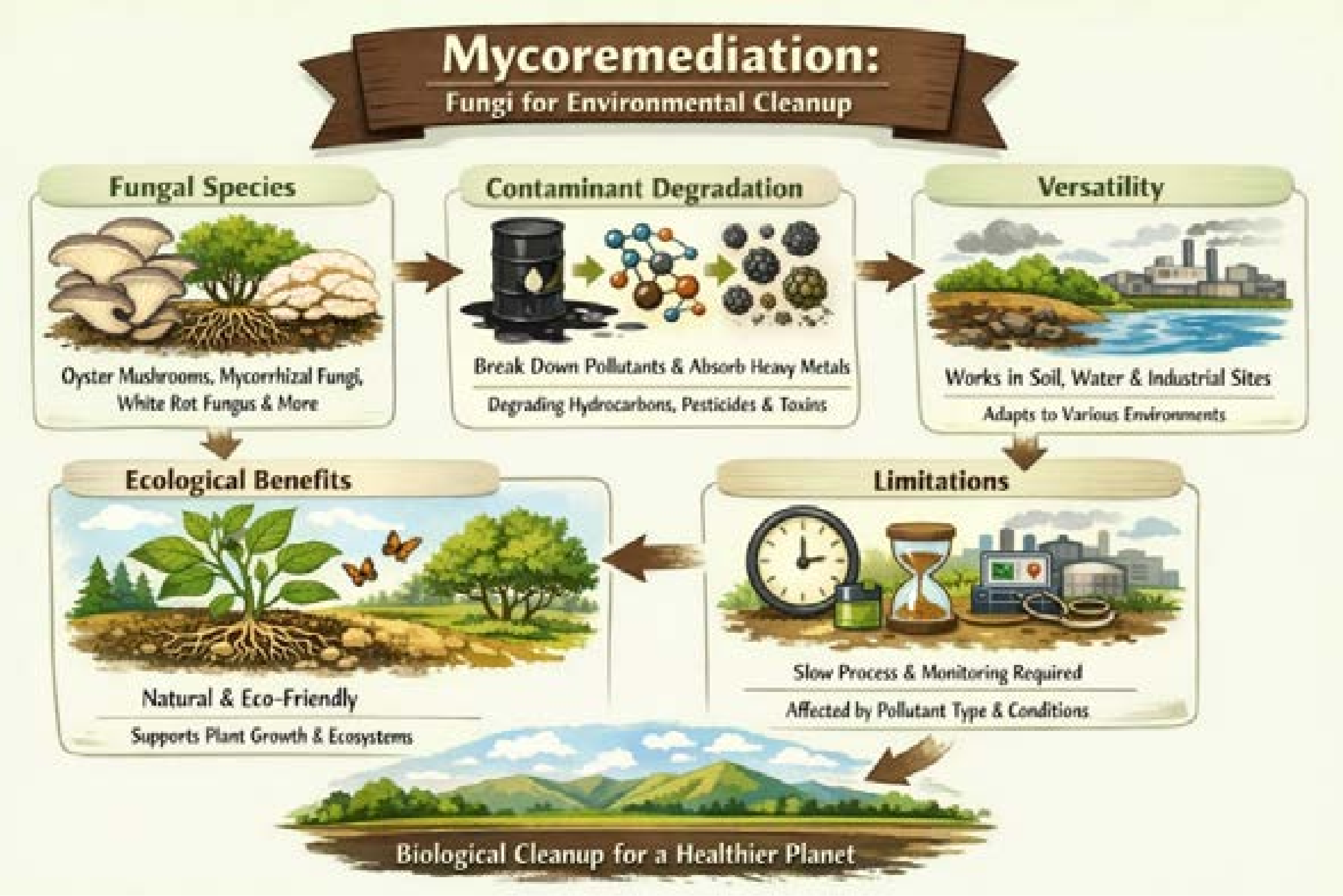

Figure 1. Conceptual diagram of mycoremediation and its mechanisms, applications and limitations.

Finally, there exists the problem of heavy metals, substances fungi are unable to decompose like they do with natural materials Thus comes the biosorption and bioaccumulation. Here, the cell wall plays a role, grabbing and trapping heavy metals using its chitin and other natural polymers. Some fungi even release sticky molecules called exopolysaccharides that form a biofilm, catching more metals and stopping them from getting inside the cell, where they'd cause real damage (Kumar et al., 2021).

Therefore, whether it is breaking down oil, neutralizing chemicals or immobilizing metals, fungi possess a remarkable set of abilities for restoring the environment.

Classification of microorganisms

Although there are 69,000 species of fungi worldwide, only a limited number have been linked to mycoremediation (Figure 2) (Pala et al., 2014).

