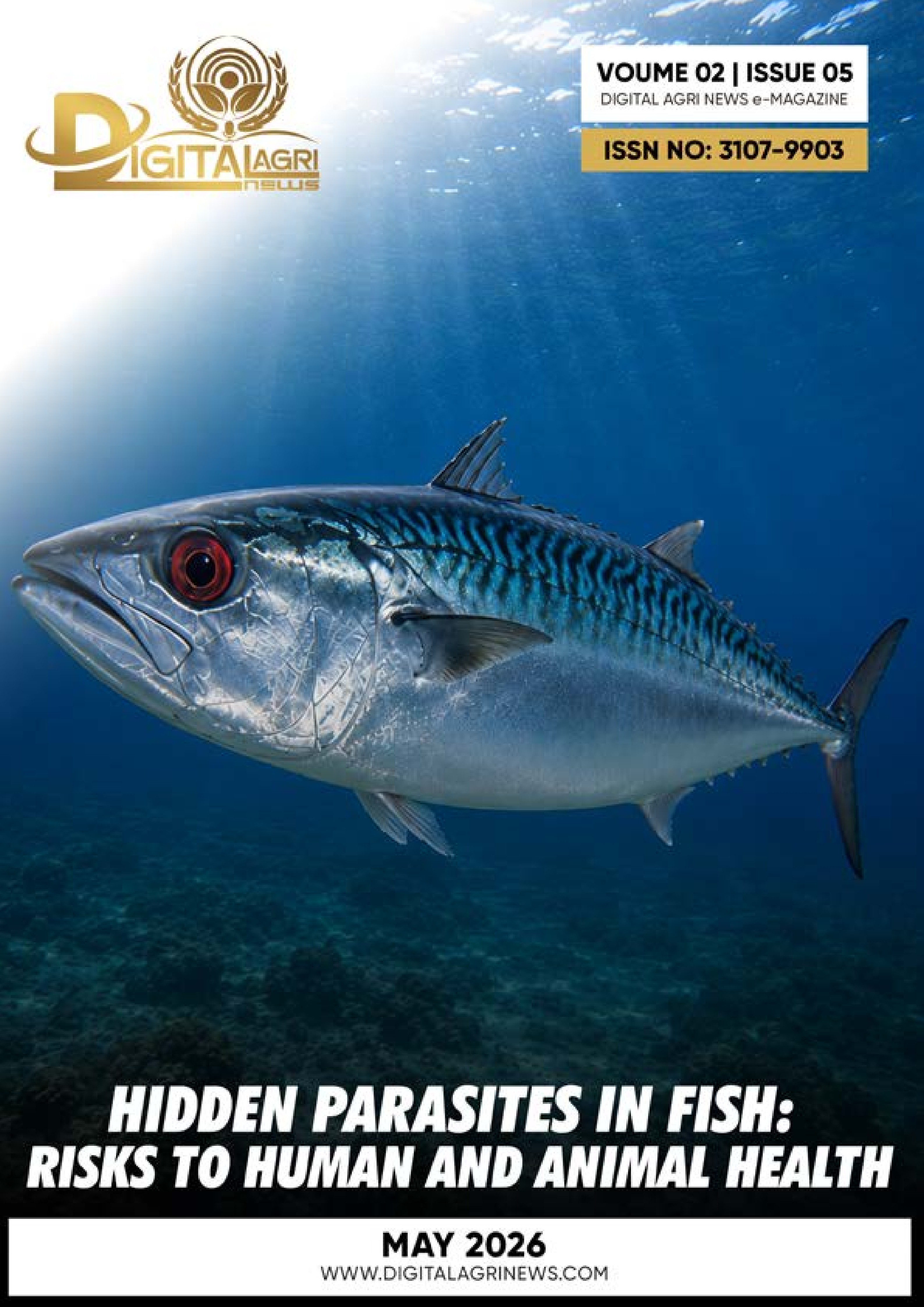
VOUME 02 | ISSUE 05
DIGITAL AGRI NEWS e-MAGAZINE
ISSN NO: 3107-9903



HIDDEN PARASITES IN FISH: RISKS TO HUMAN AND ANIMAL HEALTH

MAY 2026
WWW.DIGITALAGRINEWS.COM

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.

From market trends and crop prices to climate alerts and weather updates, from emerging technologies and sustainable practices to policy reforms and government schemes, we cover everything that matters to the agricultural community. Our goal is to empower you with knowledge that helps you make better decisions — in the field, in the marketplace, and for the future. We also believe in celebrating the spirit of farming. Through farmer success stories, expert interviews, and global agri innovations, we highlight the resilience and creativity that keep agriculture thriving even in challenging times. Every story we share is a step toward building a stronger, more connected, and more informed agri-ecosystem.

At Digital Agri News, we go beyond headlines — we provide insights, analysis, and solutions that matter. By bridging the gap between technology and tradition, policy and practice, local needs and global opportunities, we strive to create a platform where every voice in agriculture is heard and valued.

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

Greetings from Digital Agri News Magazine!

DR. ANKIT SAINI
Assistant Professor and Head
Department of Agronomy
Dr. KSG Akal College of Agriculture
Eternal university Baru Sahib Sirmour
HP

It is my pleasure to present Volume 02 - Issue 05, featuring a collection of articles that reflect the evolving landscape of modern agriculture and its role in ensuring food security, environmental sustainability, and rural prosperity.

This issue highlights several important themes, including precision farming, climate-resilient agronomic practices, sustainable nutrient management, and natural farming approaches. These topics demonstrate how scientific innovations and digital technologies are helping farmers improve productivity while conserving water, soil, and other vital resources.

A special focus has been placed on environmental sustainability through discussions on nitrous oxide emissions and their implications for climate change. The issue also explores advancements in cereal crop production, emphasizing resource-use efficiency, conservation agriculture, and climate-smart farming strategies. Additionally, readers will find valuable insights into fish-borne parasitic diseases and food safety concerns, underlining the importance of sustainable practices across agricultural and allied sectors.

At Digital Agri News, our mission is to bridge the gap between research and practice by sharing reliable, relevant, and actionable knowledge with farmers, students, researchers, and agri-professionals. We sincerely thank our authors, reviewers, and readers for their continued support. We hope this issue inspires innovation, informed decision-making, and a collective commitment toward a sustainable and resilient agricultural future.

Dr. Ankit Saini

Warm Regards

Editor-in-Chief

Digital Agri News Magazine

TABLE OF CONTENTS

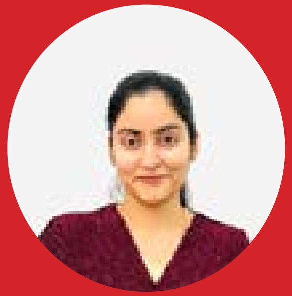
EDITORIAL BOARD MEMBER

DR. AKASHDEEP SINGH

Assistant Professor,
Department of Agronomy Dr. Khem Singh
Gill Akal College of Agriculture, Eternal
University, Baru Sahib, Sirmaur (HP)

DR. PRANEET CHAUHAN

Assistant Professor (Plant Pathology)
Dr. K.S. Gill Akal College of
Agriculture, Eternal University, Baru
Sahib (H.P.)



BHAVNEET KOUR

Project associate -I
Sher-e-Kashmir University
of Agricultural Sciences &
Technology of Jammu , Rs Pura

HIDDEN PARASITES IN FISH: RISKS TO HUMANS AND ANIMALS

**DR. NABANITA GANGULY[1], DR. JEEMI A PATEL[1]
, DR. BHUPENDRAKUMAR J THAKRE[2]**

Hidden Parasites in Fish: Risks to Humans and Animals

Dr. Nabanita Ganguly[1], Dr. Jeemi A Patel[1], Dr. Bhupendrakumar J Thakre[2]

[1] *Assistant Professor, Department of Veterinary Parasitology*
[1] *Associate Professor, Department of Veterinary Parasitology*
[2] *College of Veterinary Science and Animal Husbandry Kamdhenu University, Himmatnagar-383010*

ISSN No.: 3107-9903
Frequency: Monthly
Month: May
Volume- 2, Issue- 5

In terms of any communication correspondence is pertained to: *nabanitaganguly@kamdhenuuni.edu.in*

Introduction

Food-borne parasitic diseases (FBPB) can affect both humans and animals and may cause serious health problems. Earlier, these diseases were mainly found in developing countries because of poor hygiene, unsafe drinking water, and improper handling of food products. However, with increasing globalization, changing food habits, expansion of international food trade, consuming raw or undercooked fish and contaminated food products these infections are now becoming a worldwide concern. Lack of sanitation and awareness further supports the spread of these diseases (Tumbarski *et al.,*2020). According to the Food and Agriculture Organization, aquaculture is the fastest-growing food production sector globally and with the increasing production and consumption of fish, fish-borne zoonotic diseases are also rising worldwide. The World Health Organization estimates that nearly half a billion people are infected with fish-borne trematodes. This article highlights the major fish-borne parasitic diseases affecting humans and animals worldwide and explains their public health importance which are mainly spread through the consumption of raw or undercooked fish and are becoming an emerging food-borne health concern. Therefore, proper cooking of food, maintenance of hygiene, and public awareness are essential to protect both animal and human health from food-borne parasitic infections (McConnell JFP, 1875).