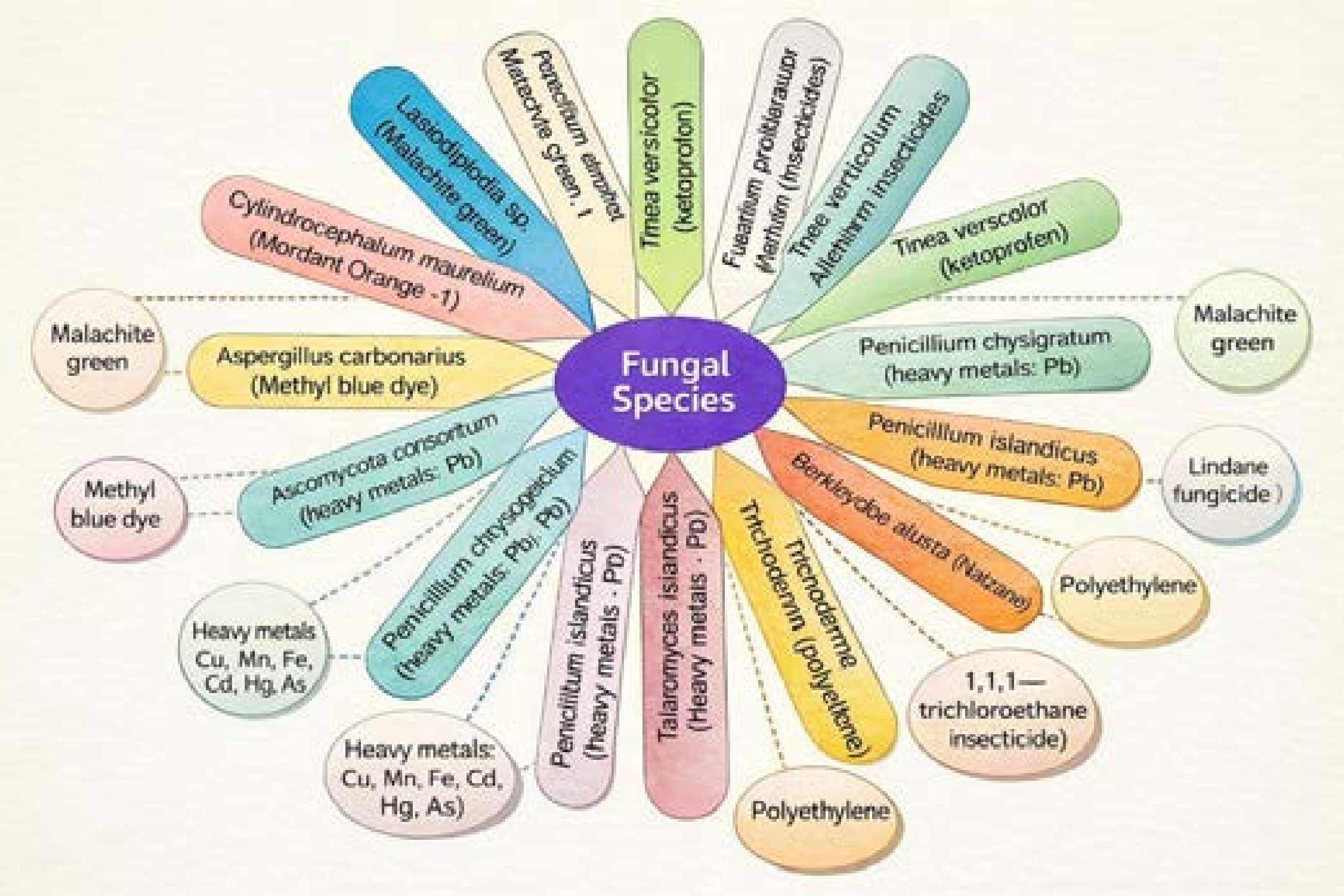

Figure 2: A visual map showing "which fungus can clean which pollutant" in mycoremediation

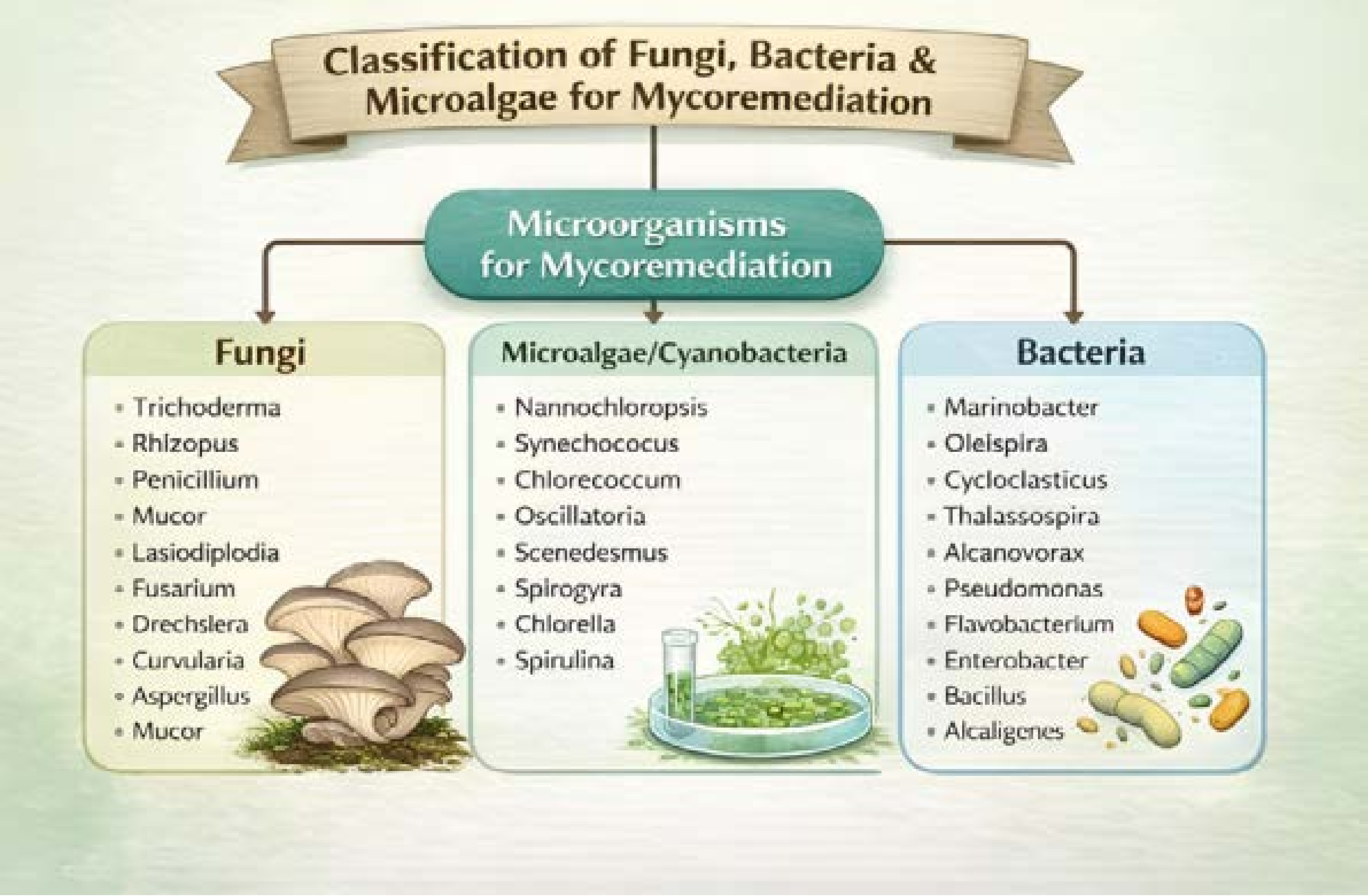

Figure 3: Classification of fungi, bacteria and microalgae (Self designed)

Highlights various key genera of fungi, bacteria and microalgae that play a role in bioremediation. Various factors, such as moisture, aeration, temperature, metal ion concentration, phosphorus availability, nitrogen, carbon and the growth and presence of fungi, are influenced by interspecific microbial competition (Lavelle and Spain, 2002).

Utilisation as a Sustainable Approach

The transition of mycoremediation from laboratory research to field-scale utilization represents a major step forward in building a circular bioeconomy and ensuring sustainable land governance. A primary utilization of this technology is the application of Spent Mushroom Substrate (SMS). SMS is the residual compost left over after the commercial cultivation of edible mushrooms. Because it remains thoroughly colonized by fungal mycelia and retains a high concentration of extracellular enzymes, SMS can be applied directly to degraded agricultural lands. This in-situ bio-amendment effectively degrades lingering pesticide residues while simultaneously improving soil structure and nutrient cycling (Nandini and Srinivasulu, 2025). Furthermore, the implementation of mycoremediation is increasingly supported by modern environmental policy. For instance, India's recent Environment Protection (Management of Contaminated Sites) Rules, 2025, establishes a strict statutory framework for identifying chemically contaminated sites and mandates rigorous remediation plans based on the "polluter pays" principle (MoEFCC, 2025). By integrating mycoremediation into standard agricultural and industrial waste management practices, ecosystems can be detoxified naturally. This biological approach completely eliminates the massive carbon footprint associated with traditional remediation, effectively returning degraded landscapes to a baseline state of health capable of supporting sustainable, climate-resilient agriculture (Akpasi et al., 2023).