Fish-derived zoonotic parasites are commonly encountered in freshwater, brackish, and marine ecosystems. Several parasitic helminths, including Liver flukes (*Clonorchis, Opisthorchis, Metorchis*), Intestinal flukes (*Heterophyes, Metagonimus*), *Echinostoma, Paragonimus, Diphyllobothrium, and Anisakis spp.*, Protozoa like *Entamoeba, Giardia, Balantidium, Cryptosporidium* etc. are transmitted through the consumption of raw or inadequately cooked fish containing infective larval stages. Traditionally, these fish-borne zoonotic infections have predominantly affected populations in low- and middle-income countries, where poor sanitation, inadequate food safety measures, traditional dietary practices, and limited public awareness contribute significantly to disease transmission and persistence.

Clonorchiasis

Clonorchis sinensis, commonly known as the Chinese liver fluke, is a fish-borne zoonotic trematode that infects humans and fish-eating animals. It inhabits the bile ducts of the liver and causes clonorchiasis, mainly through the consumption of raw or undercooked freshwater fish. The disease is commonly reported in Asian countries. C. *sinensis* was first found in 1874 in a male Chinese in Calcutta, India, by J. F. P. McConnell.

Life Cycle

Clonorchis sinensis has a complex life cycle involving humans and fish-eating mammals as definitive hosts, while freshwater snails and fish serve as intermediate hosts. Eggs containing miracidia are passed in the faeces of infected hosts and are ingested by freshwater snails, where they develop into sporocysts, rediae, and cercariae through asexual reproduction. After approximately three months, cercariae are released from the snails and penetrate freshwater fish, where they encyst in muscles or subcutaneous tissues as metacercariae. Humans become infected by consuming raw or undercooked infected fish. The metacercariae excyst in the intestine, migrate to the bile ducts, and mature into adult flukes. Egg production begins about four weeks later, and an adult fluke may produce approximately 3,000–4,000 eggs per day (Kim *et al.*, 2011).

Clinical Symptoms

Many mild infections remain

asymptomatic, while heavy infections may produce abdominal pain, indigestion, diarrhoea, fever, jaundice, hepatomegaly, inflammation of bile ducts, Gall bladder disorders etc.

Global Distribution

Globally, approximately 7–10 million people are infected with *Clonorchis sinensis*. The infection is more prevalent in countries where consumption of raw or undercooked fish is common, particularly in parts of Asia such as South Korea, China, Taiwan, northern Vietnam, Japan, and the far-east region of Russia. A countrywide survey reported the prevalence of C. *sinensis* infection to be approximately 0.4% among nearly 1.5 million individuals (Xu *et al.*, 1995).

Opisthorchis

Opisthorchis viverrini is a fish-borne zoonotic liver fluke (trematode parasite) commonly found in Southeast Asia, especially in Thailand, Laos, Cambodia, and parts of Vietnam. Humans and fish-eating mammals become infected by consuming raw or undercooked freshwater fish containing infective larvae (metacercariae). The adult flukes inhabit the bile ducts of the liver and may cause chronic hepatobiliary disease and cholangiocarcinoma (Sripa *et al.*, 2018).

Life Cycle:

Adult flukes reside in the bile ducts of humans, dogs, cats, and other fish-eating mammals, where they produce eggs that are passed in the feces into freshwater. The eggs are ingested by freshwater snails of the genus *Bithynia*, which serve as the first intermediate host. Inside the snail, the parasite develops through miracidium, sporocyst, redia, and cercaria stages. The free-swimming cercariae leave the snail and penetrate freshwater cyprinid fish, the second intermediate host, where they encyst in the muscles as metacercariae, the infective stage. Humans and other definitive hosts become infected by consuming raw or undercooked infected fish. After ingestion, the metacercariae excyst in the duodenum, migrate to the bile ducts of the liver, and mature into adult flukes.

Clinical symptoms:

Indigestion, stomach pain, diarrhoea, and constipation are common symptoms. Abdominal pain, nausea, and diarrhea might develop in severe cases. Fever, facial puffiness, enlarged lymph glands, aching joints, and rash are also symptoms of O. *viverrini infections*.

Metorchis

Metorchis conjunctus, the canadian liver fluke, is a parasite that causes metorchiasis through the ingestion of infected fish containing metacercariae. The life cycle involves Amnicola limosus as the first intermediate host and freshwater fish, including northern pike, as the second intermediate host. Humans may pass eggs of M. conjunctus in their stools, although infections are often asymptomatic (Kiyan *et al.*, 2018).

Heterophyes

Heterophyes heterophyes is a minute fish-borne zoonotic trematode that infects humans and fish-eating animals. Infection occurs through the consumption of raw or undercooked fish containing metacercariae. It is an important cause of heterophyidiasis in endemic regions, particularly around the Nile Delta (Bardhan *et al.*, 2002).

Life Cycle:

The life cycle of H. *heterophyes* involves snails as the first intermediate host and fish, especially mullets (*Mugil cephalus*), as the second intermediate host. Eggs passed in feces hatch in water and infect aquatic snails, where the parasite develops into cercariae. Cercariae leave the snail and penetrate fish, encysting as metacercariae in the muscles or scales. Humans and fish-eating mammals become infected after consuming raw or undercooked infected fish. Adult flukes develop in the small intestine and begin producing eggs that are passed in feces.

Clinical Signs

Common clinical signs of infection with *Heterophyes heterophyes* include diarrhoea, abdominal discomfort, colicky pain, indigestion, chronic enteritis, mucosal ulceration, and eosinophilia, while migration of parasite eggs to the heart may occasionally cause severe cardiac damage.

Metagonimus

Metagonimus has a broad fish host specificity, with sweetfish *(Plecoglossus altivelis)* serving as the major fish host. Humans acquire infection by consuming raw or undercooked infected fish. Adult flukes attach to the mucosa of the small intestine, causing metagonimiasis characterized by villous atrophy and mucosal hyperplasia (Uppal & Wadhwa).

Life Cycle:

The life cycle of *Metagonimus spp*. involves two intermediate hosts and one definitive host. Adult flukes live in the small intestine of humans and fish-eating mammals, where eggs are passed in feces into freshwater. The eggs are ingested by freshwater snails, the first intermediate host, in which the parasite develops through sporocyst, redia, and cercaria stages. Free-swimming cercariae leave the snail and penetrate freshwater fish, especially sweetfish *(Plecoglossus altivelis),* where they encyst as metacercariae in the tissues. Humans and other definitive hosts become infected by consuming raw or undercooked infected fish. After ingestion, metacercariae excyst in the small intestine and mature into adult flukes, completing the life cycle.

Clinical Signs

Common clinical signs of *Metagonimus* infection include fatigue, epigastric discomfort, diarrhoea, anorexia, abdominal pain, malabsorption, and weight loss, while severe infections may lead to tissue granuloma formation, convulsions, and neurological impairments due to ectopic egg deposition.

Echinostoma

Echinostomiasis is a food-borne parasitic infection acquired by consuming raw or undercooked fish and other aquatic foods containing metacercariae. Smelts and loaches are important sources of infection, particularly in Arctic regions. Clinical signs include abdominal pain, diarrhoea, anorexia, duodenal mucosal bleeding, and ulceration caused by the spines of the adult flukes. Praziquantel and Albendazole are commonly used for treatment (Silachamroon *et al.*, 2020).

Paragonimus

Paragonimiasis, commonly known as "lung fluke disease," is caused by several species of the genus *Paragonimus*, including P. *westermani*, P. *africanus*, P. *mexicanus*, P. *heterotremus*, and P. *philippinensis*. It is an important zoonotic food-borne trematode infection widely distributed in many parts of Asia, Africa, and the Americas (Silachamroon *et al.,* 2020).

Life Cycle:

The life cycle of *Paragonimus* spp. involves snails as the first intermediate host and freshwater crabs or crayfish as the second intermediate host. Eggs passed in sputum or feces reach water and hatch into miracidia, which infect freshwater snails. Cercariae released from snails penetrate crabs, crayfish, and occasionally fish, where they encyst as metacercariae. Humans become infected by eating raw, pickled, smoked, salted, marinated, dried, or partially cooked infected crabs, crayfish, or fish. After ingestion, metacercariae migrate through the intestinal wall, diaphragm, and pleura to the lungs, where adult flukes develop.

Clinical Signs

Common signs include chronic cough blood-stained sputum

(haemoptysis), chest pain dyspnoea, fever, pleural effusion, pneumothorax. The disease often resembles pulmonary tuberculosis and may remain asymptomatic in mild cases.

Diphyllobothrium

Diphyllobothrium latum is the most significant fish-borne zoonotic cestode responsible for human infection worldwide. It occurs mainly in regions where raw, undercooked, or marinated fish is commonly consumed. Both freshwater and marine fish, act as intermediate hosts, while freshwater fish serve as the main epidemiological reservoir.

Life cycle:

The life cycle of *Diphyllobothrium* latum involves two intermediate hosts and humans or fish-eating mammals as definitive hosts. Eggs are passed in feces into freshwater, where they hatch into coracidium. These are ingested by freshwater copepods (first intermediate host) and develop into procercoid larvae. When infected copepods are eaten by freshwater fish, the larvae develop into plerocercoid larvae, which are the infective stage for humans. Humans acquire infection by consuming raw or undercooked fish containing plerocercoids. In the human intestine, the larvae develop into adult tapeworms, which attach to the intestinal mucosa and produce eggs, completing the cycle.

Clinical Signs

Diphyllobothriasis mainly causes gastrointestinal and systemic manifestations, including abdominal pain, diarrhea or constipation, intestinal obstruction, sub-acute appendicitis, cholecystitis, and cholangitis. Hematological effects are prominent and include megaloblastic anaemia, vitamin B12 deficiency, pancytopenia, eosinophilia, and pernicious anaemia. Severe cases may also involve neurological, ocular, and allergic symptoms such as paraesthesia, optic neuritis, dyspnea, and hypersensitivity reactions.

Epidemiology and Control

The disease is strongly associated with dietary habits involving raw fish consumption. Environmental changes, global travel, fish trade, and shifting food practices contribute to its spread. Control measures include proper cooking of fish, improved food hygiene, public awareness, and monitoring of fish products in markets.

Gnathostoma

Gnathostomiasis is an emerging fish-borne zoonotic disease caused by nematodes of the genus Gnathostoma. It is increasingly reported worldwide beyond traditional endemic areas of Southeast Asia and South America due to travel and imported food. Important species include G. *spinigerum*, G. *hispidum*, G. *doloresi*, and G. *nipponicum*. Humans are accidental hosts, while piscivorous animals are the definitive hosts. Infection occurs through consumption of raw or undercooked infected fish or aquatic animals containing larvae. Clinical signs include migratory cutaneous swelling, gastrointestinal pain and obstruction, pulmonary, ocular, and severe neurological disease such as eosinophilic meningitis. Treatment includes Albendazole and Praziquantel.

Protozoans

The growing incidence of *Giardia*, *Balantidium*, *Cryptosporidium* in fish and other marine animals is a recent phenomenon associated with growing urbanization and increased human activities. They may have been acquired via contamination of coastal waters by sewage, run off and agricultural and biomedical wastes.

Amoebiasis

Amoebiasis is an intestinal protozoan infection caused by *Entamoeba histolytica*, leading to amoebic dysentery with significant global health impact, especially in regions with poor sanitation. Although primarily transmitted through contaminated food and water containing cysts, it has also been linked to fish-borne outbreaks in some areas due to sewage-contaminated aquaculture and consumption of raw fish. Clinical signs include dysentery, bloody diarrhoea, vomiting, dehydration, and abdominal pain. It has an estimated worldwide prevalence of 500 million people killing over 55,000 people every year (Ryan *et al.,* 2018).

Balantidium

Balantidiasis is a rare emerging zoonotic protozoal infection caused by *Balantidium* coli. It is mainly associated with pigs and is transmitted to humans through contaminated food and water, and possibly in some reports through fish-related contamination. Many infections remain asymptomatic as these parasites produce a proteolytic enzyme that digests the epithelium forming ulcers (Leiro *et al.*, 2012) but pathogenic cases may cause dysentery-like illness due to mucosal ulceration in the colon. Severe infection can lead to abdominal pain, diarrhoea, colonic ulceration, necrosis, and even bowel perforation.

Giardia

Giardiasis is an intestinal protozoal infection caused by *Giardia duodenalis* and is one of the most common causes of diarrhoea in humans worldwide. It spreads mainly through contaminated water and food, and has also been associated with fish from polluted aquatic environments such as tilapia and mullets. Infection occurs after ingestion of cysts. Clinical signs include foul-smelling diarrhoea, abdominal cramps, bloating, nausea, fatigue, and weight loss, which may persist for several weeks.

Giardiasis is one of the most common gastrointestinal protozoal infections worldwide, affecting about 2% of adults and 8% of children in developed countries. Children between 0–4 years of age are most commonly affected, and among children under 10 years, giardiasis is a major cause of epidemic diarrhoea, with prevalence rates reaching 15–20% in some regions (Ganguly *et al.,* 2025).

Cryptosporidium

Cryptosporidiosis is a gastrointestinal protozoan infection caused by *Cryptosporidium* spp. It is an opportunistic pathogen that can infect humans and animals through ingestion of oocysts present in contaminated water, food, or through improper handling of fish and aquatic products. Species such as C. *parvum* and C. *hominis* have been detected in aquatic environments and occasionally in fish-associated samples. The infection mainly affects the intestinal tract and causes watery diarrhoea, abdominal cramps, nausea, and dehydration, with more severe disease seen in immunocompromised individuals.

Emerging fish-borne parasitic zoonoses

Some of the emerging fish-borne parasitic zoonoses are *Heterophyes, Gnathostoma, Entamoeba, Balantidium* infection. Both marine mammals and birds act as reservoir for many potentially zoonotic protozoans infections (*Giardia,* *Cryptosporidium, and Entamoeba*).

Strategies for prevention and control

Over the last few decades, the global pattern of parasitic diseases has changed significantly. Infections caused by soil-transmitted nematodes (such as roundworms, hookworms, and whipworms) have generally decreased in many regions. In contrast, food-borne parasitic zoonoses especially those transmitted through fish and other aquatic foods are becoming more important. These infections are strongly linked to cultural dietary habits such as eating raw, undercooked, pickled, or fermented fish, as well as changes in food supply chains, aquaculture practices, and international travel and trade. The major challenge today lies in control and prevention at the community level. Many affected populations live in poor, rural, or remote areas where access to clean water, safe food practices, and healthcare services is limited. Lack of awareness about the risks of eating raw fish and poor sanitation further increases transmission. As a result, modern helminth control programmes need to focus more on practical implementation such as health education, food safety practices, improved sanitation, surveillance, and ensuring access to diagnosis and treatment rather than only relying on drugs.

The U.S. Food and Drug Administration recommends that fish intended for raw consumption should be frozen at temperatures below −35°C for at least 15 hours or below −20°C for 7 days to kill parasites. Similarly, the European Union's Hazard Analysis and Critical Control Points guidelines require marine fish meant for raw consumption to be frozen at −20°C or lower for more than 24 hours to ensure parasite inactivation and improve food safety.

Conclusion

Fish-borne zoonotic infections occur mainly by eating raw or undercooked contaminated aquatic foods. Globally, more than 50 helminth species from fish and other aquatic animals can infect humans, and some cause serious disease. The rise in fish-borne zoonotic diseases is mainly driven by increased use of aquatic environments, changing food habits such as consumption of raw seafood (e.g., sushi and sashimi), reduced timing of cooking of fish products. global trade of contaminated fish, international travel and migration, and spread of parasites through migratory birds and contaminated water bodies.

Control of fish-borne zoonotic parasites is challenging due to complex interactions among parasites, aquatic hosts, and environmental factors. Prevention mainly relies on maintaining good hygiene, improving awareness among consumers, producers, and handlers, and promoting safe food practices such as consuming properly cooked fish and using clean drinking water. Proper handling, processing, storage, and trade of fish products are also essential to reduce transmission. However, a lack of updated surveillance data in many regions makes control difficult. Therefore, regular monitoring of endemic areas is needed to assess infection status in both fish and humans. Environmental, ecological, and climatic changes are further contributing to the emergence and spread of these infections, making them an important public health concern.

References

1. Tumbarski, Y. (2020). Foodborne zoonotic agents and their food bioterrorism potential: a review. *Bulgarian Journal of Veterinary Medicine.*; 23 (2): 147-159.

2. McConnell, J. F. P. (1875). Remarks on the anatomy and pathological relations of a new species of liver-fluke. *Lancet* 106: 271–274.

3. Kim, J. H., Choi, M. H., Bae, Y. M., Oh, J. K., Lim, M. K., Hong, S. T. (2011). Correlation between discharged worms and faecal egg counts in human clonorchiasis. *Public Library of Science Neglected Tropical Diseases* 5:e1339.

4. Bardhan, A. (2022). Fish-borne parasites proficient in zoonotic diseases: a mini review. *Insights in Veterinary Science*. 6: 005-012.

5. Xu, L., Jiang, Z, Yu, S., Xu, S., Huang, D., Yang, S., Zhao, G., Gan, Y., Kang, Q. & Yu, D. (1995). Nationwide survey of the distribution of human parasites in China-infection with parasite species in human population. *Chinese Journal of Parasitology and Parasitic Diseases*. 13 (1): 1-7.

6. Ryan, U., Hijjawi, N. & Xiao, L. (2018). Foodborne cryptosporidiosis. *International Journal for Parasitology*.; 48: 1-2.

7. Leiro, J. M., Piazzon, C., Domínguez, B., Mallo, N. & Lamas, J. (2012). Evaluation of some physical and chemical treatments for inactivating microsporidian

1. spores isolated from fish. *International Journal of Food Microbiology*, 156: 152-160.