Case studies: *Fusarium proliferatum* CF2 has demonstrated a high ability for the degradation of the insecticide allethrin, achieving up to 95% removal under aerobic conditions within five days, highlighting its potential application in pesticide-contaminated environments (Bhatt et al., 2020). Similarly, the ligninolytic fungus Trametes versicolor has shown significant ability in the removal of pharmaceutical pollutants such as ketoprofen, with approximately 80% reduction under controlled conditions, primarily due to its efficient laccase and peroxidase enzyme systems (Coelho et al., 2020). These studies clearly indicate that fungal-mediated processes are highly versatile and effective for the remediation of diverse environmental contaminants.

Emerging Aspects of Mycoremediation

In recent times, mycoremediation has taken notable improvements. Researchers are combining fungal systems and nanotechnology they refer to this as myco-nanotechnology and it's effectively extending the limits of how effectively we can eliminate pollutants. With this approach, fungi contribute to forming nano particles, that are all the same size, maintaining stability and proves to be an effective method to eliminate heavy metals and various dangerous compounds in the environment. Fungi like Fusarium, Aspergillus and Penicillium are already known for making nanoparticles including silver, gold, and platinum, thus they serve a dual purpose, aiding both environmental cleanup and the fabrication of useful nanomaterials. Fungi don't stop there. They furthermore decrease metal toxicity through biosorption and transformation, basically locking up dangerous metals or turning them into something less harmful. Alongside this, new molecular tools are making a difference. With genetic engineering and CRISPR-Cas systems, researchers are tuning fungi to be even better at breaking down pollutants. Introduce next-generation sequencing alongside gene editing to the mix, resulting in a clearer understanding of how fungi work at a metabolic level. This lets scientists develop even more effective fungal strains for cleaning up the environment. All these new strategies show how mycoremediation is growing not just as an eco-friendly fix, but as a high-tech, sustainable answer to our pollution problems.

Conclusion

Mycoremediation offers a promising, environment friendly and a sustainable solution to the increasing issues of environmental pollution. Fungi, known for their enzymatic systems and adaptability, are essential in degrading, transforming and immobilizing various contaminants, such as heavy metals, pesticides and industrial waste. In contrast to traditional remediation techniques, mycoremediation is more cost-effective, energy-efficient and less disruptive to natural ecosystems. Additionally, recent innovations like myco-nanotechnology and molecular tools have significantly improved its effectiveness and expanded its potential applications. Although there are some limitations concerning environmental conditions and scalability, ongoing research and technological advancements are anticipated to address these challenges. In summary, mycoremediation presents significant promise as a vital approach for rehabilitating contaminated environments and fostering sustainable ecosystem management in the future.

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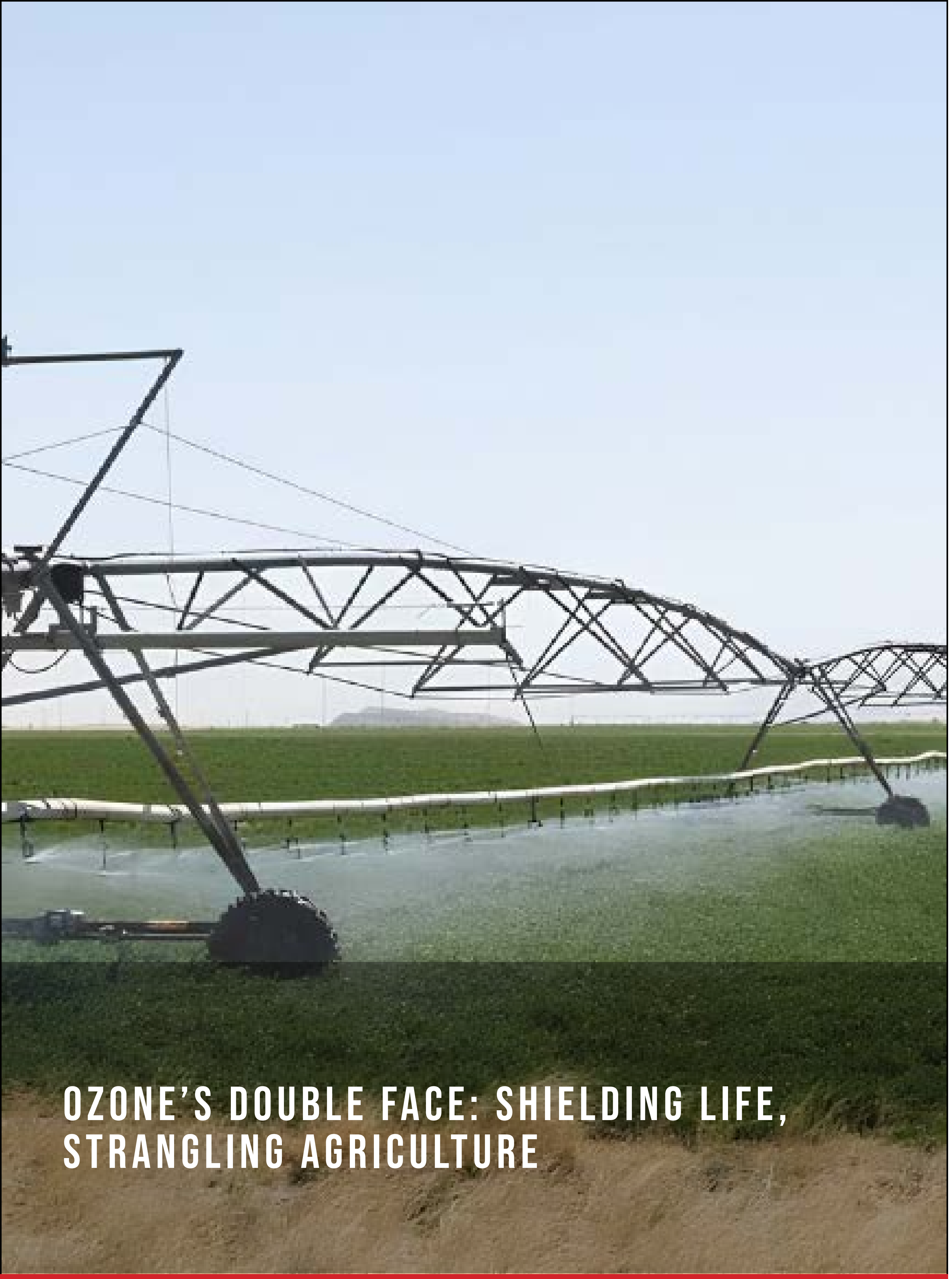

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Ozone's Double Face: Shielding Life, Strangling Agriculture