2. Ganguly, N., Thakre, B. J. (2025). Giardiasis in Human. Digital Agri News, 1 (5): 2-7.

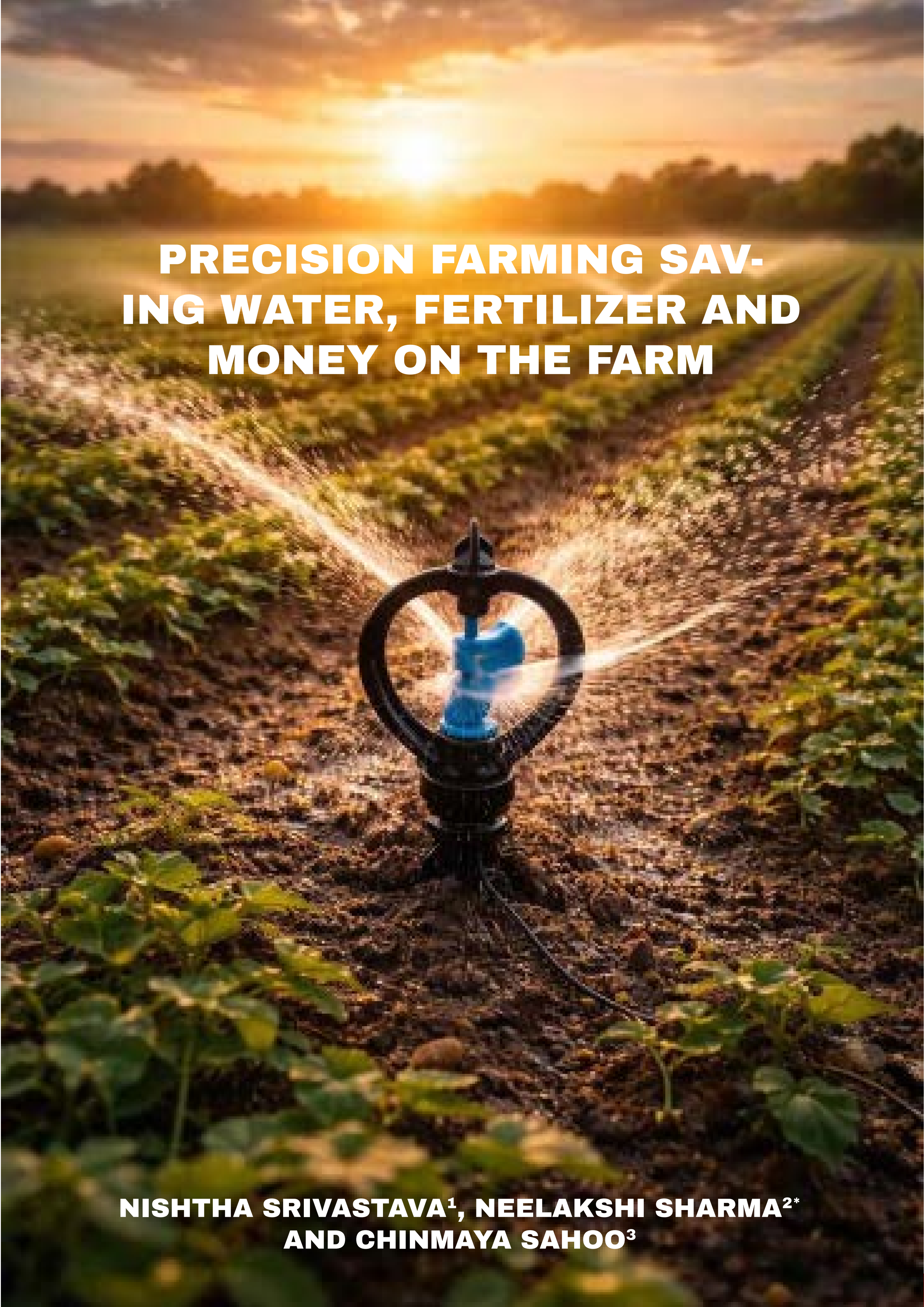
3. Sripa, B., Tangkawattana, S. & Brindley, P. J. (2018). Update on pathogenesis of opisthorchiasis and cholangiocarcinoma. *Advances in Parasitology*, 12: 97-113.

4. Kiyan, V. S., Bulashev, A. K., Katokhin, A. V. (2018). *Opisthorchis felineus* and *Metorchis bilis* metacercariae in cyprinid fish Leuciscusidus in Nura-Sarysu River, Kazakhstan. Korean Journal of Parasitology. 56 (3): 267-274.

5. Bardhan, A. (2022). Fish-borne parasites proficient in zoonotic diseases: a mini review. Insights Vet Sci.; 6: 005-012.

6. Silachamroon, U. & Wattanagoon, Y. (2020). Paragonimiasis. Hunter's Tropical Medicine and Emerging Infectious Diseases, Edn 10; 928-931.

7. Uppal, B. & Wadhwa, V. (2005). Rare case of *Metagonimus yokogawai*.. *Indian Journal of Medical Microbiology*, 23 (1):61-62



PRECISION FARMING SAVING WATER, FERTILIZER AND MONEY ON THE FARM

NISHTHA SRIVASTAVA[1], NEELAKSHI SHARMA[2*]
AND CHINMAYA SAHOO[3]

Precision Farming Saving Water, Fertilizer and Money on the Farm

Nishtha Srivastava[1], Neelakshi Sharma[2*] and Chinmaya Sahoo[3]

[1] Dr. KSG Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur, Himachal Pradesh, India
[2] Department of Soil Science, CSK HPKV, Palampur, HP, India-176062
[3] Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar- 848125

ISSN No.: 3107-9903
Frequency: Monthly
Month: May
Volume- 2, Issue- 5

In terms of any communication correspondence is pertained to:
neelakshisharma20@gmail.com

Abstract

Precision farming, also known as precision agriculture, utilizes advanced technologies such as GPS, sensors, drones, and data analytics to optimize farm management by addressing spatial and temporal variability within fields. This article highlights the role of precision farming in conserving water, reducing fertilizer use and improving economic returns, making it a key component of sustainable modern agriculture. With increasing challenges posed by climate change, population growth, resource depletion, and food security concerns, precision agriculture offers an efficient and environmentally responsible approach to crop production. Precision farming can reduce water consumption by up to 30% through site-specific irrigation, decrease fertilizer application by 20–40% by matching nutrient supply with crop and soil requirements, and lower operational costs by 10–25%, thereby enhancing farm profitability and productivity. Moreover, these practices contribute to minimizing environmental impacts such as nutrient leaching, soil degradation, and chemical runoff. The article further emphasizes that wider adoption of precision agriculture requires supportive government policies, technological subsidies, infrastructure development, and farmer training programs. Overall, precision farming represents a transformative pathway toward resilient, data-driven, and sustainable agricultural systems that benefit farmers, consumers, and the environment alike.

Keywords: Conservation, precision farming, efficiency, savings and technology

Introduction

Precision farming represents a paradigm shift in agriculture, integrating technology to tailor farming practices to specific field conditions rather than applying uniform treatments. Traditional farming often leads to overuse of resources such as, water and fertilizers thereby, resulting in environmental degradation and economic losses. However, precision farming addresses these issues by using data-driven tools to optimize inputs, which save water, reduce fertilizer waste, and cut down application cost. According to the Food and Agriculture Organization (FAO), global agriculture accounts for 70% of freshwater withdrawals, making efficient water use critical (FAO, 2020). Similarly, excessive fertilizer application contributes to soil degradation and eutrophication. This article discusses how precision farming achieves these savings, supported by real-world examples and data.

Precision Farming

Precision farming, also known as precision agriculture, is a modern farming approach that uses technology to monitor and manage crop production more efficiently.

Components of Precision Farming

Precision farming integrates technology, data and management practices to optimize agricultural operations. It typically consists of several key components that work together to enable site-specific decision-making.

1. **Global Positioning System (GPS):** GPS provides accurate location data for mapping field variations and guiding equipment, enabling precise navigation and reducing overlap in operations.

2. **Sensors and Monitoring:** Sensors collect real-time data on soil moisture, nutrients, and crop health, transmitting it with IoT for continuous monitoring and proactive adjustments.

3. **Data Analytics and Software:** Software platforms analyse sensor data using algorithms to generate insights, such as yield predictions and prescription maps for optimized inputs.

4. **Variable Rate Technology (VRT):** VRT applies fertilizers, pesticides, and seeds at variable

1. rates based on field data, matching inputs to specific zones for efficiency.

2. **Drones and Aerial Imaging:** Drones capture high-resolution images for crop assessment, detecting issues like stress or deficiencies early through multispectral analysis.

3. **Automation and Robotics:** Robotic systems perform tasks like planting and weeding autonomously, using AI for precision and reducing human labour in farming operations.

Advantages

1. **Increased Efficiency and Yield:** By targeting specific areas, farmers can optimize resource use, leading to higher crop yields (often 10-20 per cent improvements) and reduced waste.

2. **Cost Savings:** Precision application minimizes overuse of fertilizers, pesticides, and water, lowering expenses. For example, variable-rate technology can cut input costs by up to 30%.

3. **Environmental Benefits:** It reduces chemical runoff and soil erosion, promoting sustainability and better compliance with regulations like those from the EPA.

4. **Data-Driven Decisions:** Real-time data helps predict issues like pest outbreaks or drought, enabling proactive management and better risk mitigation.

5. **Scalability:** Suitable for large farms but also adaptable to smaller operations with affordable tech like smartphone apps.

Disadvantages

1. **High Initial Costs:** Equipment like GPS-guided tractors, drones, and sensors can cost tens to thousands of dollars, making it inaccessible for small or resource-poor farmers.

2. **Technical Complexity:** Requires training and expertise in data analysis, software, and maintenance, which can be a barrier for traditional farmers.

3. **Data Privacy and Security Risks:** Collecting vast amounts of farm data raises concerns about hacking, data breaches, or misuse by tech companies.

4. **Dependency on Technology:** Reliance on internet connectivity, satellites, and power sources can fail during

1. outages, weather events, or in remote areas.

2. **Potential Over-Reliance:** It might lead to reduced biodiversity if not managed carefully, as uniform high-tech approaches could overlook ecological nuances.

Challenges and Limitations

- Despite benefits, precision farming faces hurdles.
- In low-income regions, access to reliable internet and electricity limits adoption.
- Data security is another issue, as farm data could be vulnerable to cyber threats.
- Additionally, not all crops or terrains benefit equally, e.g., hilly landscapes may require specialized equipment.
- Overcoming these requires policy support, such as subsidies and training programs, to democratize access.