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Abstract

Tropospheric ozone (O3) has emerged as a major limitation to agricultural productivity as high surface concentrations (40-70ppb) of ozone inhibit photosynthesis, increase leaf senescence, and reduce time to gain filler grains. In sensitive C3 crops like rice and wheat, yields have decreased (11-20%). In highly cultivated areas such as the Indo-Gangetic Plain, the phytotoxic pollutant poses a major threat to food security and farmers' incomes. Nevertheless, significant research gaps remain in the connection between crop-level physiological harm and soil biogeochemical processes and greenhouse gas feedbacks, with most assessments based on concentration-based exposure measures rather than mechanistic ones. The paper is a synthesis of experimental data from open-top chamber experiments conducted at the Indian Agricultural Research Institute and other literature on the effects of ozone on the rice-wheat agroecosystem. Controlled exposure (60-70 ppb) significantly reduced rice yield (11-12%) due to a decrease in the number of tillers, filled grains, and test weight. In contrast, in wheat-based ecosystems, lower nitrogen uptake increased soil ammonium and nitrate concentrations, resulting in a nearly 15% increa-

-se in nitrous oxide (N_2O) emissions. The results demonstrate the dual effects of ozone: decreased crop productivity and strengthened climate feedbacks, underscoring the importance of combined mitigation and adaptive agronomic practices.

Introduction: Comprehending the Dual Nature of Ozone

Ozone (O_3) is a triatomic oxygen, which can only serve a purpose in the environment in its vertical distribution in the air. In the atmosphere at high altitudes, this plays a vital protective role for life. In contrast, at ground level, it causes negative impacts, including pollution, posing a threat to agriculture, ecosystems, and climate stability. This vertical contrast gives ozone a double face. Even though stratospheric ozone depletion has been prevented by global action under the Montreal Protocol, tropospheric ozone concentrations have increased by more than 2 times since the pre-industrial period. Surface ozone is a serious threat to crop productivity and food security nowadays, yet it remains largely unaddressed, especially in rapidly growing, industrialized areas (Ma et al., 2025).

Ozone in Different Atmospheric Layers: From Pollutant to Protective Shield

Ozone's role varies greatly with altitude. In the stratosphere, an area about 10-50 km above the Earth's surface, ozone concentrations create the ozone layer, which shields Earth's living organisms from the harmful ultraviolet-B (UV-B) radiation. This process occurs when high-energy ultraviolet radiation interacts with molecular oxygen (O_2), splitting the O_2 molecules into oxygen atoms, which then recombine with O_2 to form ozone. In the latter half of the twentieth century, the release of chlorofluorocarbons (CFCs) resulted in the depletion of the ozone layer, creating the ozone hole. However, international policies have helped restore the ozone layer, with complete recovery expected in the mid-twenty-first century.

Tropospheric ozone, by comparison, is a secondary pollutant produced by a series of photochemical reactions between nitrogen oxides (NOx), volatile organic compounds (VOCs) and methane (CH_4), along with carbon monoxide (CO) and sunlight. NO_2 (Nitrogen dioxide) is subject to photolysis, which produces atomic oxygen, which combines with the oxygen to form ozone. The disruption of the normal balance between nitric oxide and ozone in polluted atmospheres with high VOC concentrations leads to ozone accumulation. Whereas the ozone concentration in the pre-industrial period was about 10 to 15 parts per billion (ppb), current planetary values are 40 to 50 ppb, with even higher values in densely populated, highly developed areas such as the Indo-Gangetic Plain. Therefore, the same ozone that is helpful in the stratosphere is a phytotoxic pollutant in the troposphere, contributing to photochemical smog, greenhouse gas forcing, and agricultural damage.

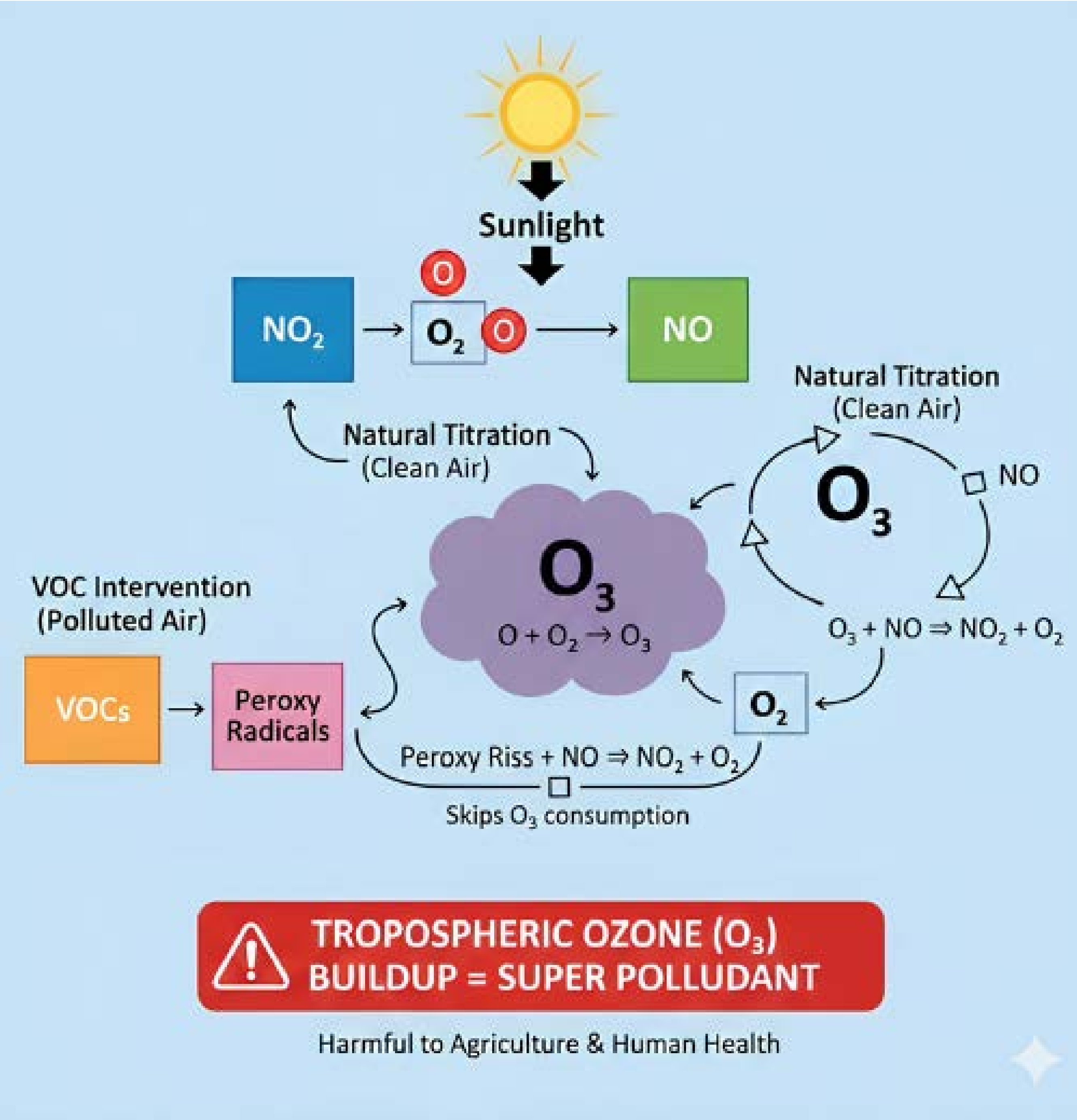

Fig. 1: Tropospheric Ozone's Photochemical Formation and Accumulation Mechanism under NO–VOC Interactions

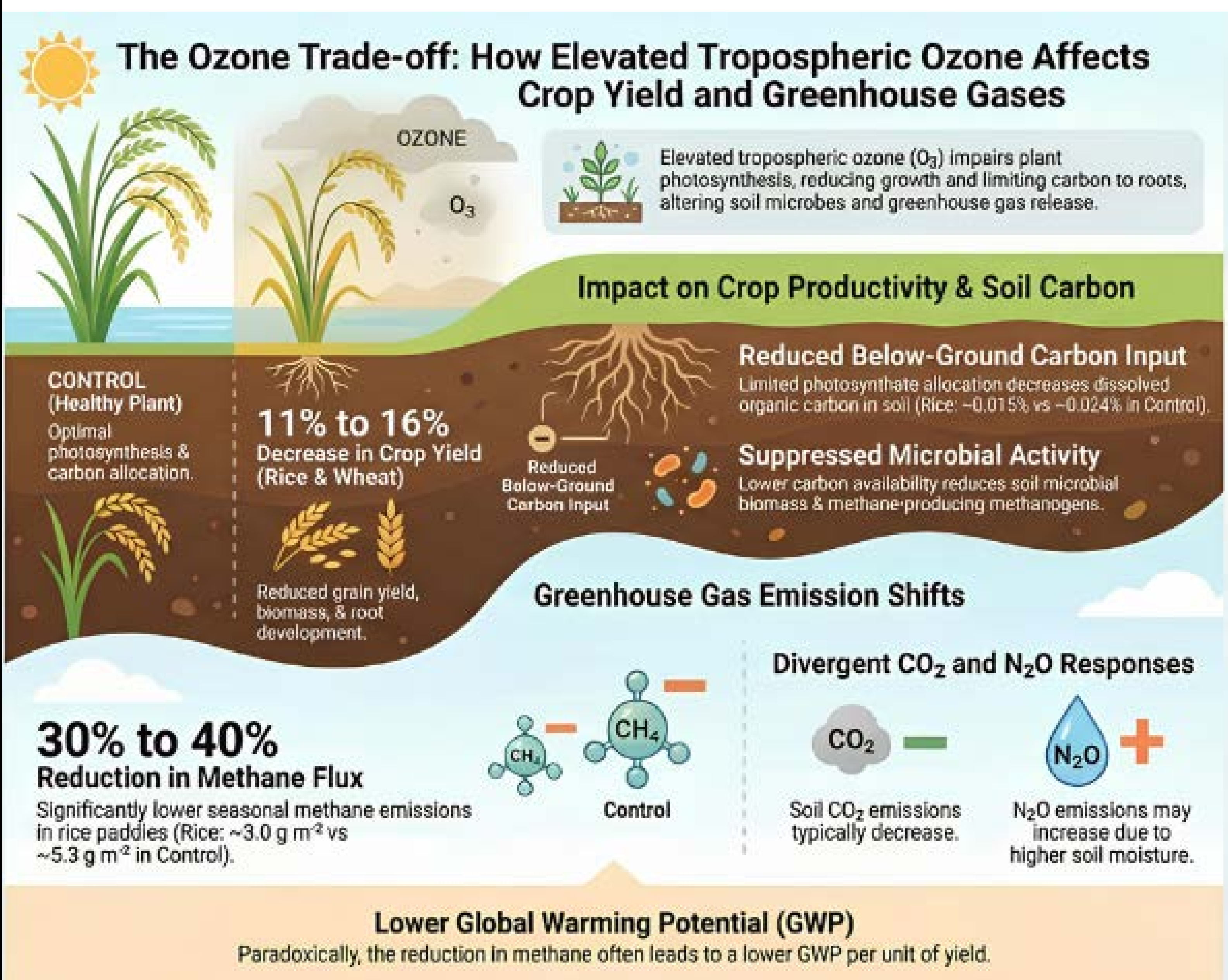

Fig. 2: Mechanistic Impact of Increased Tropospheric Ozone on Rice-Wheat Systems' Greenhouse Gas Fluxes, Soil Carbon Dynamics, and Crop Productivity

Effects of Physiology on Crop Plants

Reactive oxygen species (ROS) are produced in leaf tissues when tropospheric ozone enters plants through stomata during gas exchange. These reactive chemicals inhibit carbohydrate synthesis by damaging chloroplasts, blocking the photosynthetic electron transport chain, and decreasing Rubisco enzyme activity. Additionally, partial stomatal closure induced by ozone exposure limits carbon dioxide uptake, leading to carbon starvation. Chlorosis and early senescence, which shorten the grain-filling period, are visible symptoms.

Because they lack the carbon-concentrating mechanisms that C4 crops have, C3 crops—like rice and wheat—are especially vulnerable. Reduced biomass, poor grain development, and a notable yield decline are the cumulative results (Nowroz et al., 2024).

Rice Agroecosystems evidence

Experimentation at the Indian Agricultural Research Institute in New Delhi, using open-top chambers, showed significant damage to rice systems caused by ozone. The impacts of a high ozone concentration (around 60-70 ppb) were a 11-12% reduction in grain yield relative to the ambient environment. The most important yield parameters included the number of tillers, the number of filled grains per panicle, and test weight, all of which decreased significantly. Grain-filling was also shortened by accelerated leaf senescence. These results show that exposure to ozone, rather than variation in microclimatic conditions, was the most important cause of yield losses (Singh et al., 2015).

Nitrous Oxide Increase in Wheat Systems

In upland wheat ecosystems, ozone exposure increases nitrous oxide (N2O) emissions. Lower plant growth translates to lower nitrogen uptake, resulting in higher concentrations of ammonium and nitrate in the soil. At the same time, lower transpiration rates lead to higher soil moisture, thereby enhancing denitrification. Consequently, N2O emissions rise by 15%. This is a critical climate feedback response given N2O's high global warming potential (Hu et al., 2018).

Implications for the Economy, Policy, and Sustainability

Climate policy, farmer livelihoods, and food security are all significantly impacted by tropospheric ozone. Estimates of ozone-induced crop losses worldwide range from 79 to 121 million tonnes per year, translating into annual economic damages of roughly 11 to 18 billion US dollars. High precursor emissions and the intensive production of sensitive crops like wheat and rice make regions like East Asia and North India especially vulnerable. In areas with high population density, yield reductions endanger nutritional quality and calorie supply, in addition to lowering farmers' incomes. To deal with this challenge, a combined mitigation and adaptation framework is needed. The best way to reduce surface ozone levels is to reduce emissions of nitrogen oxides, volatile organic compounds, and methane, and mitigating methane offers particularly good prospects for reducing background ozone. At the same time, resilience to oxidative stress can be improved through agricultural adaptation strategies such as the development of ozone-tolerant cultivars, nutrient management and optimization, and diversification of cropping systems.