Future Prospects

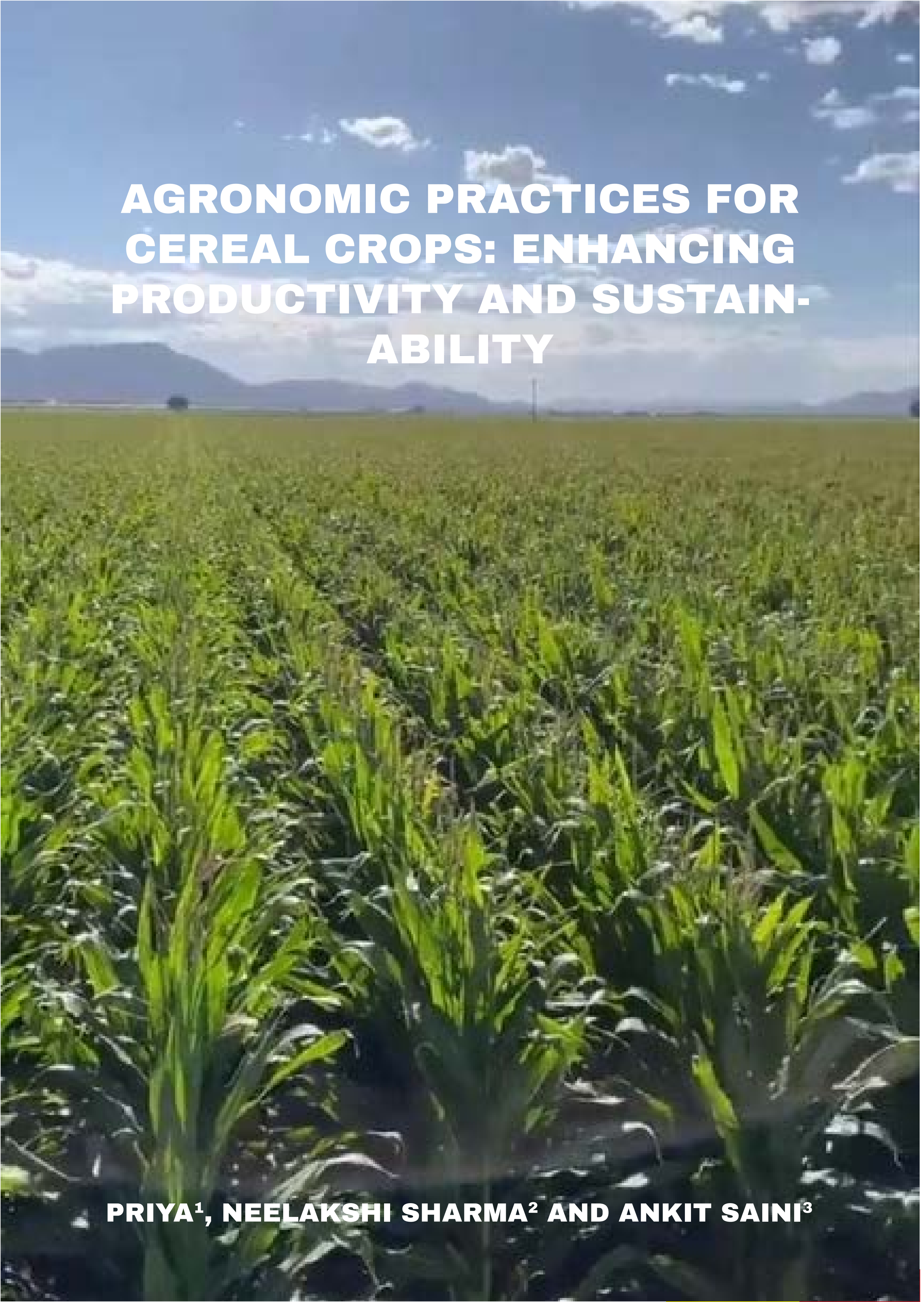
1. lies in AI-driven predictive analytics, which can forecast pest outbreaks or optimize planting schedules.
2. Integration with blockchain for supply chain transparency and climate-smart agriculture could further amplify savings.
3. Research indicates that by 2030, AI could reduce global agricultural water use by an additional 15% (IPCC, 2023).

Conclusion

Precision farming is a proven strategy for sustainable agriculture, delivering substantial savings in water, fertilizer, and money. By adopting technologies like sensors and VRT, farmers can achieve higher efficiency and resilience against climate variability. While barriers such as cost and training exist, widespread adoption could transform global food systems. Policymakers should promote incentives, and farmers are encouraged to start with pilot programs. Future research should focus on integrating AI for predictive analytics to further enhance outcomes. Ultimately, precision farming not only saves resources but also secures food security for future generations, fostering a more equitable and environmentally conscious agricultural landscape.

References

- FAO. (2020). *The state of the world's land and water resources for food and agriculture.* Food and Agriculture Organization of the United Nations.
- IPCC. (2023). Climate change 2023: Synthesis report. Intergovernmental Panel on Climate Change.
- Johnson, E., & Lee, H. (2023). Economic impacts of precision agriculture in the United States. *Journal of Agricultural Economics,* 45(2), 123-145.
- Silva, R., Pereira, L., & Santos, M. (2020). Precision farming in soybean production: A case study from Brazil. *Agricultural Systems*, 178, 102756.
- Smith, A., Jones, B., & Brown, C. (2019). Water-saving technologies in Australian agriculture. *Irrigation Science*, 37(4), 567-580.
- Thompson, L., Miller, D., & Green, T. (2021). Variable rate fertilization in corn: Efficiency gains and environmental benefits. *Precision Agriculture*, 22(3), 789-805.
- USDA. (2022). *Precision agriculture: Adoption and impacts*. United States Department of Agriculture.



Agronomic Practices for Cereal Crops: Enhancing Productivity and Sustainability

Priya[1], Neelakshi Sharma[2] and Ankit Saini[3]

[1]*Dr. KSG Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur, Himachal Pradesh, India*
[2]*Department of Soil Science, CSK HPKV, Palampur, HP, India-176062*
[3]*Dr. KSG Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur, Himachal Pradesh, India*

ISSN No.: 3107-9903
Frequency: Monthly
Month: May
Volume- 2, Issue- 5

In terms of any communication correspondence is pertained to:
ankitsaini970@gmail.com

Abstract

Cereal crops such as wheat (*Triticum aestivum*), rice (*Oryza sativa*), and maize (*Zea mays*) are vital for global food security but face increasing challenges from climate change, soil degradation, water scarcity, and biotic stresses. Recent agronomic research (2020–2025) has focused on sustainable and climate-resilient production strategies, including integrated nutrient management, biological nitrogen fixation, conservation agriculture, precision farming, remote sensing, and AI-based decision support systems. This review highlights key innovations in cereal agronomy that improve productivity, resource-use efficiency, nutritional quality, and environmental sustainability. The study emphasizes that adopting locally adapted, technology-driven, and farmer-centric practices can strengthen resilience and support global sustainability goals related to food security, climate action, and sustainable land management.

Introduction

Wheat, rice, and maize together contribute more than 70% of global cereal output. While the Green Revolution significantly boosted production in the past century, these gains are plateauing. In many developing countries, current yields are still far below potential due to improper agronomic practices, input misuse, and climate-induced stress. A recent multi-country review noted that in South Asia alone, the average yield gaps in wheat and rice remain above 30%, largely due to mismanagement of water, nutrients, and crop timing (Subedi et al., 2025). To close these gaps, a paradigm shift is underway—from input-intensive to knowledge-intensive agronomy. Researchers are now focusing on systems that are not only productive but also resource-efficient, environmentally sound, and climate-resilient.

Integrated and Site-Specific Nutrient Management

Traditional fertilizer practices—often based on blanket recommendations—have led to both overuse and underuse of key nutrients like nitrogen and phosphorus. In response, integrated nutrient management (INM) strategies are now promoted that combine chemical fertilizers with organic amendments and biofertilizers. For instance, field trials in wheat fields in India demonstrated that combining urea with farmyard manure significantly improved soil microbial biomass and increased grain protein content, compared to urea alone (Chakraborty et al., 2025).

In rice, the application of *Azospirillum and Phosphobacteria* along with half-dose of NPK fertilizers resulted in higher tiller density and improved grain yield under both irrigated and rainfed conditions. Similarly, maize grown with poultry litter and zinc-enriched fertilizers produced 20% more biomass and exhibited higher chlorophyll content.

Site-specific nutrient management (SSNM) tools, such as Nutrient Expert®, have also shown promising results. In maize trials conducted in Punjab and Nepal, SSNM practices reduced nitrogen input by 25–30% while maintaining or improving yields, demonstrating both environmental and economic benefits (Deb et al., 2025). Moreover, integrating real-time crop diagnostics—like leaf colour charts and Green Seeker sensors—enables farmers to adjust nutrient doses mid-season, preventing over-fertilization and leaching losses.

Climate-Resilient Agronomic Interventions

Mitigating Heat and Drought Stress

With rising global temperatures, cereal crops—especially wheat and maize—face increasing risks of yield loss due to heat stress during flowering and grain filling stages. Agronomic responses have included shifting sowing dates,

adopting heat-tolerant varieties, and using foliar protectants.

In wheat, early sowing by 2–3 weeks helped avoid terminal heat stress and increased yields by up to 15% in the Indo-Gangetic Plains. Foliar applications of silicon and seaweed extract were found to reduce heat-induced oxidative damage by enhancing antioxidant enzyme activity (Ponmani et al., 2025). In maize, conservation furrow planting and mulching helped retain soil moisture and buffer canopy temperatures during dry spells.