Conclusion

At the end, we can say Ozone is a deep paradox of the atmosphere: it protects life in the stratosphere but destroys agricultural sustainability on the ground. The empirical data on 11-20 per cent yield reduction, disturbed soil carbon cycling, and altered greenhouse gas fluxes confirm that air pollution, climate regulation, and agricultural sustainability are interwoven issues. The protection of the shield function of the atmosphere and the mitigation of the agricultural "strangler" paradox are therefore imperative strategic needs.

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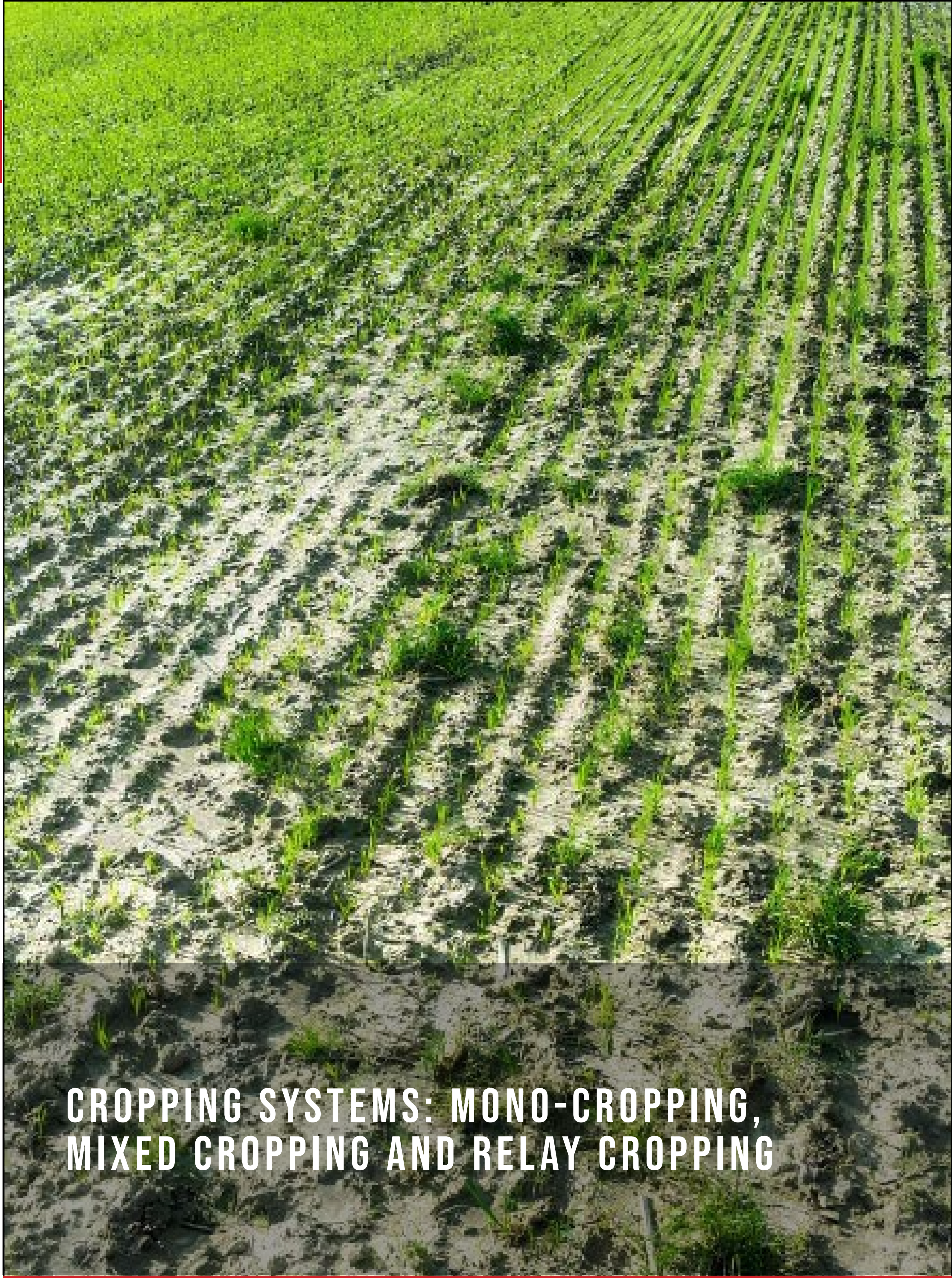

CROPPING SYSTEMS: MONO-CROPPING, MIXED CROPPING AND RELAY CROPPING

EDITION: VOLUME 02, ISSUE 03 , - MARCH 2026

Cropping Systems: Mono-Cropping, Mixed Cropping and Relay Cropping

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Abstract

Cropping systems play a crucial role in enhancing agricultural productivity and sustainability. This study evaluates three major systems monocropping, mixed cropping, and relay cropping with emphasis on their management practices, advantages, limitations, and ecological implications. A comprehensive review of peer-reviewed literature was undertaken to synthesize information on key parameters such as yield performance, pest dynamics, soil health, and biodiversity. The analysis indicates that monocropping ensures operational efficiency and is well-suited for large-scale mechanized farming; however, it is often associated with higher susceptibility to pests, diseases, and soil degradation. In contrast, mixed cropping improves resource use efficiency, minimizes production risks, and enhances ecological resilience. Relay cropping offers significant potential for maximizing land use efficiency and sustaining productivity across varied agro-climatic conditions. Overall diversified cropping systems demonstrate superior performance in sustainability indicators, highlighting the importance of integrated and location-specific approaches for achieving long-term agricultural resilience and environmental sustainability.

Keywords: Cropping systems, biodiversity, mixed cropping, ecology and agro-climatic.

Introduction

Agricultural production systems have evolved over centuries in response to climatic conditions, resource availability, socio-economic factors, and technological advancement. A cropping system refers to the sequence and arrangement of crops grown on a particular field over time, including management practices associated with planting, harvesting, and resource use (Gliessman, 2014). Sustainable cropping systems are essential for maintaining soil fertility, optimizing resource efficiency, and enhancing resilience against environmental stressors. Among, the diverse cropping systems practiced worldwide, monocropping, mixed cropping, and relay cropping represent distinct strategies with varying ecological, agronomic, and economic implications. Understanding these systems is fundamental for designing resilient agricultural models capable of meeting global food demands.

Key Agronomic Practices:

1. Agronomic practices vary across cropping systems to optimize yields, manage resources, and mitigate risks.

2. For monocropping, key practices include soil testing for precise fertilization, crop rotation every 2-3 years to break pest cycles, and integrated pest management (IPM) using biological controls and selective pesticides.

3. Irrigation scheduling via drip systems conserves water, while tillage practices like no-till reduce erosion (Francis, 1986).

4. In mixed cropping, practices emphasize companion planting for synergy, such as spacing maize and legumes to avoid competition.

5. Nutrient management involves organic amendments like compost, and weed control relies on mulching and manual weeding.

6. Pest management uses trap

1. crops and natural predators, with harvesting timed to maximize intercrop benefits.

2. Relay cropping requires precise timing: the relay crop (e.g., legumes) is sown 2-4 weeks before the main crop’s harvest.

3. Practices include staggered planting to ensure canopy overlap, soil moisture monitoring to prevent water stress, and nutrient application split between crops.

A. Mono-cropping

Monocropping, or sole cropping, involves cultivating a single crop species on a given field during one growing season.

Advantages

1. **Specialized crop management:** Uniform crop requirements simplify irrigation, fertilization, and pest management.

2. **Mechanization suitability:** Large mono-cropped fields enhance the efficiency of tractors and harvesting machinery.

3. **Higher short-term yields:** Focused nutrient and input management can maximize crop-specific performance.

Limitations

1. **Pest and disease vulnerability:** Genetic homogeneity increases susceptibility to outbreaks.

2. **Soil nutrient depletion:** Repeated cultivation of the same crop can cause nutrient imbalance and soil exhaustion.

3. **Reduced biodiversity:** Limits beneficial microflora and fauna essential for ecosystem stability.

B. Mixed Cropping

Mixed cropping refers to growing two or more crops simultaneously on the same land without a predetermined row arrangement.

Advantages

1. **Risk reduction:** Failure of one crop may be compensated by another.

2. **Improved resource-use efficiency:** Different crops exploit soil nutrients, sunlight, and water differently.

1. **Enhanced biodiversity:** Supports beneficial insects, improves soil health, and reduces pest outbreaks.

2. **Soil fertility improvement:** Leguminous crops fix atmospheric nitrogen, enriching the soil.

Limitations

1. **Difficult mechanization:** Mixed crops often require manual operations.

2. **Competition for resources:** If not properly planned, crops may compete for water, nutrients, and light.

3. **Complex management:** Requires species compatibility knowledge.

C. Relay Cropping

Relay cropping is a sequential cropping system where a second crop is sown into a standing crop before the first crop is harvested. An example is sowing lentils into standing rice nearing maturity.

Advantages

1. **Efficient resource utilization:** Light, moisture, and soil nutrients are used throughout the season without long fallow periods.

2. **Reduced turnaround time:** Eliminates the need to wait for complete harvesting of the previous crop (Andrews & Kassam, 1976).

3. **Higher land-use efficiency:** Supports intensive agriculture and improves annual productivity.

Limitations

1. **Operational complexity:** Timing of sowing is crucial.

2. **Competition during overlap period:** The young crop may face shading or nutrient stress.

3. **Requires precise agronomic planning:** Not suitable for all crop combinations.

Conclusion

Cropping systems vary widely in their design, ecological impact, and productivity potential. Monocropping is efficient for large-scale mechanized agriculture but poses sustainability challenges due to biodiversity loss and soil degradation. Mixed cropping enhances stability, resilience, and ecological balance but may limit mechanization options. Relay cropping optimizes temporal use of land resources and improves productivity, particularly in regions with short growing seasons or limited land availability. Sustainable agriculture requires integrating these systems based on local agro-climatic conditions, resource availability, and socio-economic factors. A balanced approach combining ecological benefits of mixed and relay systems with the efficiency of monocropping can support long-term agricultural sustainability and food security.

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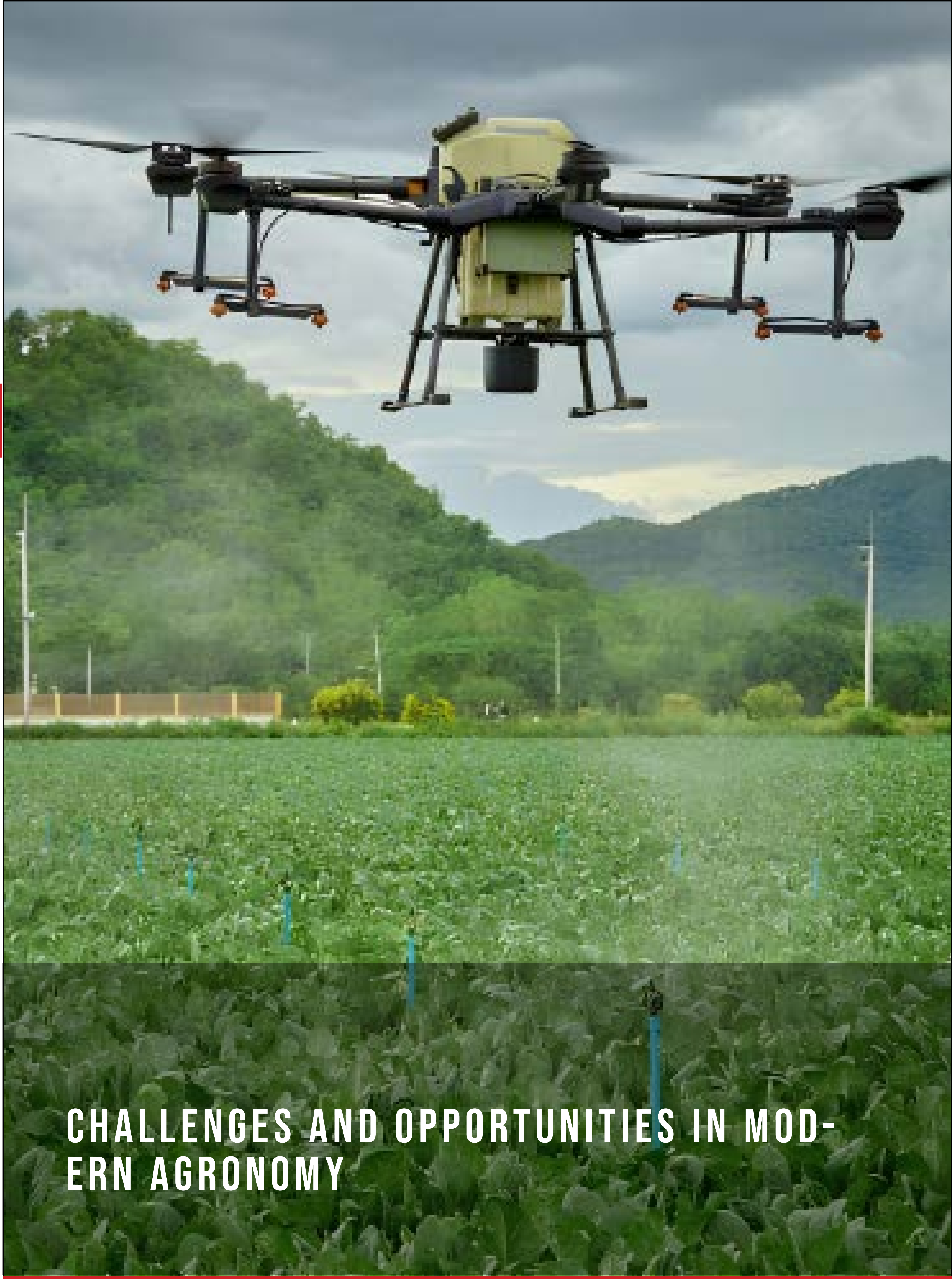