Salinity and Abiotic Stress Management

Saline soils, particularly in coastal and arid regions, present another growing challenge. In response, agronomic practices such as raised-bed planting, gypsum application, and organic mulching are increasingly used. A notable innovation is the application of olive mill wastewater as a bio stimulant under saline conditions. Recent greenhouse studies on wheat reported that olive waste extract improved root elongation, chlorophyll content, and relative water content under moderate salinity stress (Asencio-Vicedo & García-Cano, 2025).

In rice systems, the use of salt-tolerant cultivars like CSR-36 combined with alternate wetting and drying (AWD) irrigation not only improved salt tolerance but also saved water.

Crop Diversification and Sustainable Rotations

The dominance of rice–wheat monocultures has led to multiple sustainability issues: declining soil fertility, groundwater depletion, and pest pressure. Crop diversification offers a way forward.In northwestern India, replacing rice with short-duration maize or millet varieties in kharif season and introducing pulses like chickpea or lentil in rabi significantly improved soil health and enhanced farm income. Intercropping systems, such as maize + cowpea or wheat + mustard, have also shown yield advantages due to complementary resource use and natural pest suppression.

One study in Haryana demonstrated that a maize–mustard–mungbean rotation improved total productivity by 28% over traditional rice–wheat, while reducing irrigation needs by 40% (Singh, 2025). Additionally, diversified systems are more resilient to market and climate shocks.

Conservation Agriculture for Soil Health and Carbon Sequestration

Conservation agriculture (CA)—which includes minimal tillage, residue retention, and crop rotation—is increasingly adopted in cereal systems to improve long-term sustainability. In wheat–maize systems, zero tillage has been shown to reduce production costs by 20%, increase water infiltration, and improve soil organic carbon content.

Residue mulching, particularly in rice fields, suppresses weeds, reduces evaporative losses, and adds organic matter to the soil. Long-term CA trials in eastern Uttar Pradesh showed that after five years of residue retention and no-till sowing, wheat yields improved by 12%, while soil compaction decreased significantly.

Precision Agriculture and Digital Tools

Remote sensing, GIS, and drone-based monitoring are revolutionizing cereal agronomy. Vegetation indices such as NDVI (Normalized Difference Vegetation Index) and thermal imaging now help in identifying crop stress, nutrient deficiencies, and disease hotspots well before visual symptoms appear.

Recent work by Haq et al. (2025) introduced a multi-spectral remote sensing model capable of detecting early-stage drought stress in maize and rice with 92% accuracy. These technologies enable site-specific interventions, optimizing input use and minimizing losses.

Artificial intelligence (AI) is also being used in crop protection. For example, the AgriSense platform developed in Algeria uses smartphone-captured images to detect leaf rust in wheat and rice blast with 85–90% accuracy, providing farmers with real-time management suggestions.

Biofortification and Nutritional Enhancement through Agronomy

Agronomic biofortification addresses hidden hunger by increasing the micronutrient content of cereals through field-based interventions. For instance, foliar application of zinc sulfate at the booting stage in wheat increased grain zinc concentration by over 40% without affecting yield. Similarly, selenium sprays in rice improved its antioxidant properties and nutritional value. Combined strategies—applying micronutrient-rich fertilizers and using biofortified seed varieties—offer a synergistic approach. Tessema et al. (2025) report that such combinations are essential for meeting international nutrition targets, especially in regions with cereal-based diets.

Biological Nitrogen Fixation and Eco-Friendly Inputs

Reducing reliance on synthetic nitrogen is a major sustainability goal. In maize and rice, biological nitrogen fixation (BNF) using microbial inoculants is gaining momentum. Inoculation with *Azospirillum* and *Herbaspirillum* has resulted in N savings of up to 50 kg/ha under field conditions.

Forghieri et al. (2025) showed that integrating BNF organisms with reduced nitrogen fertilizers in maize systems maintained yields while lowering nitrous oxide emissions by 35%. Similarly, intercropping legumes like soybean or cowpea with cereals creates a synergistic system where nitrogen fixed by legumes benefits the cereal crop.

Circular Agriculture and Policy Integration

To scale these agronomic innovations, enabling policies and institutional support are essential. Circular agriculture—using organic waste like compost, biogas slurry, and treated wastewater—is gaining traction. Chojnacka (2025) notes that large-scale adoption of organo-mineral fertilizers in rice and maize systems across sub-Saharan Africa improved yields while reducing fertilizer costs by 25%.

Subsidy reform, training programs, and digital extension services are critical in driving adoption. Integration of these practices into national food security and climate adaptation strategies will be crucial in the coming decade.

Conclusion

Agronomic practices for wheat, rice, and maize are evolving rapidly to meet the dual challenges of food security and environmental sustainability. From integrating organic and site-specific nutrient management, to deploying climate-resilient cropping strategies and digital tools, the shift is clear: precision, sustainability, and resilience are the new pillars of modern cereal agronomy. These innovations, when adapted to local conditions and backed by supportive policies, hold immense promise to transform cereal production into a more productive, nutritious, and ecologically sound enterprise.

References

- Asencio-Vicedo, P., & García-Cano, J. (2025). Effects of olive mill wastewater extract on wheat performance under saline stress. *Journal of Soil and Plant Physiology* ,18(2), 145–159.
- Chakraborty, A., Mehra, S., & Bhatia, R. (2025). Integrated nutrient management impacts on soil microbial biomass and grain quality in wheat. *Indian Journal of Agronomy*, 70(1), 22–31.
- Chojnacka, K. (2025). Adoption of organo-mineral fertilizers in cereal systems: A review of circular agriculture innovations in sub-Saharan Africa. *African Journal of Agricultural Sustainability*, 9(3), 210–225.
- Deb, S., Tripathi, N., & Kandel, R. (2025). Site-specific nutrient management strategies for sustainable maize production in South Asia. *Field Crops Research,* 302, 108–119.
- Forghieri, M., Alvarez, P., & Rossi, L. (2025). Integrating biological nitrogen fixation with reduced nitrogen fertilization in maize: Yield and emission outcomes. *Agricultural Systems*, 215, 102–115.
- Haq, A., Rehman, S., & Ullah, M. (2025). Early detection of drought stress in cereal crops using multispectral remote sensing models. *Precision Agriculture*, 26(1), 55–72.
- Singh, R. (2025). Productivity and resource use efficiency of maize–mustard–mungbean crop rotation in Haryana. *Journal of Farming Systems Research*, 41(2), 98–109.
- Subedi, P., Thapa, B., & Mishra, S. (2025). Yield gaps and agronomic constraints in cereal production across South Asia: A multi-country analysis. *Asian Journal of Agricultural Sciences*, 17(1), 11–26.
- Tessema, Y., Gebrekidan, A., & Yohannes, M. (2025). Combined agronomic and genetic approaches for micronutrient biofortification in cereal crops. *Plant Nutrition and Food Security Journal*, 8(4), 250–268.

Five Formulas for Farm and Finance: Grow Green, Save Foreign Exchange

Arun Kumar

ISSN No.: 3107-9903
Frequency: Monthly
Month: May
Volume- 2, Issue- 5

In terms of any communication correspondence is pertained to:
ankitsaini970@gmail.com

Introduction

Higher crude oil prices increase agricultural costs by raising prices for fertilizers, pesticides, and fuel for machinery. This elevates transportation costs, driving up food prices and reducing farm income. With Brent crude oil climbing to $107 per barrel on May 12, 2026, the burden on farmers has grown heavier. Prime Minister Narendra Modi’s recent message to farmers, delivered on May 10, 2026, focuses on cutting input costs by slashing dependence on chemical fertilizers and pesticides, shifting to natural/traditional-style farming, and reducing fuel and import-linked expenses across the economy. These farmer-priority measures align with his “cost-cutting formula” for salvaging the Indian economy.

Cut fertilizer and chemical use

The core idea Modi is pushing is: reduce chemical fertilizer use by up to 50%, while protecting yields through better soil-health practices. Solid farmer-level measures include:

- Adopt natural farming / zero-chemical practices (e.g., **Jholamrit, Bijamrit, Jiwamrit, mulching, mixed cropping**) to cut NPK-fertilizer and pesticide bills.

- Use soil-testing and balanced nutrition (right dose at right time) instead of “more fertilizer =

- more yield" thinking.
- Integrate organic manure, compost, and farm-yard-waste so synthetic inputs are only supplements, not the base.

Shift to traditional and natural farming

Prime Minister is emphasizing a return to traditional, low-cost, chemical-free systems that also protect soil and biodiversity. Practical steps for farmers:

- Join National Mission on Natural Farming (NMNF); it is designed specifically to reduce input costs, improve soil health, and promote biodiversity-based systems.
- Practice crop-rotation, mixed cropping, and agro-forestry instead of monoculture, which lowers pest-pressure and fertilizer demand.
- Use cow-based bio-inputs (like cow-dung, urine preparations) as traditional, low-cost alternatives to synthetic pesticides.

Reduce fuel and energy costs on farms

PM Modi has asked farmers to move away from diesel-run pumps and fuel-heavy operations to cut import-linked bills. For farmers this means:

- Switch to solar-powered irrigation pumps instead of diesel pumps; the government is already promoting this to cut fuel and forex-linked costs.
- Use conservation-tillage and minimum-tillage tools to reduce tractor-fuel use per acre.
- Optimize timing and intensity of operations (e.g., fewer passes, grouped activities) so fuel and labour costs drop together.

Cut chemical-pesticide and input dependency

The PM's call to farmers is not just about fertilizers, but reducing overall chemical-input dependency. Concrete measures:

- Shift to Integrated Pest Management (IPM): traps, bio-pesticides, neem-based solutions, and intercropping to reduce synthetic-pesticide use.
- Grow trap-crops and

- pest-repellent crops around main crops to lower pesticide sprays.
- Use public-sector extension services and KVKs to access low-cost, science-backed, chemical-lite practices instead of blindly following dealer-advised inputs.

Macro-policy levers that support farmers

At the national level, Modi is linking farm-level cost-cutting with macro-economic saving of foreign exchange. Key supportive measures that farmers benefit from:

- Boost domestic fertilizer / bio-input production to reduce import-bills and price-volatility.
- Scale up subsidies and schemes for natural farming, solar-pumps, and organic inputs, so the transition is financially safe for small farmers.
- Promote local and regional value chains (e-NAM, FPOs, organic-certification) so farmers get better prices without relying on export-linked, high-input crops.

How this “single formula” can help the Indian economy

In simple terms, Modi’s “formula” is: farmers cut fertilizer/chemical use by 30–50%, adopt natural-traditional methods, and reduce fuel-and-import-linked costs → lower import-bill, healthier soil, cheaper farm-inputs, and stronger rupee. If scaled across even 30–40% of farmland, this can significantly reduce India’s import-dependence on fertilizers, diesel, and pesticides, while improving farm profitability and ecological resilience.

If you tell me your state and crop (e.g., wheat in Punjab, sugarcane in UP, rice in Telangana), I can give you a practical 1-page checklist for your farm to follow this “formula” in a systematic way.

One study in Haryana demonstrated that a maize–mustard–mungbean rotation improved total productivity by 28% over traditional rice–wheat, while reducing irrigation needs by 40% (Singh, 2025). Additionally, diversified systems are more resilient to market and climate shocks.

Note: *Views expressed in the article are author’s personal*

Arun Kumar is an Agricultural Economist and Researcher at NCDEX

WHY DO WE NEED TO WORRY ABOUT NITROUS OXIDE EMISSIONS IN A CLIMATE-CHANGING WORLD?

GAURAV RAJ KACHHAWAHA[1*], ANANDKUMAR NAOREM[2], DIVYA BHARGAVA[3], PRAVEEN KUMAR SOLANKI[4], RITIKA PANWAR[5]

Why do we need to worry about nitrous oxide emissions in a climate-changing world?

Gaurav Raj Kachhawaha[1*], Anandkumar Naorem[2], Divya Bhargava[3], Praveen Kumar Solanki[4], Ritika Panwar[5]

[1,2,3,4] *ICAR- Central Arid Zone Research Institute, Jodhpur-342003, Rajasthan (India)*
[5] *Jai Narain Vyas University, Jodhpur, Rajasthan, India*

ISSN No.: 3107-9903
Frequency: Monthly
Month: May
Volume- 2, Issue- 5

In terms of any communication correspondence is pertained to:
gkachhawaha11@gmail.com

In dedication to World Environment Day 2026, raising awareness about nitrous oxide and its impact on climate and environmental sustainability.

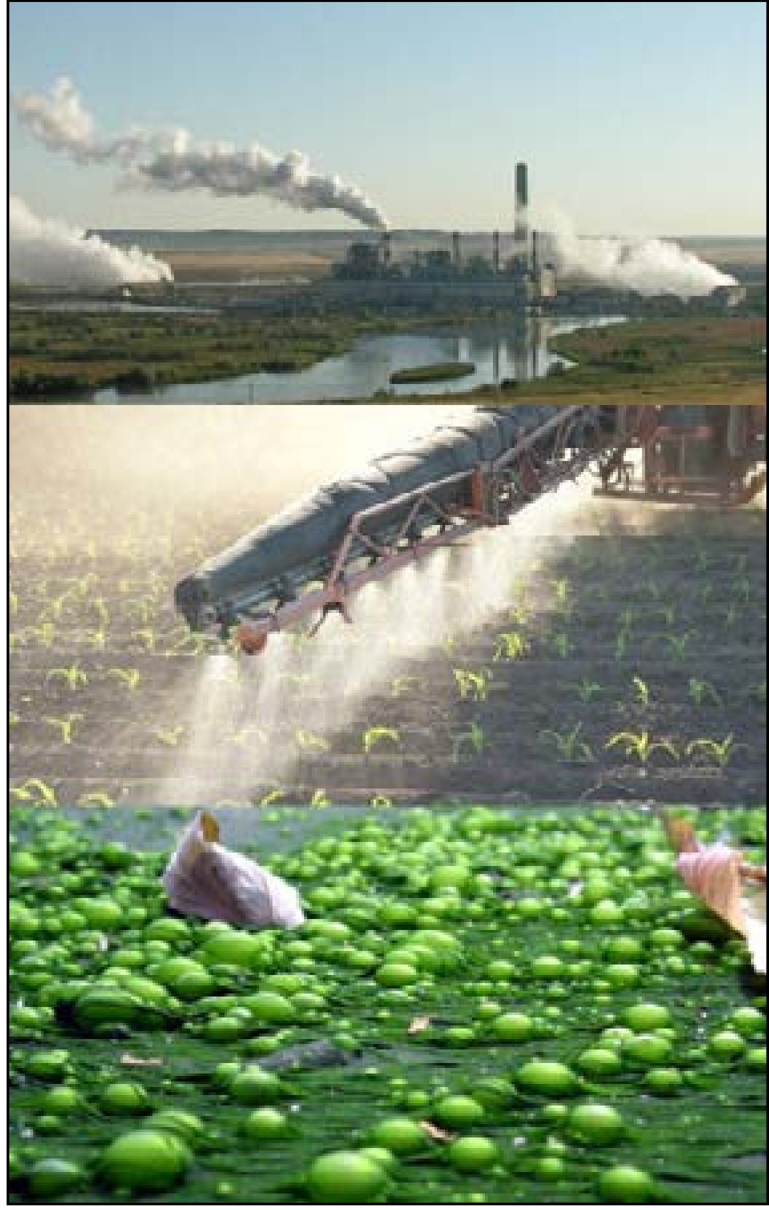
Abstract

The theme for World Environment Day 2026, “Inspired by nature, for climate, for our future”, places special focus on the call for climate action that is sustainable and provides a goal for the world to unite in the fight against climate change. It is true that all efforts to curb climate change begin with CO2; however, there is another colourless and odourless greenhouse gas that has long been ignored, and that is nitrous oxide (N2O). It is the gas that is known to be the most dangerous and is worsening climate change at an alarming rate (Tian et al., 2020). The world is trying to solve the problem of world hunger by relying on an economically driven agricultural practice that provides incentives to treat land with an abundant supply of nitrogen to produce more crops. Once the soil has an abundant supply of Nitrogen, it undergoes a series of microbial transformations, including nitrification and denitrification, that result in copious amounts of N2O released into the environment (Butterbach-Bahl et al., 2013). From a scientific perspective, N2O has a Global Warming Potential that is 273 times that of CO2. It also has a long residence time, being able to survive in the atmosphere for over a century. The other atmospheric concern is the depletion of the Ozone Layer (Ravishankara et al., 2009). There is an alarming environmental

paradox that is related to food security, whereby the agricultural practices that have been developed to bring food security are simultaneously threatening ecological security and environmental sustainability. The increase in N2O emissions is now associated with the degradation of soil, the imbalance of the atmosphere, the loss of biodiversity and climate instability. Looking at the “Inspired by nature. For climate. For our future” theme, it has become critical to reduce Nitrous Oxide emissions to achieve the goal of sustainable Nitrogen management, sustainable agriculture and nature-based climate solutions. The core focus addresses the vital needs to ensure the environment and safety for the future of humanity.

The Science and History of the “Silent Threat”: From Medical Miracle to Climate Crisis

The N2O history began in 1772 with the discovery of the molecule by the English chemist Joseph Priestley. Then, its mild anaesthetic properties were further studied by Humphry Davy. Davy called the gas ‘laughing gas’. For a long time, N2O was considered a medical miracle. In the early 20th century, the invention of the Haber-Bosch process allowed the production of synthetic nitrogen fertilisers (Erisman et al., 2008). This industrial process further disrupted the already existing imbalance of the nitrogen cycle. In the 20th century, agriculture was further advanced by an even larger production of crops. The negative consequences of this large-scale agricultural process were first studied by the scientist and Nobel Prize winner Paul Crutzen in the 1970s. He showed that excess nitrogen in soil was being converted to N2O, which was then emitted to the atmosphere (Crutzen, 1970). N2O is a silent threat to the environment as it is invisible to the human eye. In addition, it is a completely colourless and odourless gas. N2O is also extremely stable as a molecule. The gas is made up of two nitrogen atoms and a single oxygen atom (N-N-O). This stability, in addition to its asymmetrical structure, allows for excellent absorption of infrared radiation, which ultimately contributes to the greenhouse gas effect. In addressing the management of N2O, researchers categorise its sources into two distinct groups (Tian et al., 2020). Enlist the two groups. Natural sources contribute to a portion of global emissions, predominantly emitted by microorganisms in tropical forests, natural soils, and oceans as part of the Earth’s intrinsic nitrogen cycle. Conversely, anthropogenic sources have significantly exacerbated the situation. The vast majority of human-induced N2O emissions originate from agricultural activities, particularly the extensive use of synthetic fertilisers and animal manure (Syakila & Kroeze, 2011). Additionally, some smaller, anthropogenic sources include industrial chemical production, wastewater treatment, and the combustion of fossil fuels and biomass. The release of N2O from agricultural soils presents significant atmospheric concerns. This molecule exhibits an exceptionally prolonged atmospheric lifespan, persisting for approximately 114 years prior to decomposition. Due to its extended duration and heat-absorbing chemical properties, N2O possesses a Global Warming Potential (GWP) that is 273 times greater than that of carbon dioxide CO2 over a century. Additionally, N2O exhibits unique behaviour as it ascends into the atmosphere. It gradually migrates into the stratosphere, where it undergoes a reaction with ultraviolet sunlight to form nitric oxide NO. This secondary chemical reaction actively depletes the Earth’s protective ozone layer. Currently, N2O is identified as the predominant ozone-depleting substance emitted by anthropogenic activities (Ravishankara et al., 2009). N2O is increasingly recognised by scientists as a significant concern for the future, as it lies at the intersection of climate change and global food security. With the global population nearing eight billion, the demand for food and, consequently, the fertilisers required for its production is expected to escalate. Without an urgent transformation in agricultural practices to mitigate these emissions, the rising levels of N2O pose a threat to negate the climate progress achieved through the reduction of CO2 and fossil fuel usage. Addressing this silent threat is essential for achieving the climate action objectives set for World Environment Day 2026.