CHALLENGES AND OPPORTUNITIES IN MODERN AGRONOMY

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Challenges and Opportunities in Modern Agronomy

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Abstract

With the constantly increasing population and extended urbanization, people's migration toward cities and fragmentation of agricultural land is increasing day to day. This stands to be the biggest challenge faced by agriculture and mankind in the near future. The problems mentioned here in this article are considered to be modern agricultural challenges like climate change, development of resistance among species and subspecies, inflation etc. Apart from this, there is a complete change in the trend and tastes of the consumers regarding food and eating habits. Loss of biodiversity, decreasing underground water levels and land productivity are some of the results of the past actions by mankind. With the advent of newer technologies, there comes new problems too. Skillset and availability of skilled labour come under this category. Some of the solutions include Climate-Smart Agriculture, Adopting Ag-Tech, treated seeds & Genetically Modified Crops, protected agriculture & Precision Agriculture, Improved Management Practices, adopting new technologies like Data analysis, Big Data, Drone technology and others. A detailed set of challenges faced by the farmers in recent agriculture and the acts of solutions that can withhold and improve the state of agriculture and its dependents.

Keywords: Agronomy, climate change, precision farming, sustainability and resource efficiency

Introduction

The global population is expected to reach 9.5 billion by 2030. Developing and underdeveloped nations will see a way bigger population surge. People moving from rural to urban areas for a better life puts finite resources in relatively smaller areas under crazy pressure. This messes with the economy of these nations and makes the challenges with sustainable agriculture production and land management even worse. Modern agriculture faces a bunch of challenges like climate change, soil management, keeping crops healthy, and boosting soil biodiversity worldwide. With population growth and urbanization happening fast, the land available for farming is shrinking like crazy. This brings up big questions about nutrition and food security for the growing population worldwide. Plus, people's lifestyles are changing, leaving them dealing with malnutrition issues. The farming community and research groups globally be on top of their game with lots of other factors. Here's what they are dealing with climate change, soil erosion, underground water levels dropping, biodiversity loss, population rising, urbanization, migration, labour availability and agricultural land shrinking.

Climate change

Climate change refers to long-term shifts in global average temperatures and other weather patterns such as precipitation etc. The impact of global warming is causing climate change and the consequences are being felt around the world in different ways (IPCC, 2014). Consequently, some parts of the world are facing severe drought, whereas others are facing severe floods. Further, there is a chance of submergence in the coastline city and habitats too (Irrgang et al., 2022). Increases in temperature have been shown to decrease crop yields over time, while simultaneously encouraging the growth of weeds and pests, making agriculture highly susceptible to climate change (Malhi et al., 2021). Some major problems like methane mitigation in paddy fields, and livestock rearing has to be addressed with immediate effect. Agriculture, forestry and other land use cause 23% of the greenhouse emissions.

Natural Calamities

Natural calamities pose a very big threat to agriculture. Some of the major natural calamities include floods, droughts, tsunamis etc. A large amount of fertile land suitable for cultivation may submerge under the water and there may be chances of soil erosion due to flash floods and tsunamis. Global warming and its consequences are one of the reasons for flash floods and submerging of coastal lands due to increased mean sea levels. Agriculture sector is extremely vulnerable to the natural catastrophes such as droughts, floods, storms and tsunamis in developing nations and could lose nearly a quarter of the total yield.

Soil erosion

Soil erosion happens when water or wind breaks off and takes away soil particles, causing soil to degrade. This impacts how productive the soil is and whether it's sustainable for farming. Right now, only about 12% of the world's land is good for farming. Soil erosion hurts agriculture big time. The consequences include less productivity, lower yields, less efficient irrigation, and reduced land suitability. Recent studies show that the rate at which land is getting taken over by degradation is as high as the rate at which land is getting degraded.

Land limitations

1. You can't grow every crop on any piece of land. Different soils have different things like structure, texture, fertility, water availability, and agro-meteorological factors.

2. These things affect how productive the land and crops are, limiting what crops you can grow where.

3. Along with environmental factors, how farmers do things impacts soil quality. Soil degradation eats away at natural resources.

4. This means we need to take care of the soil so it stays productive.

Opportunities in Modern Agronomy

1. **Precision Agriculture and Smart Farming:** Precision agriculture utilizes advanced technologies like GPS, IoT sensors, AI, and drones to optimize farming practices. Researchers are exploring ways to improve real-time monitoring, automated irrigation, and site-specific crop management to enhance productivity while minimizing

1. resource wastage.

2. **Climate-Resilient Crops:** With climate change threatening food security, scientists are developing drought-resistant, flood-tolerant, and heat-resistant crops through genetic modification and selective breeding. This research ensures stable crop production in extreme weather conditions.

3. **Vertical and Urban Farming:** The rising global population and decreasing arable land have led to innovative farming solutions like vertical farming and hydroponics. Researchers are focusing on sustainable urban agriculture to produce fresh food locally, reducing dependence on traditional farmland.

4. **Soil Health and Regenerative Agriculture:** Soil degradation is a critical issue, prompting research into regenerative farming practices such as cover cropping, no-till farming, and organic composting. These methods help restore soil fertility, increase microbial activity, and enhance carbon sequestration.

5. **Sustainable Pest and Disease Management:** Integrated pest management (IPM) strategies, including biopesticides, beneficial insects, and AI-driven early detection systems, are being developed to reduce dependency on chemical pesticides and minimize environmental impact.

6. **Agri-Biotechnology and Genetic Engineering:** Advances in biotechnology, such as CRISPR gene editing, are enabling scientists to enhance crop resistance, improve nutritional content, and develop biofortified crops that combat malnutrition worldwide.

Conclusion

The planet's needs and the expectations of the consumers are changing with time recently. The state of agriculture is to be changing with regard to meeting these. Simultaneously, the pressure over the sector to thrive through the challenges clouding stands to be an obligatory mission. For this purpose, the identification of problems and their solutions is important for meeting the basic necessities of the world. It concentrated on recognizing the most important challenges faced in the agriculture sector and the farmer community and also has discussed a few subjects which have the capability to resist the challenging issues. Farmers face climate change, soil fertility loss, resource availability, urbanization, etc. However, there are aspects like, climate smart agriculture, GM crops, agriculture technologies etc., that can stand in par with these problems as solutions. Nevertheless, the outcomes for these solutions can be varying based on various factors like, type of soil, possible investment, sources available. Considering all these points, the agriculture sector has to be given a strength of push for it to stand tall and meet the par necessities of the population.

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