Impact of Nitrous Oxide on Agriculture and Environmental Sustainability

Modern agriculture faces a critical environmental challenge: while nitrogen fertilisers are vital for boosting food production, they also contribute to climate change through N2O emissions. As farmers strive to meet the demands of a growing global population, they increasingly depend on synthetic nitrogen. However, a large portion of this nitrogen is not utilised by crops, leading to microbial processes like nitrification and denitrification that release N2O, a potent greenhouse gas (Butterbach-Bahl et al., 2013). These dynamic turns fertile soils into significant greenhouse gas sources, compounding the effects of climate change. The repercussions go beyond atmospheric warming; they pose severe risks to global food security. As temperatures rise and weather patterns become erratic, resulting in prolonged droughts, floods, and heatwaves, agricultural productivity takes a hit, especially in regions already vulnerable to food shortages (Lobell et al., 2011). Staple crops such as wheat, rice, and maize are particularly susceptible to these climatic stresses, leading to reduced yields and lower nutritional quality. This interplay between agricultural practices and climate change highlights the urgent need for sustainable farming strategies that minimise nitrogen loss while maintaining food security in a rapidly changing world. Excessive nitrogen application not only boosts short-term crop output but also gradually deteriorates soil health. It increases soil acidity, depletes organic matter, and disrupts the diversity of beneficial microorganisms, which are essential for maintaining soil fertility and nutrient cycling (Guo et al., 2010). Over time, this degradation undermines the soil's ability to retain water and nutrients, leading to greater reliance on chemical inputs for agricultural productivity. Moreover, nitrogen runoff from these fields contaminates rivers, groundwater, and wetlands, resulting in eutrophication and algal blooms, which threaten aquatic biodiversity (Smith et al., 1999). This degradation creates a vicious cycle: declining soil fertility compels farmers to apply even greater volumes of fertilisers, exacerbating environmental harm, economic burdens, and greenhouse gas emissions. N2O thus emerges not only as a potent greenhouse gas but also as a key indicator of the imbalance between food production, soil health, and climate stability. To tackle these challenges effectively, adopting approaches like precision farming, sustainable nitrogen management, regenerative agriculture, and nature-based solutions is crucial. These practices aim to protect soil health, ensure long-term food security, and meet global climate goals, safeguarding the future of humanity and the environment.

Mitigation Measures: Toward Sustainable Nitrogen Management

Emission of N_2O has become an imperative issue that needs to be dealt with for making agriculture climate resilient and sustainable. Considering that agriculture is the main source of N_2O emissions, sustainable nitrogen management becomes a key approach for mitigating N_2O emissions. The excessive use of nitrogen fertilisers needs to be replaced with precision-based use of fertilisers according to soil type and crop requirements. Organic farming, crop rotation, conservation agriculture, and biofertilizer use will improve the soil conditions without increasing the level of greenhouse gas emissions (Kanter et al., 2020). Scientific experts are also encouraging the use of nitrification inhibitors and controlled-release fertilisers for reducing the loss of nitrogen and limiting N_2O emissions (Akiyama et al., 2010). In addition, efficient irrigation system management and proper manure management also play a significant role in reducing emissions. Moreover, activities like afforestation and agroforestry also assist in maintaining ecological balance and enhancing carbon sequestration. It also requires a robust policy approach, scientific advancement, and education for farmers to make farming practices more climate-smart (Fig. 1). Keeping in view the objectives of World Environment Day 2026, sustainable and nature-based solutions are needed to reduce Nitrous Oxide emissions.

Conclusion

N_2O deserves consideration for its unparalleled potential to accelerate global climate change and environmental disruption. N_2O has emerged as the most significant greenhouse gas linked to the global agricultural sector. The excessive use of nitrogen fertilisers and unsustainable practices of land management have been the main culprits. Although fertilisers containing nitrogen have been pivotal

Fig.1: Strategies for mitigating N2O Emissions Toward Climate-Resilient and sustainable agriculture

in increasing the production of food globally, their excessive and inefficient use has caused disruption to the natural nitrogen cycle and caused farming systems to become ongoing sources of atmospheric pollution. This represents an extraordinary paradox that agriculture is both a major contributor and one of the main victims of the current climate crisis. Increasing temperatures and recurrent droughts and floods, combined with soil degradation and loss of biodiversity, are leading to a loss of resilience in crops and threaten the production of food globally as well as the sustainability of agriculture in the long term. Furthermore, the climate change-induced reductions in food availability are likely to increase inflation and economic instability, and lead to migration and increased geopolitical tensions and conflicts for resources. This will have impacts on the foundations of human and societal wellbeing. N_2O deserves the status of the most critical consideration for its atmospheric persistence, potential to drive global warming, and the unique and critical depletive effect on ozone in the upper atmosphere. The use of sustainable practices of nitrogen management combined with regenerative agriculture, precision farming, and climate-related practices, integration of these practices, and mitigation of emissions from soil is the ethical and scientific imperative to enable the retention of the soil's nitrogen and enhance food security. This "silent threat" should be the primary consideration for protecting the well-being of humanity and the planet.

References

- Akiyama, H., Yan, X., & Yagi, K. (2009). Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N2O and NO emissions from agricultural soils: meta-analysis. Global Change Biology, 16(6), 1837–1846. https://doi.org/10.1111/j.1365-2486.2009.02031.x

- Butterbach-Bahl, K., Baggs, E. M., Dannenmann, M., Kiese, R., & Zechmeister-Boltenstern, S. (2013). Nitrous oxide emissions from soils: how well do we understand the processes and their controls? Philosophical Transactions of the Royal Society B Biological Sciences, 368(1621), 20130122. https://doi.org/10.1098/rstb.2013.0122

- Crutzen, P. J. (1970). The influence of nitrogen oxides on the atmospheric ozone content. Quarterly Journal of the Royal Meteorological Society, 96(408), 320–325. https://doi.org/10.1002/qj.49709640815

- Erisman, J. W., Sutton, M. A., Galloway, J., Klimont, Z., & Winiwarter, W. (2008). How a century of ammonia synthesis changed the world. Nature Geoscience, 1(10), 636–639. https://doi.org/10.1038/ngeo325

- Guo, J. H., Liu, X. J., Zhang, Y., Shen, J. L., Han, W. X., Zhang, W. F., Christie, P., Goulding, K. W. T., Vitousek, P. M., & Zhang, F. S. (2010). Significant acidification in major Chinese croplands. Science, 327(5968), 1008–1010. https://doi.org/10.1126/science.1182570

- Kanter, D. R., Bartolini, F., Kugelberg, S., Leip, A., Oenema, O., & Uwizeye, A. (2019). Nitrogen pollution policy beyond the farm. Nature Food, 1(1), 27–32. https://doi.org/10.1038/s43016-019-0001-5

- Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. Science, 333(6042), 616–620. https://doi.org/10.1126/science.1204531

- Ravishankara, A. R., Daniel, J. S., & Portmann, R. W. (2009). Nitrous oxide (N 2 O): the dominant Ozone-Depleting substance emitted in the 21st century. Science, 326(5949), 123–125. https://doi.org/10.1126/science.1176985

- Smith, V., Tilman, G., & Nekola, J. (1999). Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution, 100(1–3), 179–196. https://doi.org/10.1016/s0269-7491(99)00091-3

- Syakila, A., & Kroeze, C. (2011). The global nitrous oxide budget revisited. Greenhouse Gas Measurement and Management, 1(1), 17–26. https://doi.org/10.3763/ghgmm.2010.0007

- Tian, H., Xu, R., Canadell, J. G., Thompson, R. L., Winiwarter, W., Suntharalingam, P., Davidson, E. A., Ciais, P., Jackson, R. B., Janssens-Maenhout, G., Prather, M. J., Regnier, P., Pan, N., Pan, S., Peters, G. P., Shi, H., Tubiello, F. N., Zaehless, S., Zhou, F., . . . Yao, Y. (2020). A comprehensive quantification of global nitrous oxide sources and sinks. Nature, 586(7828), 248–256. https://doi.org/10.1038/s41586-020-2780-0